

# **A WEB 2.0 GIS G-GOVERNMENT WEBSITE FOR THE GAUTENG CITY-REGION**

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A dissertation submitted to the Faculty of Engineering and the Built Environment,  
University of Witwatersrand, Johannesburg, in fulfilment of the requirements for  
the degree of Master of Science in Engineering.

Johannesburg, 2011

## **DECLARATION**

I declare that this dissertation is my own, unaided work. It is being submitted for the Degree of Master of Science (Engineering) in the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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21 February 2011

## **ABSTRACT**

As the world advances towards an increasingly connected and spatially enabled Internet society, governments need to adopt new Web GIS technologies to become more efficient and connected with their citizens. Responding to this need, the Gauteng City-Region Observatory (GCRO) GIS website was developed to provide a g-government application for Gauteng City-Region (GCR), using a combination of GIS and Web 2.0 technologies. The website visualises governmental data in new dynamic ways, using a rich Internet application (RIA) viewer that integrates data from various sources including Google Maps. The Technology Acceptance Model (TAM) was used to determine the success of the GCRO g-government website by measuring user acceptance at the prototype and implementation stages of the project. High acceptance scores were achieved by the GCRO GIS website, thus confirming that the GCRO staff and local and provincial government in the GCR are ready to utilise g-government.

## **ACKNOWLEDGEMENTS**

I would like to acknowledge and thank the GCRO, Gauteng Department of Economic Planning, Gauteng Planning Commission and Professor David Everatt for their constant support and belief in the GCRO GIS website project. Marcelle Hattingh and the City of Joburg online maps website team were extremely helpful in providing information for the CoJ website and including the TAM questions in the CoJ online maps website user review questionnaire. Thanks are also expressed to my supervisor, Prof Rex van Olst, who was always willing on short notice to provide valued input and guidance throughout the project. Finally and most importantly, thank you to my wife and daughter who had to give up so much of their time to support me.

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## ACRONYMS

|        |                                                           |
|--------|-----------------------------------------------------------|
| API    | Application Programming Interface                         |
| CDNGI  | Chief Directorate National Geo-spatial Information        |
| CGIS   | Corporate Geo-Informatics                                 |
| CoJ    | City of Johannesburg                                      |
| CSI    | Committee for Spatial Information                         |
| CSIR   | Council for Scientific and Industrial Research            |
| CUO    | Cape Urban Observatory                                    |
| DBSA   | Development Bank of Southern Africa                       |
| DVD    | Digital Versatile Disc                                    |
| eNaTIS | National Traffic Information System                       |
| GCR    | Gauteng City-Region                                       |
| GCRO   | Gauteng City-Region Observatory                           |
| GeoGCR | Geographic Information System for the Gauteng City-Region |
| GIS    | Geographical Information System                           |
| GPG    | Gauteng Provincial Government                             |
| GPS    | Global Positioning System                                 |
| HSRC   | Human Sciences Research Council                           |
| HTML   | Hypertext Markup Language                                 |
| HTTPS  | Secure Hypertext Transfer Protocol                        |
| ICT    | Information Communication Technology                      |
| IPS    | Intruder Prevention System                                |
| IT     | Information Technology                                    |
| JCSE   | Johannesburg Centre for Software Engineering              |
| KML    | Keyhole Markup Language                                   |

|       |                                                          |
|-------|----------------------------------------------------------|
| MOU   | Memorandum of Understanding                              |
| MSD   | Map Service Definition                                   |
| MXD   | ESRI ArcMap Document or Project File                     |
| NGO   | Non-Governmental Organisation                            |
| OS    | Ordnance Survey                                          |
| OWL   | Web Ontology Language                                    |
| PC    | Personal Computer                                        |
| PSI   | Public Sector Information                                |
| RDF   | Resource Description Frameworks                          |
| RIA   | Rich Internet Application                                |
| RSS   | Really Simple Syndication                                |
| SDI   | Spatial Data Infrastructure                              |
| SDK   | Software Development Kit                                 |
| SIM   | Subscriber Identity Module                               |
| TAM   | Technology Acceptance Model                              |
| UJ    | University of Johannesburg                               |
| UK    | United Kingdom                                           |
| UTAUT | Unified Theory of Acceptance and Use of Technology Model |
| VGI   | Volunteered Geographic Information                       |
| VPN   | Virtual Private Network                                  |
| WAMMI | Website Analysis and Measurement Inventory questionnaire |
| WFS   | Web Feature Service                                      |
| WGS84 | World Geodetic System 1984                               |
| WITS  | University of the Witwatersrand, Johannesburg            |
| WMS   | Web Map Service                                          |
| XML   | Extensible Markup Language                               |

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# 1. INTRODUCTION

## 1.1 The Gauteng City-Region

The Gauteng City-Region (GCR) is an integrated cluster of cities, towns and urban nodes that together make up the economic heartland of South Africa. It is anchored by the three large metros of Johannesburg, Tshwane and Ekurhuleni with a number of smaller urban centres including Germiston, Alberton, Boksburg, Benoni, Springs, Nigel, Heidelberg, Vereeniging, Vanderbijlpark, Krugersdorp, Randfontein and Westonaria that spread out across the Gauteng Province to create an almost continuous urban agglomeration (refer to Figure 1-1).

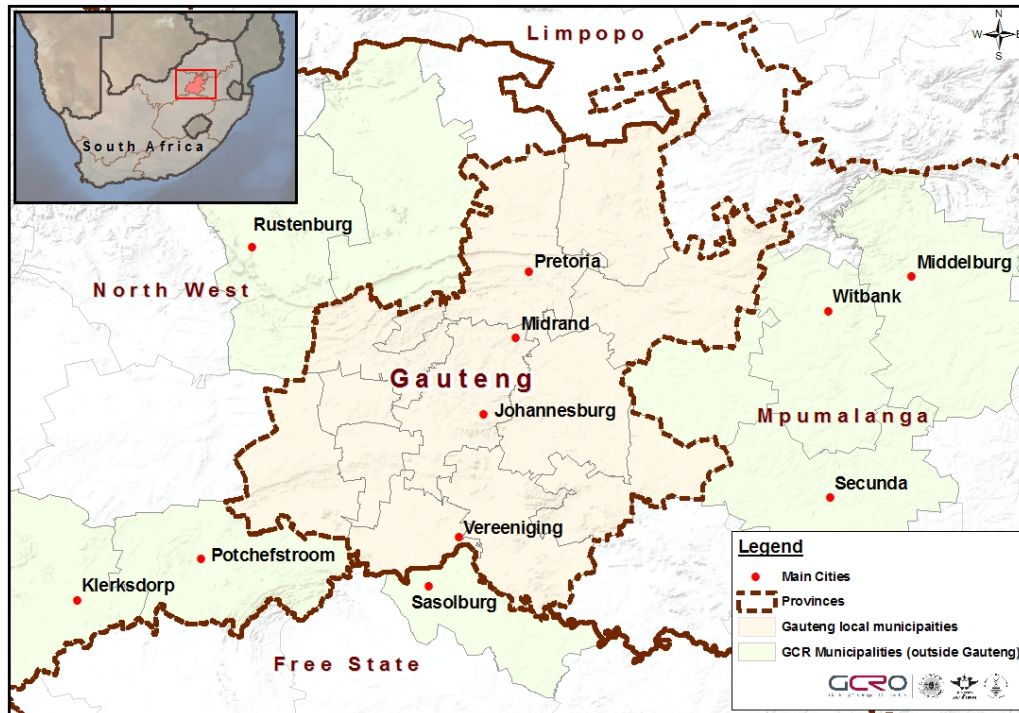


Figure 1-1: The Gauteng City-Region (GCR)

The city-region is a relatively new concept in South Africa. A city-region is defined as a group of cities within a wider territory that have an interdependent relationship forming an economic footprint that comprises the city-region [1]. Cities have distinct but complementary functions. They interact across local and

administrative boundaries through people, resources, information, finances and services. A city-region is therefore more than just a city and some nearby towns – it stretches from beyond the core city or cities to urban, semi-urban and rural areas surrounding and within commuting distance of the city [2]. The GCR economic footprint extends beyond the border of Gauteng to include Rustenburg in the north-west, Potchestroom and Klerksdorp in the south-west, Sasolburg in the south and Witbank, Middleburg and Secunda in the east. All of these centres are functionally integrated with the cities and towns of Gauteng and constitute an extended GCR with a total population of 13 million that spills over into the three neighbouring provinces of North West, Free State and Mpumulanga.

Turok [1] states: “It is widely argued that if policies towards spatial planning, infrastructure and service delivery are devolved to the city-region level and coordinated across relevant local authority jurisdictions, they may improve the efficiency of labour and housing markets, streamline transport systems and generate economic spin-offs through increased productivity, knowledge spillovers, and innovation”. Adopting a successful city-region approach therefore, will advance the interests of all citizens in the city-region [3]. A key component of a successful city-region approach will be effective coordination and cooperation between all spheres of government in the GCR.

A few examples of global city-regions in the world include greater London, Isle de France (Paris), the Randstad in Holland (consisting of the four cities of Amsterdam, Rotterdam, Utrecht and The Hague), Sao Paulo and Mumbai. In South Africa, Gauteng and the greater Cape Town area are considered to be primary city-regions, with eThekweni/Msunduzi (Durban/Pietermaritzburg) as a possible third city-region.

## **1.2 Gauteng City-Region Observatory**

The idea for the GCR was first formally expressed by the Gauteng Premier in his opening address to the Legislature in February 2005: "... only through co-operating internally would we be able to compete more effectively externally. ... Success in effectively tackling the twin challenges of unemployment and poverty increasingly depends on our ability to position and grow ourselves as a successful global city region within the global economy" [4]. The Gauteng Provincial Government (GPG) recognised the need to build Gauteng as a globally competitive city-region and established the Gauteng City-Region Observatory (GCRO) in September 2008 as a partnership between GPG, the University of Johannesburg (UJ) and University of the Witwatersrand, Johannesburg (WITS) [5]. Local government is also represented on the GCRO board.

Behind the motivation for setting up the GCRO is a vision for a fast growing and dynamic urban region that through better planning and management, and in particular improved co-operative government relations between all spheres of government, will become more functionally integrated, spatially coherent, globally competitive, economically productive, environmentally sustainable and socially inclusive.

The GCRO's first year of its existence focused on gathering baseline data, such as Statistics South Africa demographic layers, and building GCR primary data sets. In order to better understand the GCR and its citizens' quality of life, the GCRO commissioned the first ever GCR-wide Quality of Life/Customer satisfaction survey. The survey was completed in 2009 and measures a wide range of issues such as levels of satisfaction with government services, poverty, socio-economic status, movement within the GCR and quality of life. Although most provincial and municipal departments have their own customer satisfaction surveys, this survey allows comparisons across the entire GCR, including the economic footprints outside of Gauteng. The Quality of Life survey provides a bottom-up perspective to enable values and attitudes to be mapped on top of other socio-economic variables.

### **1.3 Web 2.0/Government 2.0**

A measure of success of the GCRO will be the provision of information such as the results from the Quality of Life survey in a usable format that is understood and used by both government, who will use it to develop future policies and programs, and the public, who will be able to interact with the data or use it for their own purposes. Worldwide, increasingly connected citizens and stakeholders are demanding that governments deliver services more effectively and efficiently as conventional governmental systems fail to address the current challenges of increasing globalisation, crime, poverty, pandemics and service delivery failure [6]. The recent spate of violent service level delivery protests bear testament to this in the global context. Governments need to respond to these new challenges and redefine how they manage and share information, make policies and deliver services.

Hughes, MacMillan and Medd [6] proclaim: “Change your world or the world will change you” in their report on the future of collaborative government and Web 2.0. Web 2.0 is a second generation of web development and design technology, focusing on facilitating communication, information sharing, interoperability and collaboration on the Internet [7]. Web 2.0 is not just about new technologies such as blogs and wikis, it represents a shift in culture that views the Internet as a platform for deploying services, rather than merely a source of information from static web pages [6]. Web 2.0 promotes the principles of sharing, collaboration and data integration on the Internet.

When collaborative government, simply defined as working in conjunction with others [8], is empowered by Web 2.0 technology, the result is referred to as Government 2.0. According to Jack Dangermond, founder and president of ESRI, “Gov 2.0 is taking constituent services to the next level, by leveraging and encouraging more citizen participation through Web 2.0 technologies” [114]. Government 2.0 is about leveraging the power of Internet-based Web 2.0 tools to change the way governments interact with society, share information and ultimately, achieve better outcomes for citizens [6].

## **1.4 G-government**

G-government relates to the use of maps to improve Government 2.0. It may be considered as the use of the Internet (and more recently Web 2.0 technologies) and GIS (Geographical Information System) to create a more effective government [9, 10]. The value of GIS and spatial data to governments can never be underestimated as the majority of government data is spatially based and is best visualised and interpreted using a Web GIS mapping application. For years GIS remained a tool used only by GIS professionals within government, limiting the full potential of GIS as an analysis and problem solving tool [11]. Web 2.0 mapping applications such as Google Earth, however, have revolutionised public access to spatial data and GIS technology, forever altering public expectations of what is possible online. Governments need to meet these expectations by spatially enabling their data and systems with fresh innovative Web GIS mapping applications and opening access to their vast resources of data.

## **1.5 Problem Statement**

“Constraints on access to data remain one of the greatest challenges to extending the use of Web GIS in government.” [11]

Studies in Singapore have revealed that 83% of government departments required spatial data, but only 35% had access to the data and a mere 40% of this spatial data was shared [12]. A similar situation exists in South Africa, as Sharif [13] has indicated there are still problems accessing government information. Within the GCR, online access to spatial information in the GPG is limited and not publically accessible via web mapping services. Furthermore, some GPG staff have expressed frustration with the lack of access to shared spatial information within the various GPG departments [14]. The GCR extends over a vast area and there is no single source of data to describe and analyse the city-region to enable coordinated planning across local and provincial government. GPG policy-makers do not have access to, nor make use of interactive web mapping sites that could assist in the strategic planning of the GCR.

The GPG Department of Economic Development is attempting to rectify this situation within the GPG and fundamentally transform provincial information service delivery through its GeoGCR (Geographic Information System for the Gauteng City-Region) project. The aim of which is to implement a shared information services model for provincial geographic information [15-17]. The GeoGCR project was kick-started in November 2010 with the appointment of a consultant and establishment of a steering committee to guide the project. However, a previous attempt by the Gauteng Shared Services Centre to implement a central GIS unit was never fully realised and implemented. There are also numerous examples of failed IT (Information Technology) applications and projects, such as the recent failure of the R408 million eNaTIS (National Traffic Information System) project [18, 19], which may influence government's acceptance of new applications and technology.

The problem therefore is that there is no publically accessible website that can provide spatial data for the GCR in a format that can be easily understood, accepted and utilised by both specialists and policy-makers to assist with decision-making in the city-region, which prompted the GCRO to investigate the development of a GIS website.

## **1.6 The development of a g-government website for the GCR**

The GCRO recognised the need for g-government within the GCR. A project was initiated at the start of 2010 to develop a Web 2.0 GIS mapping application to provide publically accessible spatial data describing the GCR and serve as a model for a g-government website. The GCRO GIS website makes use of various government datasets and results from the Quality of Life survey, displayed and visualised using Web 2.0 technology provided by the ESRI Adobe Flex sample viewer. The website enables the users to have a better understanding of the GCR by providing base data and thematic layers offering different perspectives of the GCR, such as population distribution, poverty and the latest 2009 Quality of Life survey results as maps and dynamic popup graphs, and GIS analysis tools for the

user to make better informed decisions and policies regarding the future development of the GCR.

The main users of the application were identified as the GCRO stakeholders, namely: local and provincial government and other government agencies. The website design focused on a simple “Google Maps-like” design, to enable and encourage high ranking government officials (with no mapping or GIS experience) and the general public to utilise the website. This would ensure open access to information about the GCR through the Internet to all GCR citizens and policy-makers.

The acceptance and usage of the Web 2.0 g-government website by GCRO, GPG and local government staff, was measured using the Technology Acceptance Model (TAM), by developing and analysing TAM questionnaires at the prototype and implementation stages of development. TAM, developed by Davis in 1989 [20], is an information systems theory that models how users accept and use a new technology. A user’s decision about how and when they will use the new technology is mainly influenced by perceived usefulness and perceived ease of use and these two constructs form the main two usage behaviour determinants [20]. TAM can be used to evaluate the success of a new system by using survey questionnaires to measure the users’ responses to a new system. However, according to Davis and Venkatesh [21], as early as the initial design phase, user acceptability of a new system can also be gauged before the system is implemented. This input from users at a pre-prototype or proof of concept stage will allow changes to be made to the initial design, to ensure acceptability and usage of the implemented system [21]. TAM was therefore used in the GCRO GIS website project, to guide the initial design and then measure the user acceptance of the g-government website.

The key research to be investigated in this dissertation can be summarised as:

**Can a Web 2.0 GIS g-government website site be successfully developed for the GCRO and used by government, by turning government data and GIS layers into dynamic interactive maps and graphs, easily accessible by both the policy-makers and citizens?**

The next chapter provides a literature review which considers Web 2.0, Government 2.0 and g-government in more detail, before discussing design considerations for Web 2.0 GIS applications and the Technology Acceptance Model. This is followed by the research methodology chapter which is broken into two main sections. The first section details the design methodology used to develop the GCRO GIS web application. The second section describes the use of TAM to develop a questionnaire to measure user acceptance and determine whether the website development was successful. The post- and pre-implementation strategies used to positively influence user acceptance of the GCRO website are also included in this section. The final implemented GCRO GIS website is presented and discussed in chapter 4, with an analysis of the TAM results. These record high user acceptance scores for the GCRO GIS website, that compare favourably when benchmarked against an existing local government GIS website.

The final chapter concludes that based on the high TAM user acceptance scores, GCRO staff and GCR government departments and stakeholders are ready to utilise g-government to assist with planning and decision-making in the GCR. This presents exciting prospects for further research that could delve into the more social collaboration and interactive aspects of Government 2.0 such as:

- Volunteered Geographic Information (VGI), defined by Goodchild [22] as the creation of geographic information on the web by large numbers of private citizens.
- The use of mobile phone g-government applications to connect citizens and governments.

This research also confirmed that TAM is a useful methodology to not only assist with the development of a new GIS web application such as the GCRO GIS website, but proved useful in the evaluation of user acceptance of an existing Web GIS application, the City of Johannesburg (CoJ) Online maps. The results of which can be used to guide the redesign process that CoJ is embarking on.

The TAM questionnaires used to evaluate user acceptance are available in the appendices of this dissertation, which also contains the GCRO GIS website specifications, prototype design document and a paper entitled “Enabling successful g-government through the development of a Web 2.0 GIS website for the Gauteng Provincial Government”, presented at the Map Africa 2010 conference.

## **2. LITERATURE SURVEY**

This literature survey, covering both academic and commercial publications, focuses on the key research areas of developing a Web 2.0 g-government website and measuring user acceptance of this new technology. A Web 2.0 definition, exponential growth of Web 2.0 applications and Web 2.0 security concerns are initially discussed, followed by the role of Web 2.0 in the shifting approach to public service delivery towards Government 2.0. A description of g-government and open access to government data are reviewed in the next section, with a few examples of international and local implementations of g-government provided. The chapter is concluded with a review of Web 2.0 GIS design considerations and the Technology Acceptance Model used to determine user acceptance, including pre-prototype testing, and pre- and post-implementation interventions.

### **2.1 Web 2.0**

Prior to Web 2.0, people could access information off the Internet but did not really participate in its evolution [23], i.e. the web consisted mainly of static web pages. Web 2.0 in contrast, represents the second generation of web development and design with new web applications that enable improved interaction, communication, interoperability and sharing on the web [7]. Not only can users access information, but they can now actively participate and contribute. Wikipedia, the “free encyclopaedia that anyone can edit”, is a classic Web 2.0 application that has been written and edited collaboratively by Internet users around the world [24]. O’Reilly [25, 26] describes how following the bursting of the Internet dot-com bubble in 2001, a new Web 2.0 emerged as the result of the business revolution moving to the Internet as a platform. Exciting new web applications and web sites were built to harness collective intelligence and expand and improve the more people used them [26]. This shift from Web 1.0 with static HTML (Hypertext Markup Language) pages, to a dynamic Web 2.0 with the web as a platform harnessing collective intelligence, is best described by way of examples listed in Table 2-1.

Murugesan [27] defines Web 2.0 as both a usage and technology paradigm shift. The usage paradigm is centred on more interactive and collaborative applications that facilitate flexible web design, updates and creative reuse, resulting in better, faster and richer user interfaces combining information from different sources [27]. This is backed up by Serrano and Torres' [28] view, that "Web 2.0 isn't so much a new technology as a new way of using web technologies".

Table 2-1: Examples of the shift from Web 1.0 to Web 2.0 applications (adapted from O'Reilly [25])

| Web 1.0                    | Web 2.0       |
|----------------------------|---------------|
| Ofoto                      | Flickr        |
| Britannica Online          | Wikipedia     |
| Personal websites          | Blogging      |
| Screen scrapping           | Web services  |
| Publishing                 | Participation |
| Content management Systems | Wikis         |

There is however, no concise widely agreed upon definition for Web 2.0 [7, 23, 27, 29], but Murugesan [27] considers it to be an umbrella term which encompasses several new technologies, including:

1. **Blogging** – a web log or powerful two-way web communication tool whereby people enter thoughts, ideas, suggestions and comments on blog web sites.
2. **RSS (Really Simple Syndication)** – a web feed format XML (Extensible Markup Language) file that informs users of updates on websites or blogs. Users can keep up to date with websites without actually visiting them.
3. **Wikis** – a simple collaborative authoring tool that allows users to create or edit content on a webpage, such as the online encyclopaedia Wikipedia.
4. **Web mashups** – a web page or web site that combines data, information and services from multiple sources on the web.

A key feature of Web 2.0 sites is rich usability, with rich Internet applications (RIAs) that run in web browsers and have all the features and ease of use of traditional desktop applications without requiring specific software installations, devices or platforms [29, 30].

Fu and Sun [30] summarise the main characteristics of Web 2.0 that make it more interactive, integrated and useful to its users, as: “Web 2.0 = User-generated content + the web as a platform + a rich user experience”.

The GCRO GIS application can be described as a Web 2.0 application as it makes use of RIA technology provided by the Adobe Flex software and web map mashups to combine base maps from Google Maps with GCRO web mapping services published by ArcGIS Server.

## **2.2 Growth of Web 2.0**

Worldwide, Internet users have embraced public Web 2.0 applications such as MySpace, Flickr, You Tube, Facebook and more recently the social networking and micro blogging application Twitter. The statistics are staggering with over 500 million active users on Facebook (August 2010) [31] and 190 million users tweeting 65 million times a day on Twitter (June 2010) [32]. Examples of Web 2.0 GIS websites include the commercial web mapping applications such as Google Maps, Microsoft Bing Maps, Google Earth, Yahoo Maps and Mapquest [30]. The use of online maps is also impressive with nearly a billion people having used Google Maps and at least 500 million having downloaded Google Earth [33]. In South Africa, the growth of the number of South Africans with access to the Internet had reached five million in January 2010, with six million predicted by the end of 2010 [34].

Businesses and enterprises have also realised the benefits of Web 2.0. The 2009 McKinsey global survey reports that 69% of respondents' companies have gained measurable business benefits such as more innovative products and services, more effective marketing, better access to knowledge, lower cost of doing business and

higher revenues [35]. For example, companies are using social networking applications such as Facebook, blogs and wikis to actively engage with customers and staff [36]. Despite the recent recession, respondents also reported that they would continue to invest in Web 2.0 [35].

With the exponential growth of Web 2.0, what does the future hold? O'Reilly and Batelle [37] recently referred to the future of Web 2.0 as "Web Squared". The Internet is evolving once again to harness collective intelligence through both user and sensor input. For example, mobile phones have evolved to become multiple sensory devices with cameras and GPS (Global Positioning System) receivers. Apple collects GPS data daily from its iPhone users who have approved the use of the location-based applications on the phone, to analyse traffic patterns and density [38]. The latest TomTom Go Live GPS navigation units now contain SIM (Subscriber Identity Module) cards with HD traffic live updates calculated from anonymous mobile phone users and other traffic data sources, downloaded to the devices every three minutes [39]. As more users and sensors feed more Internet applications and platforms with information, the Web is becoming smarter and set to grow exponentially with extraordinary opportunities and mind bending applications: "Web meets world – that's Web Squared" [37].

Web 3.0 or the Semantic Web, is envisioned to provide the technologies whereby the semantics (or meaning) of information on the web is defined to enable machines to better understand and directly process data on the web [40]. The use of Web 3.0 Resource Description Frameworks (RDF) and Web Ontology Language (OWL) facilitate the development of multisite mashups and merged graphs [41]. Examples of the semantic web, such as the United States' government website, data.gov, which provide a "new generation of 'linked data' mash ups" [42] are beginning to emerge, but the full realisation of the Semantic Web, according to Fu, Zhu and Sun [40], is still a long way off.

### **2.3 Web 2.0 security concerns**

As Web 2.0 is changing the way we work and interact socially on the Internet by offering new ways to collaborate and communicate, and more corporate and government data is served on an insecure Internet, Web 2.0 tools come with an increasing range of risks such as inappropriate content, viruses, worms and malware (malicious software) and accidental or malicious data loss [36]. There is no point banning Web 2.0 sites from employees within company and government networks as most of the Internet applications are either using or migrating to Web 2.0 technology. It is therefore vital that companies continue to adopt Web 2.0 and at the same time secure and control access to data, i.e. by controlling content, which involves a shift away from passwords and filters to all-encompassing Essential Information Protection strategies that identify and tag valuable information before adding layers of security to it [36]. Rudman [29] also recommends a series of technological safeguards that companies should implement to secure Web 2.0 applications, including:

- Next generation reputation-based web filters on both inbound and outbound communications.
- Blocking access to suspect sites.
- Anti-malware software that include anti-virus, anti-spy ware and spam filters.
- Network technology such as firewalls with the latest patches.
- Web 2.0 policies informing and educating users of the risks.

According to Fu and Sun [43], there are a number of techniques that can be used to secure GIS data published as web services, such as:

- Use of a private network if the web service and clients are on a separate private network.
- Use of a VPN (Virtual Private Network) to enable secure connections across the Internet.

- Role-based authentication to assign privileges to authorised users accessing the service.
- Security tokens which ensure only authorised users with a valid token can access the service.
- HTTPS (Secure Hypertext Transfer Protocol) which encrypts the data transferred between the web service and client.
- Reverse proxy that provides an additional layer of defence by masking the web server behind the reverse proxy.

## 2.4 Government 2.0

“The days of governments at all levels – national, state/provincial or local – operating primarily as singular entities are over. Tomorrow’s governments cannot deliver the policy outcomes that society expects if they continue to hold onto yesterday’s monolithic-leadership model.” [6]

Governments around the world need to change the way they function and interact with society, or they will fail to overcome today’s current challenges and alienate their citizens [6]. This need has been primarily spurred by citizens around the world placing new demands on governments to reform the public sector [44]. The evolving approach to public service delivery is clearly illustrated in Figure 2-1, with an initial shift from traditional government and modes of delivery, to e-government and e-services, to a new paradigm of a fully connected government committed to enhancing the value of services available for all citizens [44].

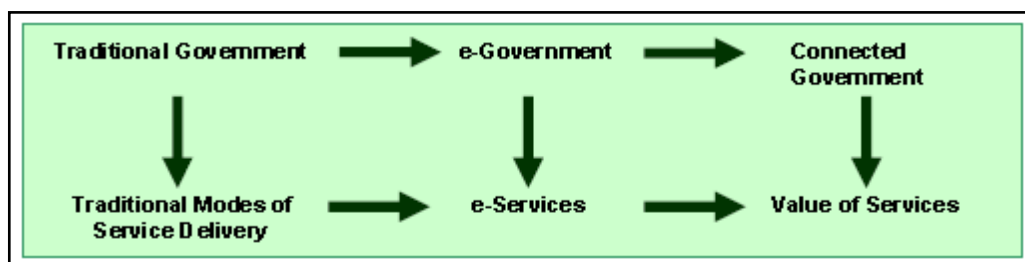


Figure 2-1: Evolving approach to public service delivery [44]

The first wave of e-government which focused on “the use of information and communication technology to provide and improve government services, transactions and interactions with citizens, businesses and other arms of government” [45], was a significant step forward with regard to interacting with and making information available to citizens. Web 2.0 is proposed as the latest technological initiative to assist in bringing governments closer to their citizens [46] and opening access to government data.

However, governments themselves have not been transformed and need to embrace a new networked model of government [6]. This need to transform, together with emerging Web 2.0 technologies, will facilitate a new form of collaboration to improve how governments function together with other governments, non-governmental organisations (NGOs), the private sector and citizens to solve complex problems and enhance service delivery. Collaborative government, simply defined as working in conjunction with others [8], enabled by Web 2.0 technology is referred to as Government 2.0. Elements of Government 2.0 include: collaboration, mashups, social networking, user generated content (crowd sourcing and volunteered geographic information), cloud computing and open systems [47].

The 2008 United National survey report of e-government readiness<sup>1</sup>, which presents an assessment of e-government across the world, was encouraging, with South Africa ranked 61 out of a total 189 countries with an e-readiness score of 0.5115 [44]. The survey was led by Sweden (0.9157) followed by Denmark, Norway and the United States. Africa as a region lagged far behind the world average of 0.4543, with a lowly score of 0.2776, with Europe averaging 0.6469 (refer to Figure 2-2).

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<sup>1</sup> The e-government readiness index is a composite index comprising the web measure index, the telecommunication infrastructure index and the human capital index, with the survey focusing mainly on the ‘government to citizen’ (G to C) and ‘government to government’ (G to G) aspects of e-government [44].

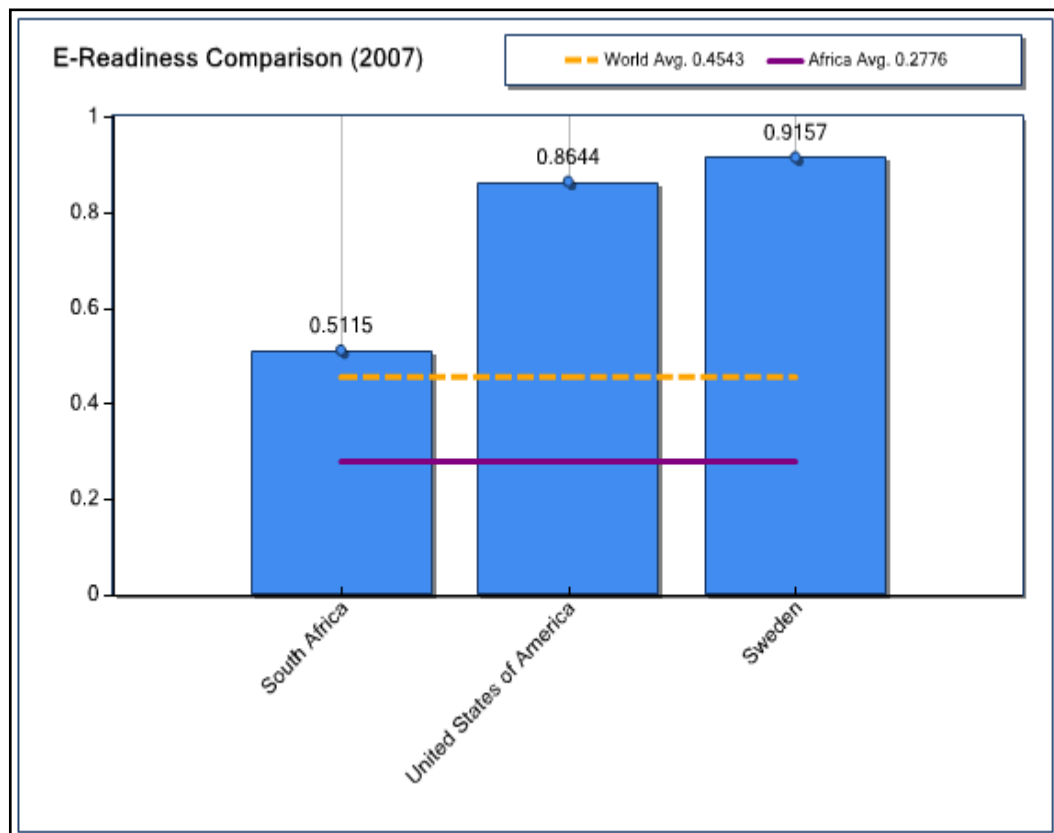


Figure 2-2: 2008 E-Readiness Comparison [48]

The updated 2010 report, *E-Government Survey 2010: Leveraging e-government at a time of financial and economic crisis*, concludes that “citizens are benefiting from more advanced e-service delivery, better access to information, more efficient government, management and improved interactions with governments, primarily as a result of increasing use by the public sector of information and communications technology” [49]. However, of concern is the decline of South Africa’s ranking from 61 to 97 out of 184 countries with an e-government development index<sup>2</sup> score of 0.4306, its lowest score since the first global e-government survey report was released in 2003 (refer to Figure 2-3). This 2010

<sup>2</sup> E-government development index is a weighted average of three normalised scores on the most important dimensions of e-government, namely: scope and quality of online services, telecommunication connectivity, and human capacity [49].

index score, listed in Table 2-2, places South Africa fourth behind Tunisia, Mauritius and Egypt in the African region.

Table 2-2: 2010 United Nations e-development in Africa [49]

| Rank | Country       | E-government development index value |        | World e-government development ranking |      |
|------|---------------|--------------------------------------|--------|----------------------------------------|------|
|      |               | 2010                                 | 2008   | 2010                                   | 2008 |
| 1    | Tunisia       | 0.4826                               | 0.3458 | 66                                     | 124  |
| 2    | Mauritius     | 0.4645                               | 0.5086 | 77                                     | 63   |
| 3    | Egypt         | 0.4518                               | 0.4767 | 86                                     | 79   |
| 4    | South Africa  | 0.4306                               | 0.5115 | 97                                     | 61   |
| 5    | Seychelles    | 0.4179                               | 0.4942 | 104                                    | 69   |
| 6    | Cape Verde    | 0.4054                               | 0.4158 | 108                                    | 104  |
| 7    | Libya         | 0.3799                               | 0.3546 | 114                                    | 120  |
| 8    | Botswana      | 0.3627                               | 0.3647 | 117                                    | 118  |
| 9    | Lesotho       | 0.3512                               | 0.3805 | 121                                    | 114  |
| 10   | Gabon         | 0.3420                               | 0.3228 | 123                                    | 129  |
|      | World average | 0.4406                               | 0.4514 |                                        |      |

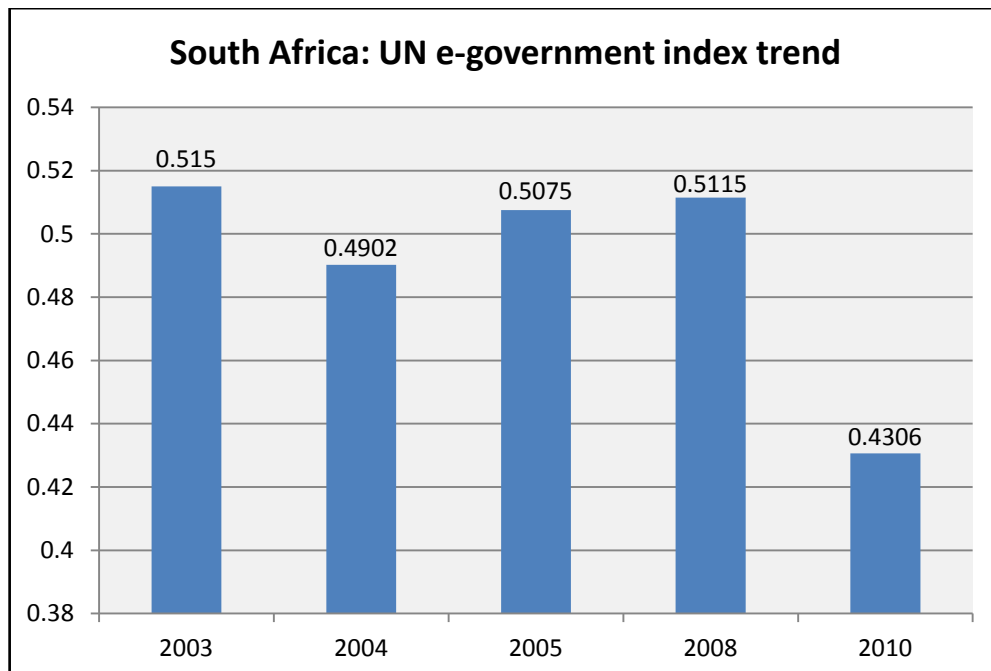


Figure 2-3: Graph depicting South Africa's e-government index trend [50]

The reason for South Africa's drastic drop in rankings is not mentioned in the report, but may be in part due to significant changes to the survey instruments that were introduced, which focused more on how governments are using websites and portals to deliver public services and increase opportunities for their citizens to participate in decision making [49]. The majority of the countries' rankings decreased slightly compared to the 2008 survey, but the report makes a pertinent point: "a drop in a country's ranking may serve as a reminder of the need to devote greater resources to improving online services and expanding access to telecommunication infrastructure" [49]. Obviously a key focus area for the South African government is to improve its e-government services.

At the 2008 Govtech conference, National government decision-makers promised the South African government would not be left behind and was working towards a Government 2.0 model with real time access to information for both government and its citizens [51]. The R2.5 billion "Who am I" online project with smart identity cards, by the department of Home Affairs was listed as a prime example of a Government 2.0 project.

However, previous failures of expensive government IT applications and projects, such as the recent R408 million eNaTIS project, which made headlines as a result of a number of system failures and shortcomings raised by the Auditor-General [18, 19], may influence government's willingness to adopt and invest in new applications and technology. The web as an information sharing tool is also restricted within some government spheres with a number of local municipalities still struggling to get broadband Internet access [52].

E-Government and Government 2.0 remain a challenge in South Africa.

## **2.5 G-government (Web 2.0 GIS) and open access to public data**

G-government is defined as using the Internet and GIS to create more effective government [9]. The g-government definition has been recently updated by defining the use of GIS and new Web 2.0 technology as g-government [10]. According to Jack Dangermond, ESRI president, it is all about Web GIS extending the vision of e-government [53]. Approximately 80% of government data is spatially based [11] and can be best visualised and interpreted using a GIS web mapping application. Therefore, Tickner [10] states that g-government can improve the way governments connect with its citizens by hosting map web portals to organise and display the vast government data resources. As Web 2.0 applications such as Google Earth have revolutionised public access to spatial data and GIS technology, governments need to spatially enable their data and systems with fresh innovative mapping applications.

As a key component of the Web 2.0 revolution, O'Reilly [25] recognised that data would provide the competitive advantage in harnessing collective intelligence – “Data is the ‘Intel Inside’ of the next generation of computer applications”. Parsons [54], a geospatial technologist at Google, expands this by stating that “there is a simple relationship between ease of access to information and economic activity”. Although not as yet quantified, each new technological advance that resulted in more effective publication and distribution of information has generated massive economic activity by creating new markets and businesses [54]. O'Reilly quotes the example of the Apple iPhone that has attracted some 150 000 applications, but almost none of which were developed by Apple itself [55].

The United States has been a strong supporter of g-government, where in 2000 the term “G-Gov” first appeared when the then vice president, Al Gore, realised its potential: “We have an unparalleled opportunity to turn a flood of raw data into understandable information about our society and planet” [10]. As opposed to other parts of the world where GIS adoption has been slow, due to government data not being freely available, free government data in the United States has been

made available for a number of years resulting in the wide spread use of GIS and varied GIS applications [56]. The MD iMap viewer utilised in the State of Maryland, is just one example of a Web 2.0 mapping application which provides both government and public access to the State's enterprise GIS, by combining maps with government performance statistics and graphs in a RIA [57].

Other countries are also beginning to realise the importance of g-government and open access to data. The United Kingdom's (UK) Ordnance Survey (OS), which traditionally charged for access to its data, launched the OS OpenData initiative on 1 April 2010. OS OpenData is an online portal providing free access to a range of GIS layers [58] and web map development tools such as the OS OpenSpace API (Application Programming Interface). The quote below summarises the benefits of g-government and opening access to public data:

“This shows the UK is at the cutting edge of a digital revolution .The move to free up public data encourages fresh thinking - people re-using information in different and more imaginative ways than may have originally been intended. A seemingly endless stream of new applications and websites continues to show the potential of combining information, creative vision and digital technology. Increasing access to Ordnance Survey data will attract a new wave of entrepreneurs and result in new solutions to old problems that will benefit us all. It will also drive a new industry, creating new jobs and driving future growth. The changes signal a wider cultural change in Government based on an assumption that information should be in the public domain unless there is a good reason not to - not the other way around. Greater openness, accountability and transparency in Government will give people greater choice and make it easier for individuals to get more directly involved in issues that matter to them.” Communities Secretary John Denham [58]

The UK government is further enhancing the use of government data through the “Show us a better way” website run on behalf of UK government by the Power of Information Taskforce [59]. The website promotes new and innovative use of

public government datasets through a competition that funds good ideas of proposed applications to be built with public information, with examples such as crime mapping, fix my street and farm subsidy maps. Ordnance Survey has a specific GIS based competition called GeoVation – innovation through geography, which aims to help “communities address their unmet needs through the application of geographic data, skills and expertise” [60]. The figure below depicts the process, with entrants posting their ideas on the GeoVation forum and the best candidates attending a GeoVation camp to prototype ideas, before the finalists attend a showcase event to win a share of the £25 000 prize [60]. These are examples of a true realisation of Government 2.0 with citizen participation uploading data and ideas to the government and government supporting and funding the use of government data and development of applications that meet the needs of its communities.



Figure 2-4: The GeoVation challenge process [60]

In the South African context, there are a number of spatial data policies and legislation in place, such as the Promotion of Access to Information Act (Act 2 of 2000) and Spatial Data Infrastructure (SDI) Act (Act 54 of 2003), that were designed to promote access to information. However, despite all the policies in place, there are still problems accessing government information in South Africa [13]. In a presentation to the HSRC (Human Sciences Research Council) in August 2009 entitled, “Maximising the value of Public Sector Information (PSI)”,

Sharif [13] listed his preliminary findings from his doctoral research, “ many obstacles and problems exist:

- Open availability of information
- Lack of systematic approach to collect, manage and store the data
- Institutional and socio-cultural barriers
- Poor quality and quantity of data and information at municipal levels
- Timeliness of information
- Reliability of information (use of private external consultants and the difficulty to verify and trust the methodologies used in these reports)
- Lack of the culture of appreciating the value of PSI” [13].

Dr Derek Clarke, Chief Director: National Geo-spatial Information in the Department of Rural Development and Land Affairs, argues that institutions continue to operate in silos with limited cooperation between key stakeholders [61]. Sharif [13] maintains that it is not the policies that are the problem, but rather the implementation of PSI policy. For example, it has taken 7 years from the promulgation of the SDI Act to the formation and first meeting of the Committee for Spatial Information (CSI), a committee responsible for the successful implementation of South Africa’s SDI and ensuring that South Africa makes effective use of its geospatial data for the benefit of all its citizens [62].

Many of the national base mapping layers such as 1:50 000 topographical layers and 10 000 orthophoto map series are freely available from the national mapping organisation, the Chief Directorate National Geo-spatial Information (CDNGI) [63]. However, access to the CDNGI data, is obtained through manual requests and a copy of the data delivered on a DVD (Digital Versatile Disc) or hard drive. The CDNGI is attempting to rectify this by developing a multi-server environment to provide seamless direct access to all the CDNGI’s spatial and related data through an Intranet/Internet web portal with Web Feature Services (WFS) and Web Map Services (WMS) [63].

At a provincial level, data is not publically accessible and it is often only available to other provincial or local departments through personal relationships. The Cape Urban Observatory (CUO) is working on a Memorandum of Understanding (MOU) between the Western Cape Provincial Government and City of Cape Town [64]. “These negotiations aim to facilitate formal relations between the two organisations, reducing the reliance on personal relationships and providing a clear data sharing framework” [64]. Furthermore, improved integration of spatial data between national, provincial and local government in the Western Cape is being facilitated by the CUO through the development of a regional SDI [65].

The Gauteng Provincial Department of Economic Development has recognised the need to fundamentally transform provincial information service delivery and is launching an ambitious project called the GeoGCR [15-17], which as depicted in Figure 2-5 aims to provide:

- **Access** – through the establishment of a single gateway to provincial geographic information
- **Enablement** – by spatially enabling the public sector
- **Optimisation** – by defining the legal, hardware and software requirements to make use of the latest new mapping technologies
- **Leadership** – by leading the way in public sector data and infrastructure and meeting the business needs of each stakeholder.

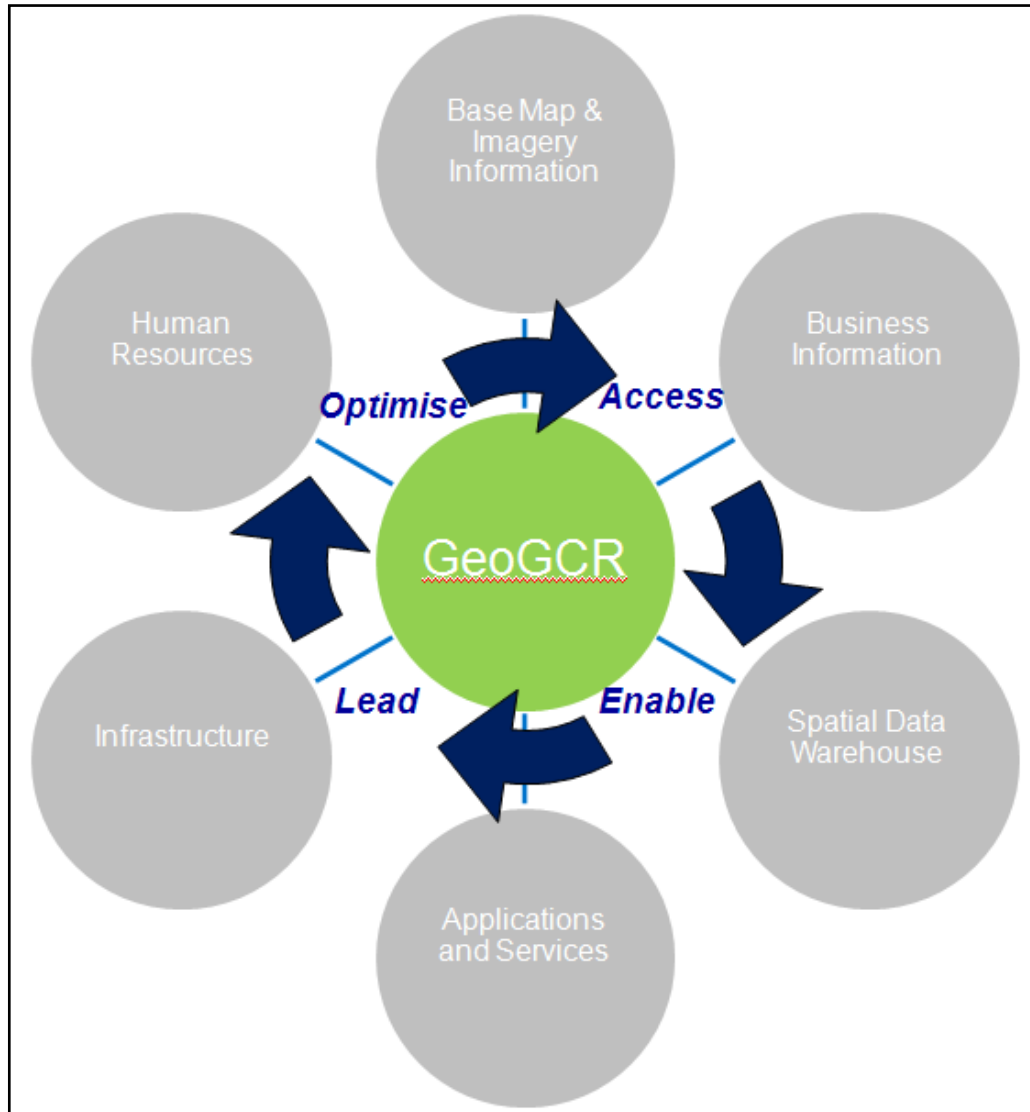


Figure 2-5: The building blocks of the Gauteng GeoGCR [17]

The lack of free public open access to some municipal GIS data was debated in the November/December 2009 issue of Position IT [66, 67], with Shuttleworth Foundation Intellectual Property Fellow, Andrew Rens, describing it as “a missed opportunity for innovation” [66].

In order to overcome the policy implementation problems and ensure open and easy accessibility to government data, a high level of coordination and collaboration is urgently required [13]. Some of the measures proposed by Sharif [13] include: increasing the awareness about the importance of public

sector information and implementing new follow-up, monitoring and evaluation methods and activities to ensure effective utilisation of public sector information. This is the role that the newly formed CSI has to successfully fulfil in order to meet the geospatial needs of the country.

## **2.6 Web 2.0 design**

The GCRO GIS website was developed as a Web 2.0 application to provide g-government. However, Murugesan [27] cautions that although Web 2.0 applications have enabled better, faster and richer applications, it also poses a new design and development dilemma: “fast and easy versus well designed and well engineered”. Various open source applications and widgets, small stand-alone applications embedded in third party sites and originally derived from the idea of code re-use [68], are freely available online. Inexperienced developers can easily build applications by copying source code from existing websites or integrating widgets and modifying sample viewers [29]. This “wave of cookie-cutter sites emerging on the Internet”, have been built and deployed, with in many cases very little thought to originality and the user interaction with the site [69]. Not only is there a danger of good web design practices being ignored, but developers may, according to Rudman [29], unknowingly incorporate malicious code into their applications, giving rise to security weaknesses, although this can be prevented by reviewing all code (including widgets) and running vulnerability tests.

User-centred and usage-centred system design, are two different methods developers can employ to ensure applications meet the needs of its intended users. User-centred design, which is driven by user input with substantial user involvement, focuses on the users in terms of user experience and satisfaction, whereas usage-centred design is driven by models and selective user input, with a focus on usage and improved tools supporting the accomplishment of tasks [70]. Usage-centred design asks questions such as: “Why is this needed? Why would users interact with the software? What are they trying to accomplish?” to help the developer design a more usable system [71]. Section 2.7 on the Technology Acceptance Model (TAM), delves into more detail regarding the measurement of

the perceived usefulness and ease of use of new applications, and pre- and post-interventions that can aid user acceptance of new applications.

In terms of design considerations of a commercial site such as the subscription based CoJ online maps, Rayport and Jaworski [72] define seven design choices that form the basis of an effective website design, referred to as the 7Cs framework of website design (Table 2-3). Using the 7Cs framework, websites known for their good website design and superior customer experience, can be analysed and then compared to the website being developed [73].

Table 2-3: 7Cs framework for website design [73]

|                      |                                                                                                                      |
|----------------------|----------------------------------------------------------------------------------------------------------------------|
| <b>Context</b>       | Site's layout and design – functionality vs. aesthetically dominant or both (integrated)                             |
| <b>Content</b>       | Text, pictures, sound and video that websites contain, including offering dominant store types                       |
| <b>Commerce</b>      | Site's capabilities to enable commercial transactions – functional tools and pricing                                 |
| <b>Community</b>     | Ways that the site utilises user-to-user communications to enable feelings of membership and shared common interests |
| <b>Connection</b>    | Extent to which the site is linked to other sites – links out and in                                                 |
| <b>Customisation</b> | Site's ability to tailor itself to different users or to allow users to personalise the site                         |
| <b>Communication</b> | Ways that the site enables site-to-user, user-to-site or two-way communications                                      |

Regarding the design of e-government applications that provide Web GIS, Pratt and Fu [11] call for special attention to be given to the following:

- **Capacity planning:** Current and future requirements for network bandwidth, database and Web and GIS servers should be considered to allow scalable solutions to be developed.
- **Security:** Effective security measures need to be introduced to protect sensitive government information and protect citizen privacy.
- **Interoperability:** Adherence to industry and Web GIS standards must be followed to ensure access to information through various software tools within government agencies.
- **Extensibility:** Web applications should consider extensible design to cater for future growth and the constantly changing web environment.

GIS applications add another layer of web design complexity in terms of appropriate cartographic techniques and map design. Web maps have different requirements to traditional maps, as complex detailed Web GIS maps will not be easily understood by users or result in frustratingly slow downloads. Users have grown used to simple map interfaces and fast map downloads from mapping sites such as Google Maps and Bing Maps.

Successful and simple to use online maps often means making compromises and resisting classical GIS interfaces which only GIS professionals will understand [74]. A good public mapping website, according to Charlie Savage, founder of social mapping website Mappbuzz, has to be: “the obvious things – fast, intuitive, easy to navigate, nice graphic design – but it shouldn’t overwhelm the user, either with data or unfamiliar concepts” [74]. Agrios [75] presents a sample methodology for creating successful web maps, which forms the basis of the GIS design methodology applied in this research that is discussed in chapter 3.1. A few of the recommendations include: employing strong cartography, implementing scale dependencies to enhance performance and improve clarity, and using the same coordinate systems to avoid projection on the fly [75]. ESRI [76, 77] has also published a number of white papers describing various

techniques to ensure simpler map design and improved performance. Jones [78] makes a pertinent point: “Do not lose sight of the core values, principles and techniques of GIS mapping just because web mapping is in vogue”. The basis of any Web GIS application should be to remain relevant, up to date and use high quality data.

Web design and good quality data are key determinants of whether a web application is accepted and used. The Technology Acceptance Model (TAM) discussed in the next section, provides a methodology for determining and measuring user acceptance.

## **2.7 Technology Acceptance Model (TAM)**

The most widely employed model of IT adoption and use is TAM [79]. By understanding and measuring users’ perceptions of the usefulness and ease of use of a new system, the acceptance and subsequent usage of the system can be determined. Davis [20] defined these main two predictors of system usage or technology acceptance measures as:

**Perceived usefulness** – “the degree to which a person believes using a particular system would enhance his or her job performance”, i.e. a user will make use of a system if they believe it will help them to perform their job better,

**Perceived ease of use** – “the degree to which a person believes a system would be free of effort”, i.e. a user may not use the system if they believe the system is too hard to use.

TAM is illustrated in Figure 2-6 and depicts how the behavioural intention to use a system is determined by the perceived usefulness of the system and its perceived ease of use, with perceived usefulness having the stronger effect on user acceptance.

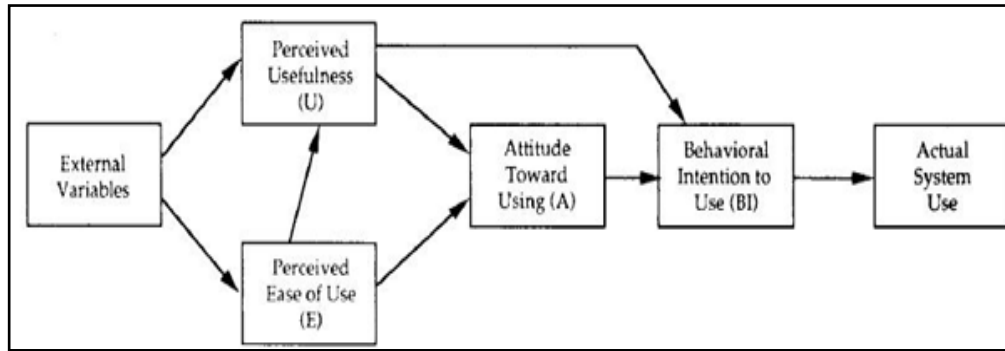


Figure 2-6: Original TAM [80]

The original TAM has been further developed over the past 20 years. TAM2, published in 2000, incorporated additional constructs that influence user acceptance [81]. These included social influences such as subjective norm (regarded as the influence of people important to the user that think the system should be used) and image (which is the degree to which the new system may enhance a user's status), and cognitive instrumental processes such as job relevance, output quality and result demonstrability [81]. In order to integrate various user acceptance models, the Unified Theory of Acceptance and Use of Technology Model (UTAUT) was formulated by Venkatesh et al. [82]. UTAUT identified that performance expectancy, effort expectancy, social influence and the facilitating conditions are direct determinants of user acceptance and usage behaviour, while gender, age, voluntariness for use and experience were also recognised as key moderators. Another questionnaire developed by Kirakowski and Claridge to evaluate the quality of use of websites and user satisfaction, the Website Analysis and Measurement Inventory (WAMMI) questionnaire, is also recognised as a good tool for the evaluation of websites [115, 116].

Bagozzi [83], although acknowledging TAM as a remarkable model, criticised it for being too simple and leaving out important variables and processes. However, recently TAM3 was developed to combine TAM2 [81] and the model of determinants of perceived ease of use [84] to present a complete model of the determinants of individuals' IT adoption and use [79]. TAM3 is depicted in Figure 2-7 and theorises that the determinants of perceived usefulness will not

influence perceived ease of use and vice versa. The role of experience in IT adoption and continued use is highlighted though, as with increasing experience using the new application, despite the effect of perceived ease of use on behavioural intention decreasing, the effect of perceived ease of use on perceived usefulness will increase [79]. This means that even if users gain experience on using the new application, perceived ease of use of the application has a significant effect on the user acceptance and long term usage of the system. Ease of use remains an important part of system design.

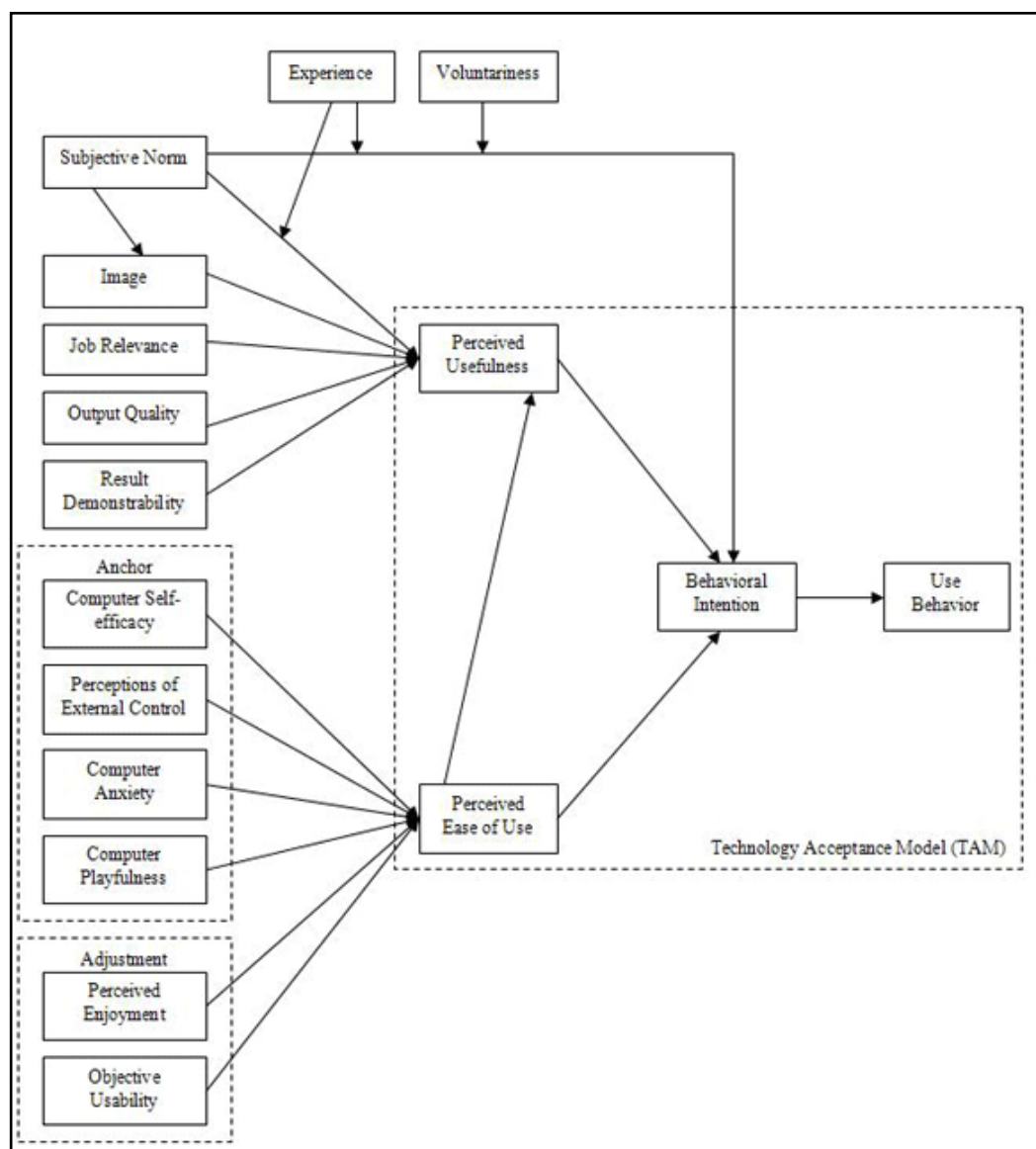


Figure 2-7: TAM3 [79]

## **2.8 TAM Pre-prototype testing**

User acceptability of new systems has traditionally been tested towards the end of the software development. This is based on the assumption that users must have access to at least a working prototype of the new application before developers can measure whether users intend to use the system. Davis and Venkatesh [85] applied TAM to pre-prototype applications, to test whether a user's intentions to use a system could be measured at the pre-prototype or proof of concept stage of software development, where the systems features and functionalities are presented. Their study was based on seven questions measuring behavioural intention, perceived usefulness and perceived ease of use. Their findings concluded that a user's behavioural intention and perceived usefulness measured at a pre-prototype stage (i.e. with no direct hands-on experience), accurately reflected future usage behaviour after system implementation [85].

This ability to predict final usage early in the project has significant advantages. Depending on the user acceptance results, managers may decide whether to go ahead with the development as planned, modify the system functionality or abandon the project before significant losses are incurred. Different applications designs and solutions can also be presented to review which design users would prefer to use. However, the authors also warn that given the stability of user acceptance gained at an early stage of the projects, user's perceptions and expectations will be difficult to change if the system does not deliver as promised [85].

## **2.9 Pre- and post-implementation interventions**

Drawing from the determinants of perceived usefulness and ease of use described in TAM3, Venkatesh and Bala [79] proposed a list of interventions that should be applied in the pre- and post-implementation stages of new IT applications within an organisation. The pre-implementation interventions are designed to minimise the initial resistance to new applications and provide a realistic preview of the system for the potential users. They include: design characteristics, user participation, management support and incentive alignment.

When designing a new system, the information-related and system-related characteristics need to be considered. The information-related components in a GIS web application would consist of the spatial data and how it is visualised with maps, graphs and charts. The system-related characteristics would be the actual web application and Web 2.0 tools. Venkatesh and Bala [79] propose that the information-related characteristics will influence perceived usefulness, i.e. if a system can provide the relevant information in a timely, accurate understandable format that can help make better decisions, users are more likely to accept and use the system. If the system can be characterised as reliable, flexible and user friendly, then users will have a high degree of perceived ease of use and have less stress-related anxiety.

By encouraging user participation in system development and implementation activities such as system evaluation and customisation, prototype testing and business process change initiatives, the users will generate a better understanding of the system features, organisation resources and management's support. This may lead to reduced anxiety about the new system and a higher level of perceived usefulness from the user.

Management support is defined as the "degree to which an individual believes that management has committed to the successful implementation and use of a system" [79] and directly influences both perceived usefulness and ease of use. Top management's support in the form of commitment and communication of the new system implementation is critical to the system success and adoption.

Incentive alignment relates to the interests and incentives an employee may expect to gain by using the system. It is not only linked to organisation rewards, but may entail that the new application fits with his/her job requirements and value system, e.g. using the new system would give them an advantage over another department.

Post-implementation procedures occur after the deployment of a new system and represent organisational, managerial and support activities to enhance the user acceptance of the system. The procedures should make users feel the new system

is an opportunity to enhance their job performance and that they have the necessary support and resources. These interventions are listed as training, organisational support and peer support [79].

Venkatesh and Bala [79] summarise their findings by concluding that managers can now use the TAM3 framework to decide what interventions to apply during the pre- and post-implementation stages. For example, for complex systems, interventions that focus on creating favourable ease of use perceptions, such as system design characteristics, user participation, training and peer support, may be more relevant. Voluntary systems should include interventions that focus more on perceived usefulness, such as information design characteristics, user participation, incentive alignment, training, and organisational and peer support. Given that these interventions all have associated costs, managers can decide on where best to allocate resources for interventions to minimise system resistance.

TAM is therefore a useful methodology to measure user acceptance of the GCRO g-government website developed for the GCRO and its government stakeholders using Web 2.0 technology. The system design strategies discussed in chapter 2.6 are important software development methodologies to be implemented to ensure user acceptance, with user-centred design contributing to perceived ease of use and usage-centred system design influencing perceived usefulness. Although the GCRO GIS website is not a commercial website, the 7C's framework of website design also provides a useful framework for effective web design and user acceptance.

The next chapter lists in more detail the research questions investigated as part of the development of the GCRO g-government application, before focusing on a specific website design methodology for a Web 2.0 GIS website and the development of a TAM questionnaire to measure user acceptance.

### 3. METHODOLOGY

The purpose of this research is to design and develop a g-government website for the GCRO, to be used by the Gauteng Provincial Government, and measure user acceptance of the Web 2.0 GIS website application. The research project is thus split into two components: firstly, a GIS design component which requires the latest Web 2.0 tools to provide relevant, dynamically visualised GIS maps and innovative GIS visualisation of government datasets, in the form of popup graphs linked to the map layers, in a simple, easy to use, optimised GIS application directed at the GCR policy-makers. Secondly, to assess whether the GCRO g-government solution was successful, by measuring the users' response to a Web 2.0 GIS website and determining user acceptance through the use of TAM questionnaires at the prototype and implementation stages of development.

The research will evaluate the following questions:

- What design methodology should be considered when developing a GIS Web 2.0 application?
- Can TAM be used to measure the technology acceptance of a GIS website?
- How does the GCRO GIS website's ease of use and usefulness compare to an existing local government GIS website?
- Is the g-government website development using Web 2.0 technology and the visualisation of spatial government data a success, in terms of sharing and opening access to public sector spatial data?

This chapter will therefore discuss a GIS web development methodology that was applied in the development of the GCRO GIS website, and review the TAM methodology used to measure user acceptance, including the TAM3 pre- and post- implementations utilised to enhance user acceptance.

### 3.1 A Web 2.0 GIS design methodology

Successful GIS web applications are achieved by the right combination of GIS layers symbolised in a visually dynamic way, with an easy to use application, that is stable and responsive and meets the user requirements of both GIS and non-GIS users. Web 2.0 has produced a flood of development starter kits, sample viewers and APIs, with the result that almost anyone involved in GIS or IT – even with limited or no programming experience – can build a GIS website. This has lead to an exponential growth of Web GIS applications and data, which although a necessary step in increasing accessibility to spatial data and GIS applications, poses a new design and development dilemma: “fast and easy versus well designed and well engineered” [27].

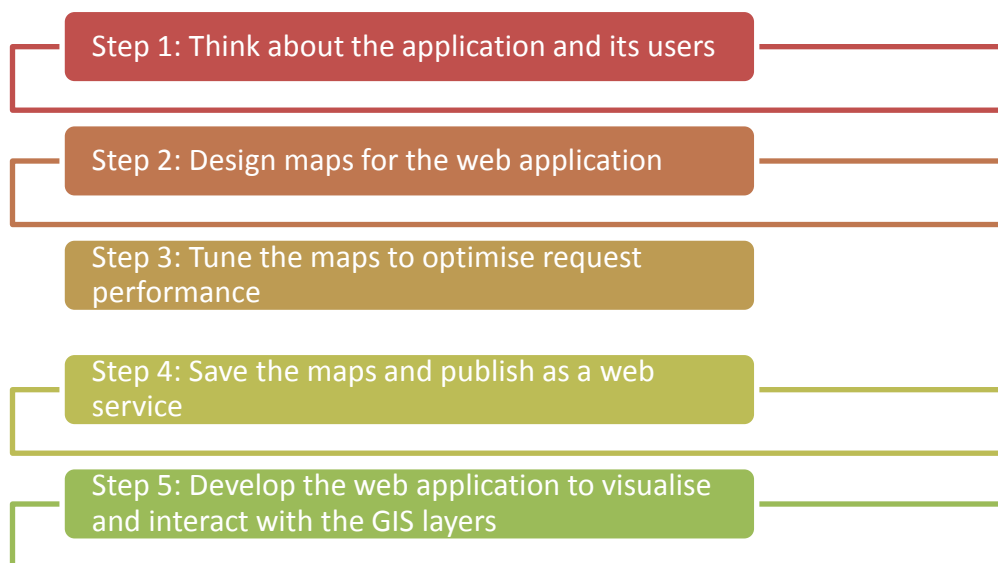


Figure 3-1: Sample methodology for creating effective web mapping applications (adapted from [75])

Agrios [75] argues that “effective web maps have a specific focus and are designed so users can interact with them to accomplish meaningful tasks”. In order to achieve this, a five step methodology for developing an effective GIS web map application with optimal performance (refer to Figure 3-1) was used to

design and build the GCRO GIS website. A detailed description of each of the steps is described below.

### **3.1.1 Step 1: Think about the application and its users**

Step 1 is an obvious starting point when planning a GIS website, but should be considered carefully in terms of a number of questions to be used as a guide for planning a map-based web application [75]:

- *“What is the business need/purpose of the web mapping application?”*
- *Who are the end users?*
- *Is this an internal or external website?*
- *What data will be included in the application?*
- *How will the data be used? Visualisation? Spatial query? Attribute query?*
- *Will the data be used with other services to create a mashup?”* [75]

These questions were debated during a brainstorming session with GCRO staff held in January 2010. This process assisted GCRO to think about the GCRO GIS website users and how the application could benefit them – an important consideration prior to drawing up the GCRO website specification.

#### **Business need/purpose of the web mapping application?**

There was an initial focus by the GCRO in its first year of operation, to collect existing government base datasets and generate new datasets to be used to map and research the city-region. Various maps were prepared and made available as pdf/jpeg downloads on the GCRO website ([www.gcro.ac.za](http://www.gcro.ac.za)). However, the GCRO recognized that in order to ensure that the GCR information was fully utilised, the GIS maps and data needed to be visualised in a dynamic interactive GIS website.

The business need was therefore identified as: enabling users to develop a better understanding of the GCR by providing base data and thematic layers offering different perspectives of the GCR, such as population distribution, poverty and the

latest 2009 Quality of Life survey results as web maps and dynamic graphs; and GIS analysis tools for the user to make better informed decisions and policies regarding the future development of the GCR.

### **End users**

The main users of the application were identified as the GCRO staff and stakeholders, namely: the GPG Planning Commission, GPG Office of the Premier, GPG Department of Economic Development, local government officials and other GCR government agencies. These users are responsible for planning the future development and direction of the GCR and are mainly high ranking government officials with no mapping or GIS experience. Hence the need for a simple “Google Maps-like” Web GIS design. Public access was also a requirement, ensuring open access to information describing the GCR through the Internet to all GCR citizens. Therefore a freely accessible, simple to use, Internet site was required to provide access to local and provincial government and citizens.

### **Data**

As described in chapter 1, the GCR is an integrated cluster of cities, towns and urban nodes that together make up the economic heartland of South Africa. To obtain datasets and maintain data from the local and district municipalities and provincial governments constituting the GCR, would require a dedicated fulltime effort. Data availability, accuracy and currency would also vary across the different authorities. Frustratingly, freely available websites such as Google Maps, often serve more up to date imagery and base layers than the data available within many government departments. It was recognised that online spatial datasets can offer a viable alternative to sourcing governmental base datasets such as imagery and streets, and can provide a seamless coverage across a wide area. Web 2.0 technologies such as data mashups and APIs provide the tools to access these online datasets.

There are various sources of online base datasets: Google Maps, Microsoft Bing Maps and ESRI online resources. Another source to consider is open data initiatives such as OpenStreetMap, which offer free (licensed under the terms of the Creative Commons Attribution Share-Alike 2.0 license) downloadable street datasets for the world that were generated by Internet users uploading spatial data [86].

Fu and Sun [87] describe important considerations to be made when designing GIS mashup applications, including:

- **Quality and authority of the mashup sources** - With so many online commercial and open data sources now available on the web, quality can vary considerably and it is vital that government mashup applications only use authoritative data sources that are regularly updated.
- **Copyright and terms of use** - Despite most of the online data sources being available free of charge, data providers often retain copyright. Mashup API terms of use must be complied with by mashup developers to avoid infringing copyrights. [87]

Google Maps is one of the most popular commercial Web 2.0 mapping sites. It was found to offer the most up to date imagery covering the GCR and provide dynamic functionality such as Google Street View. Regarding copyright, there were concerns initially that by using the Google Maps API, Google had the right to access the user's data [88] . However, this concern was allayed as the user has the choice to opt out, and in fact, Google is no longer collecting this data [89]. Google Maps was therefore selected to provide the base layers in the GCRO GIS website application and data mashups with the GCRO layers. Four Google Maps layers were used as the base maps: street maps, satellite/aerial imagery, hybrid view (a combination of satellite imagery with labels and streets) and physical maps (a combination of topographical backdrop with labels and streets).

Table 3-1: GCRO data grouped into themes

| Theme                                                                                                               | Description                                                                                                                                                                                              |
|---------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <b>GCRO administrative layers</b> | Base administrative layers such as municipal, provincial and ward boundaries. The GCR poly-centric model is also included to provide the user with a graphic illustration of the GCR model and boundary. |
|  <b>Demographics</b>               | Population dot density maps and graphs.                                                                                                                                                                  |
|  <b>2009 Quality of Life</b>       | Various Quality of Life survey indices that were developed and mapped from the 2009 Quality of Life survey, such as a decent work index and satisfaction with government.                                |
|  <b>Economic</b>                  | GCR's economy, mapped using commercial datasets (Afrigis Bizcount database), census unemployment and Quantech Gross Value Add statistics per local municipality.                                         |
|  <b>Spatial Structure</b>        | Land use, provincial and urban land cover and the provincial urban edge layers.                                                                                                                          |
|  <b>Transport</b>                | Basic transport layers such as streets, railways and the Gautrain route and stations.                                                                                                                    |

With regard to the various GCRO GIS layers that had been assembled, the data was divided into various themes to be used to analyse and obtain a better understanding of the GCR. These themes can be interacted with individually, or layers from different themes can be overlaid. Six themes were identified and are listed in Table 3-1. The 2009 Quality of Life theme, described in the introduction chapter, was specifically created to visualise government survey questionnaire datasets from the 2009 Quality of Life survey. The development of these data themes will be an ongoing process as more GCR data becomes available or is generated from GIS data projects or analysis.

## How will the data be used?

Various Web 2.0 GIS websites were reviewed to gain an understanding of the available GIS Web 2.0 tools and applications. An excellent example identified as a model for the GCRO website base application was the MD iMap web application [57].

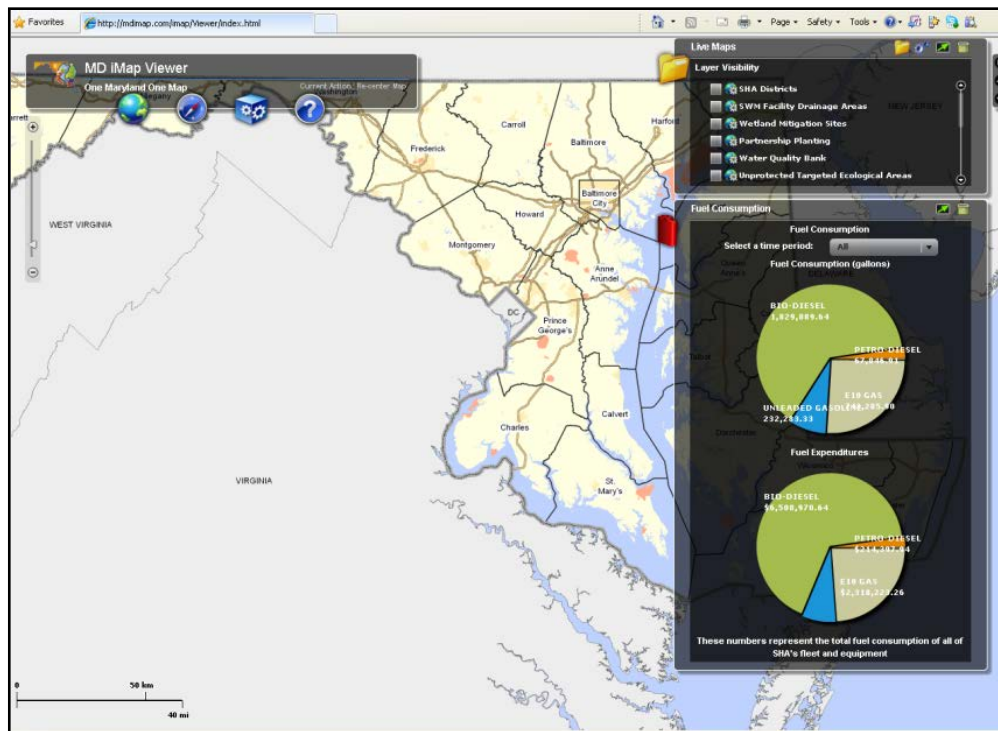


Figure 3-2: MD iMap ESRI Flex mapping application (2009 version) [90]

This website, depicted in Figure 3-2, was developed for the State of Maryland in the United States, to inform public users about the performance of government, by presenting government information and statistics in a dynamic interesting format [57]. It forms part of the State of Maryland's Governor, Martin O'Malley's vision of "one Maryland" and was recognised by President Barack Obama during an address to the National Governors Association on 23 February, 2009: "Instead of passing the buck on accountability and efficiency, governors like Martin O'Malley and Governor Kaine have revolutionised performance management

systems, showing the American people precisely how their governments are working for them” [57].

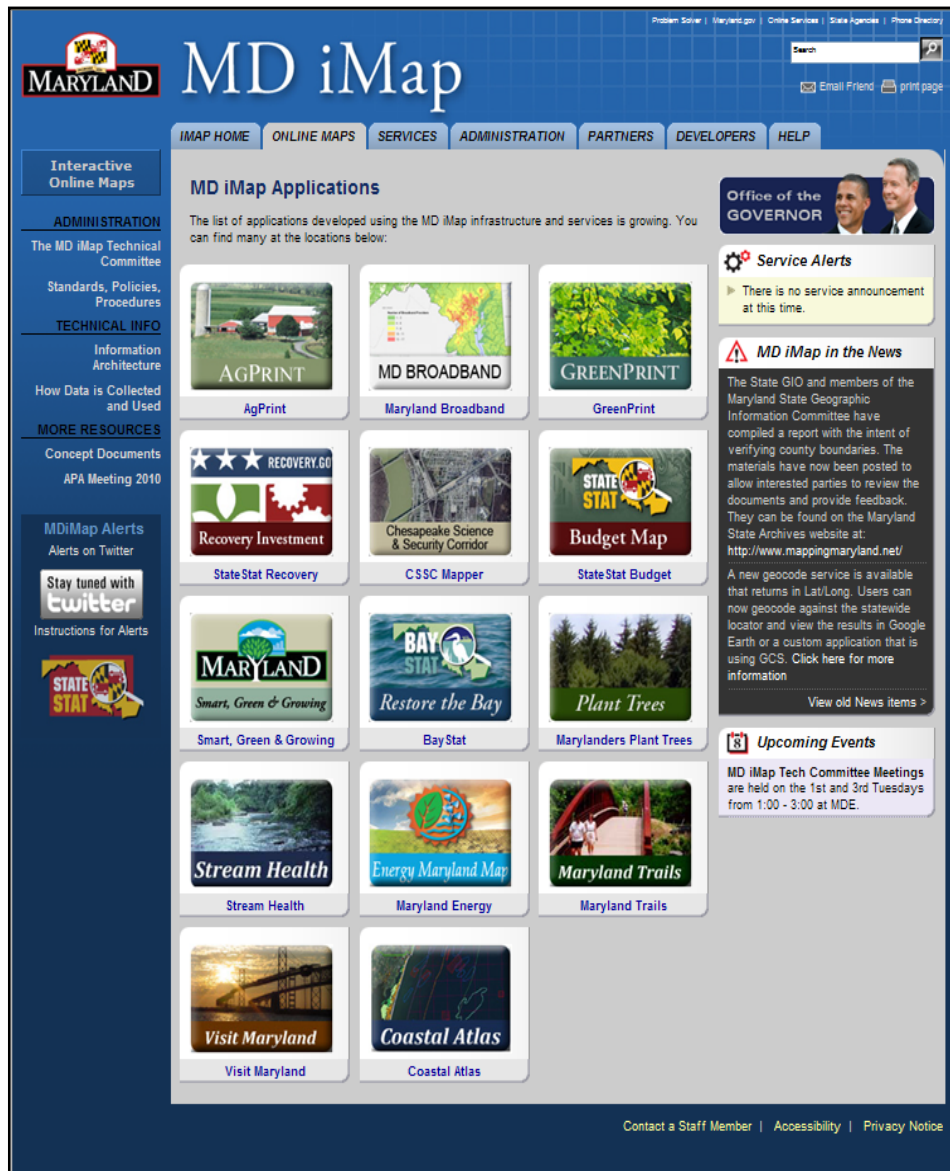


Figure 3-3: MD iMap website (2010 version) [91]

The MD iMap viewer uses the ESRI ArcGIS Server Flex viewer to visualise GIS layers with RIA tools and dynamic graphs – features that were immediately identified as key Web 2.0 components of the GCRO website which could be

utilised to map and graph the GCRO data in a unique and dynamic way. A specific example of this is the mapping and graphing of the 2009 GCRO Quality of Life Survey. Data that would normally only be reported in reports and graphs, was visualised in the GCRO application as a dynamic theme with mapped indices linked to dynamic graphs, providing a spatial perspective per local municipality across the GCR.

The MD iMap website continues to evolve and has since been redeveloped and re-launched as the One Maryland-One Map MD iMap portal, offering various interactive GIS maps such as broadband coverage and Statestat recovery investment maps, as depicted in Figure 3-3 [91].

## **Specification**

Drawing on all the above considerations, and using the 2009 MD iMap website as a model, a Web 2.0 GIS application specification was compiled for the GCRO GIS website (attached as Appendix A). The GCRO GIS website specification required the use of the latest Web 2.0 tools such as GIS data mashups, APIs and RIAs.

### **3.1.2 Step 2: Design maps for the web application**

#### **Separating data into base map and operational layers**

Good Web GIS map design practice is to divide data into base map layers, which primarily are used as background layers, and operational layers that users interact with to perform decision-making and task-based functions [75, 76]. Operational layers are normally served dynamically, whereas base map layers, that typically do not change or require updating frequently, should be cached. The separation of base map and operation layers is one of the most important steps to ensure optimal web mapping performance [75]. According to ESRI [92], “Map caching is a very effective way to make your ArcGIS Server maps run faster. When you create a map cache, the server draws the entire map at several different scales and stores copies of the map images. The server can then distribute these images whenever

someone asks for a map. It's much quicker for ArcGIS Server to hand out a cached image than to draw the map each time someone requests it". A disadvantage of cache is that it takes a long time to create and should not be used if features are regularly updated, as this would require a regeneration of the map cache each time a layer is updated. An example of Map cache is depicted in Figure 3-4.

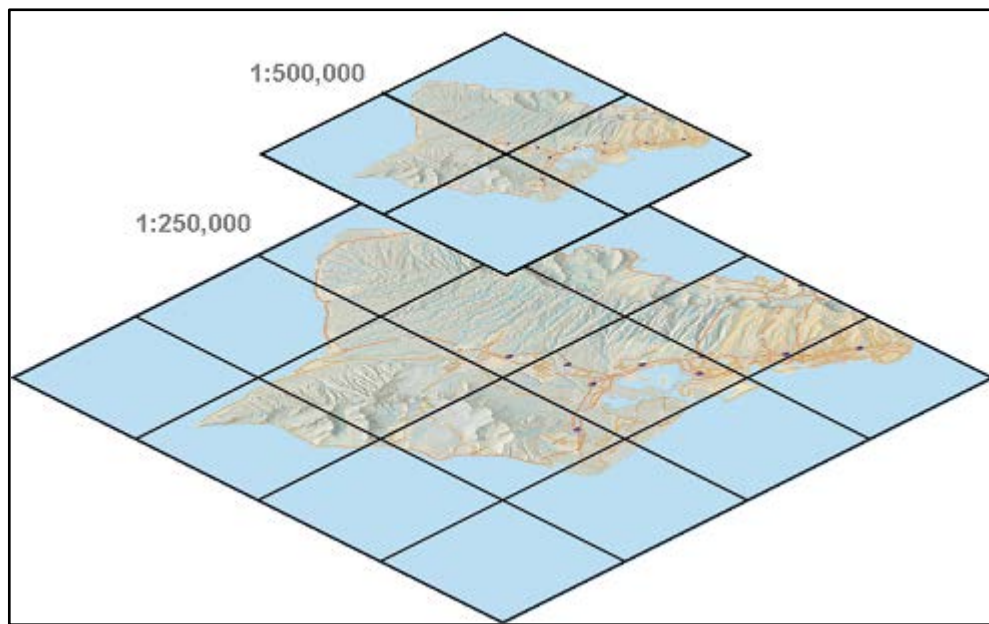


Figure 3-4: An example of map cache at different scales [92]

One of the reasons that Google Maps download and display so fast is that they make use of server-side caching [92]. The Google Maps layers were therefore designated as base map layers within the GCRO GIS website, with the API accessing the Google Maps cache from the Google servers.

The GCRO administrative layers theme was also designated as a base map as it provided the GCR administrative base map context and is switched on by default when the application is opened. It was not, however, cached and therefore functions like an operational layer. This is due to the multiple layers in the theme

and the fact that users need to interact with this theme through queries and selecting which of the administrative layers are to be displayed.

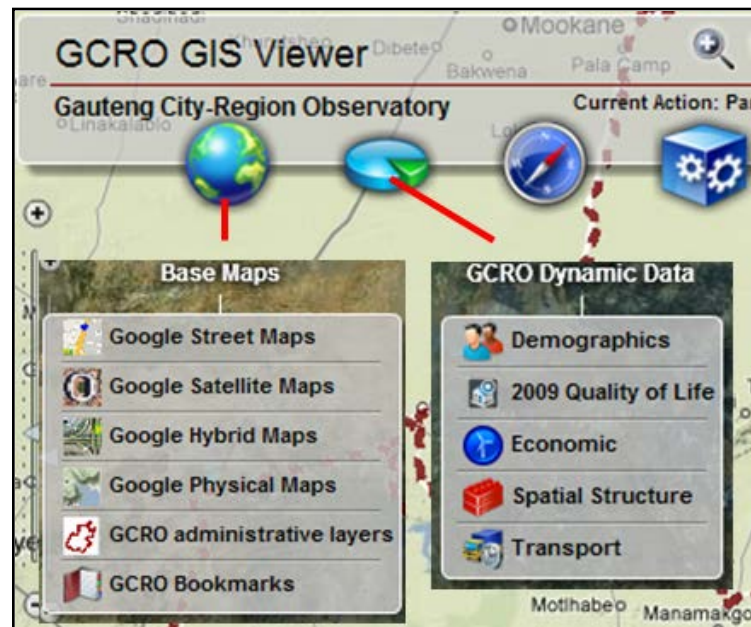


Figure 3-5: GCRO GIS application: base map and operational (dynamic theme) layers

The separation of the GCRO GIS layers into base map and operational layers is depicted in Figure 3-5, with the operational (dynamic) layers grouped into five themes, as described earlier in this chapter. As ESRI ArcGIS server 9.3.1 was utilised to publish the data, the data were mapped and symbolised in ArcMap (ArcView licence), with each of the five operational themes and GCRO administrative layer theme, developed in separate ArcMap map documents. The focus, where possible, was on a unique dynamic way of representing data. For example, as opposed to a more traditional way of mapping population per ward by varying the colour per polygon, dot density maps were used to display the distribution of the 2001 Census population across the GCR. In the case of the 2009 Quality of Life survey theme, various indices were compiled and grouped by local municipality to provide a citizen's perspective per municipality across the GCR. The GIS data attributes for each of the Quality of Life survey layers, were

also defined to enable graphs to be drawn for each of the layers (refer to Figure 4-6 and 4-7 in chapter 4.1).

## **Tools**

Tools that perform processes beyond mapping should also be considered carefully together with base maps and operational layers as part of web design strategy [93]. To ensure optimal performance, tools that are relatively simple and use data on the client side should run on the client. Server-side processing should be used when complex analysis and processing is required.

## **GIS web mapping compromises**

Diacono [74], states that designing maps for web applications means making compromises. These include employing strong cartography, using scale dependency to enhance performance and improve clarity and maintaining coordinate systems for all layers used in the application [75]. Strong cartography was employed in the GCRO themes by ensuring both the layer symbology and labels were clearly visible on a standard PC (Personal Computer) or laptop screen and that each layer within a theme was uniquely represented and identifiable with other GCRO theme layers switched on or overlaid on the various Google Map base maps. The use of Google Maps as base map layers also required that the GCRO themes used the same scales and coordinate system (WGS84 Web Mercator) as Google Maps [92]. Each of the GCRO layers source data were projected to WGS84 Web Mercator and the Google Maps' scale levels applied to the ArcMap documents.

Scale dependencies, whereby layers only display at predetermined scales, were applied where possible to some of the GCRO layers to ensure the layers only displayed at an appropriate scale to avoid unnecessary processing by the server and improved performance. For example, the Gauteng land use layer in the Spatial Structure theme is not clearly discernable at the Gauteng extent and took a long time to draw at small scales. A scale dependency was set whereby the layer is only visible when a user zooms in beyond a scale of 1: 288 895.

### 3.1.3 Step 3: Tune the maps to optimise performance

To ensure that the maps that a user requests are rendered by the server as quickly as possible, it is necessary to tune the maps to optimise performance.

Table 3-2: The Map Service Publishing toolbar and tools (adapted from [75])

|  | Tool name                          | Tool function                                                                                                                                                                             |
|-----------------------------------------------------------------------------------|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                   | <b>Analyze Map</b>                 | Examines the map contents, provides suggestions for improving performance and returns errors for layers and properties incompatible with the optimised drawing engine.                    |
|                                                                                   | <b>Preview</b>                     | Draws the map using the new ArcGIS 9.3.1 optimised drawing engine; provides an idea of how fast the map will draw and whether the new drawing engine has changed the look of any layers.  |
|                                                                                   | <b>Save Map Service Definition</b> | Saves ArcMap document or project file (.mxd) as an optimised Map Service Definition (.msd) file.                                                                                          |
|                                                                                   | <b>Publish To ArcGIS Server</b>    | Creates .msd file on the server (arcgisservice\arcgisinput folder) and publishes the .msd file to ArcGIS Server; requires the same administrative privileges as other publishing methods. |
|                                                                                   | <b>Options</b>                     | Options for improving the quality of text and line work in the map.                                                                                                                       |

The desktop software used to design the web maps for the GCRO GIS website, ArcMap version 9.3.1, provides a new tool called the Map Service Publishing toolbar, to analyse the performance of each of the layers in the ArcMap map

document. The Analyse map button (highlighted with a red square in Table 3-2), provides the main functionality as it cycles through each layer and generates a report indentifying potential performance bottlenecks and/or errors that must be addressed before a map service is published [75].

As visible in Figure 3-6, a dialog box opens at the bottom of the ArcMap application when the Analyse tool is run and contains errors, warnings and messages. These guide the user to:

- Identify errors that may prevent the service from being published (which in the case of the .msd file format, must be resolved before saving),
- Resolve warnings that will ensure optimal performance from the published map service.

The preview window tests the draw speed of the layers at different scales and provides the user with an opportunity to test the effect of changing various settings on draw speeds.

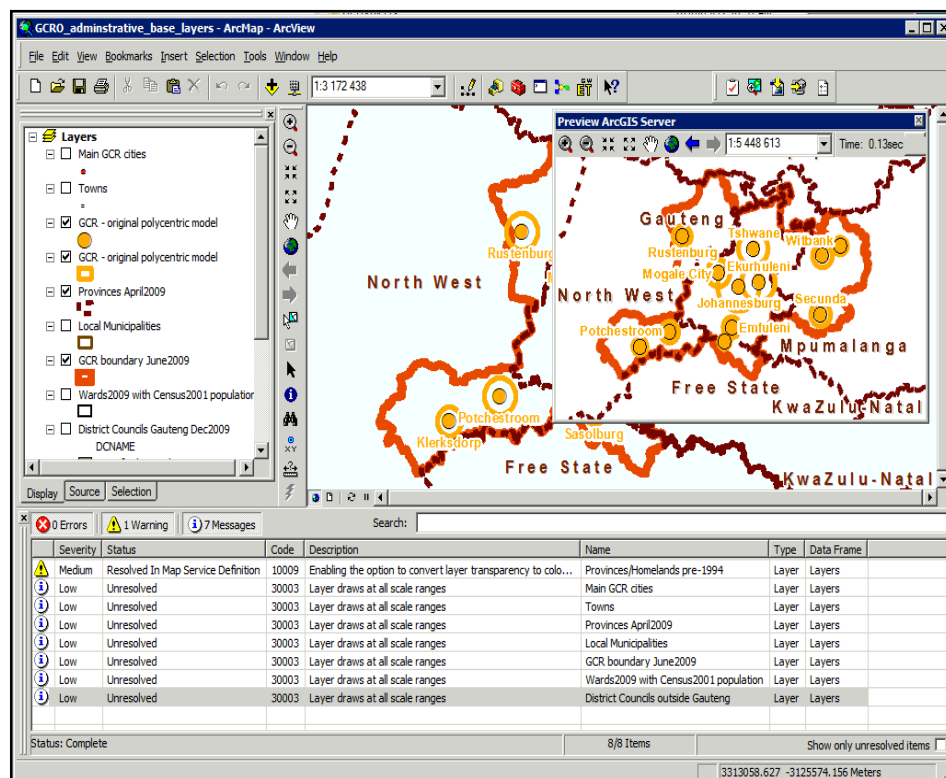


Figure 3-6: Map Service publishing toolbar analyse dialog box and preview window

## GIS data format

The format of the GIS data is another factor that may influence performance. ESRI advises that an enterprise ArcSDE geodatabase is used for large ArcGIS Server system implementations, as a result of benefits such as hi-availability support, backup and recovery, concurrency, scalability and a tendency to provide superior performance [77]. However, the performance of web services sourcing data from an ArcSDE geodatabase is dependent on a dedicated database administrator to tune, optimise and maintain the ArcSDE geodatabase. Provided that the published data is relatively static and enterprise capabilities of ArcSDE such as versioning are not required, a file geodatabase offers a good alternative to serve Web GIS data, as they provide good performance with minimal extra configuration [77].

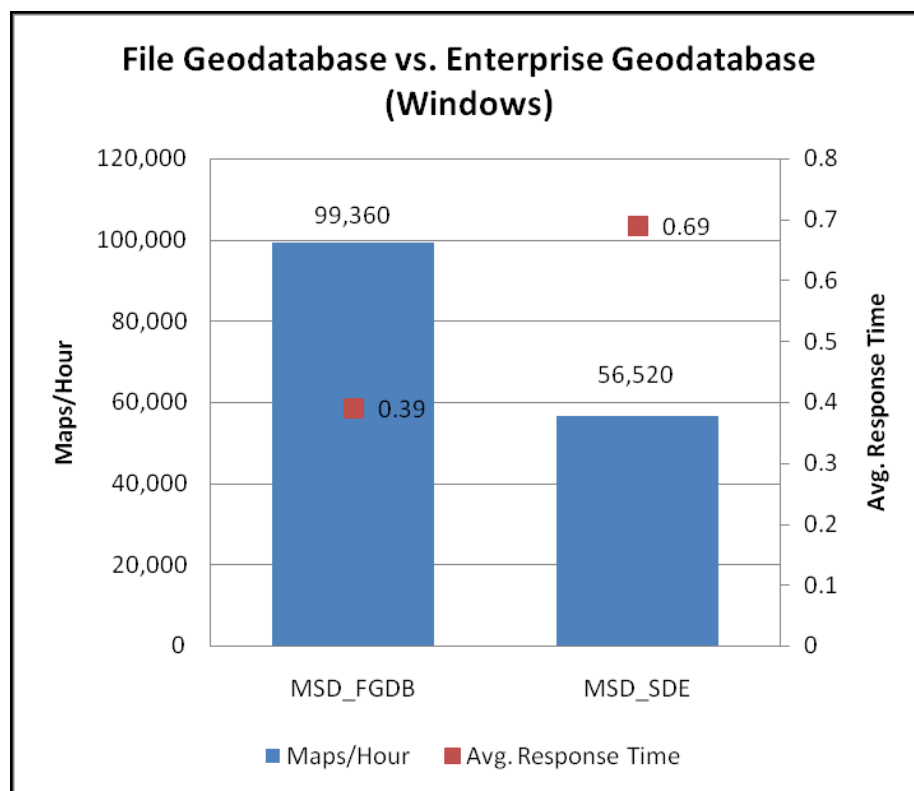


Figure 3-7: File Geodatabase vs. Enterprise ArcSDE Geodatabase performance comparison test [77]

Figure 3-7 illustrates the results of a performance comparison test performed by ESRI on two optimised map services using different data sources, ArcSDE

(MSD\_SDE) versus file geodatabase (MSD\_FGDB). The results indicated that the map services referencing a file geodatabase actually outperformed the enterprise ArcSDE geodatabase, with maximum throughput of 99 360 maps per hour versus 56 520 respectively [77]. The ArcSDE geodatabase results, however, are dependent on optimisation and tuning implemented on the database and could be significantly improved by optimisation and tuning of the geodatabase and network [77]. The results, however, indicate that a file geodatabase with no configuration produced excellent performance results. For this reason, all the vector data accessed by the GCRO GIS application are stored in file geodatabases.

Various server hardware, network and scalability configurations will also affect the web map's performance but are beyond the scope of this research.

#### **3.1.4 Step 4: Publishing the maps as web services.**

##### **Map Service Definition (MSD) format**

Once the map document has been tuned using the Map Service Publishing toolbar, and depending on how the map will be used and the type of data it contains, a user has the choice of saving the ArcMap documents in one of two formats used to publish the web map service [75]:

- **MXD:** if the map users layers not supported by the 9.3.1 optimised rendering option (such as dot density symbology), or the published map service uses analysis tasks such as geoprocessing.
- **MSD:** if the map service will be served dynamically and only provide mapping, KML (Keyhole Markup Language) or WMS capabilities.

The MSD format is an optimised version of the standard ArcMap .mxd project document file format specifically designed to enhance the performance of published map services [77]. The results of a performance test comparing the maps per hour and average response times of three different map services sourcing data from an ArcSDE geodatabase (refer to Figure 3-8), revealed that the

optimised MSD service offered the best performance, slightly better than an ArcIMS map service (an older ESRI web map publishing software) and significantly better than a standard MXD map service [77].

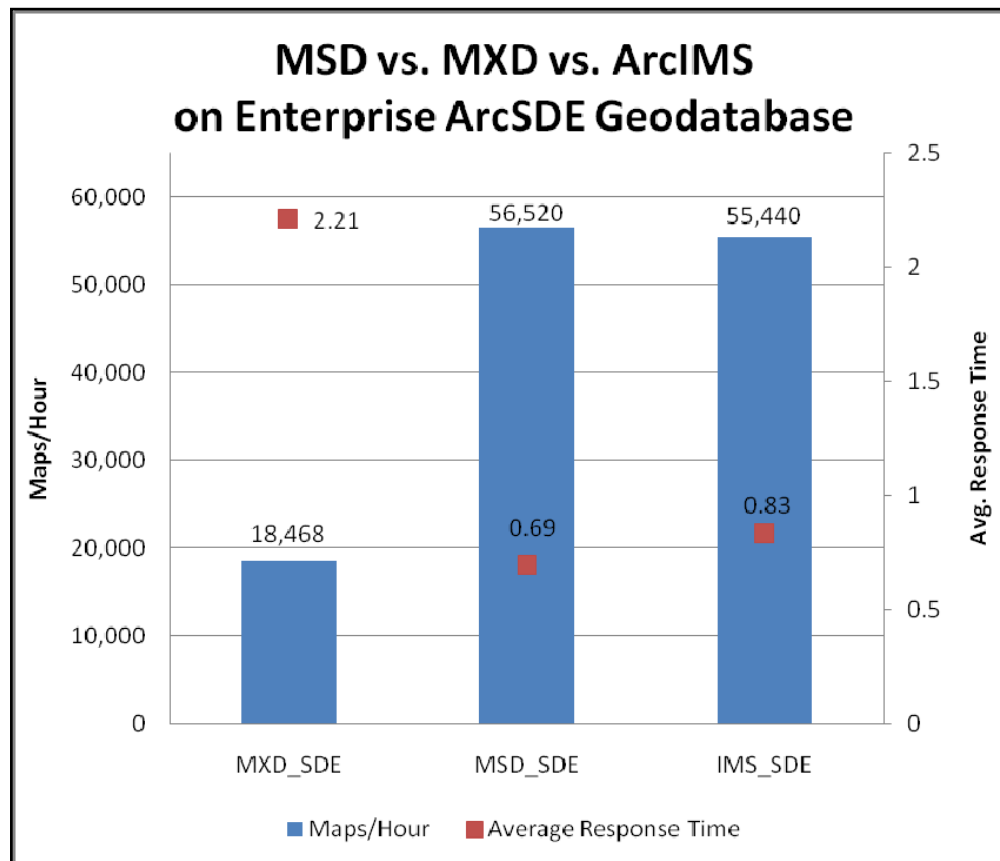


Figure 3-8: MXD/MSD/ArcIMS performance comparison test results [77]

Cached maps, however, provide the best performance for serving GIS data, with less load placed on the server [76], but dynamic MSD services provide a good alternative, having the additional advantages such as providing users with the flexibility to toggle the visibility of individual layers and the ability to serve the updated data as soon as the geodatabase is updated [75]. None of the GCRO themes could be cached because of the MXD/MSD functionality that was required in the application (such as dynamically switching on and off individual layers within each theme). However, good response times for rendering the map services

were achieved due to the use of the cached Google Maps as base layers, and in most cases, only a couple of dynamic GCRO theme layers switched on at any point in time. The result: a vast improvement in server response times and reduced server load compared to earlier GIS website applications using older Web GIS software such as ArcIMS, which required the server to render all the visible layers.

Four of the GCRO themes (GCRO Administrative layers, 2009 Quality of Life, Spatial Structure and Transport) were published as optimised MSD map services using the Publish to ArcGIS Server tool, within the Map Service Publishing toolbar. Two of the themes had to be published as MXDs due to the dynamic cartographic symbology used to visually represent the Census 2001 population and unemployment data as dot density maps, which is not supported in the MSD format.

## **Security**

As discussed in chapter 2.3, securing web services is an important part of securing a web application, especially in the case of potentially sensitive government information. Various techniques were implemented to safe guard the GCRO GIS server and web services, including:

- Hosting the GCRO GIS server in a secure data centre that deploys security measures such as IPS (Intrusion Prevention System), which is designed to monitor the network and system activities for malicious activities and attempt to block and report any malicious activity [94].
- Role based authentication that was applied to the GCRO GIS web services to ensure that only authorised users can access the GIS web services through the web.
- A security token that was implemented in the GCRO GIS viewer to allow the GCRO GIS application to access the GIS web services without the need for user names and passwords.

### 3.1.5 Step 5: Web application development

ESRI software (ArcGIS Server 9.3.1), was utilised to develop the application as it is the standard GIS software deployed by the GCRO. ESRI provides a range of RIA Web 2.0 software development kits (SDKs) such as web mapping APIs and application development frameworks to build dynamic applications that access the ArcGIS Server services [76]. These are depicted in Figure 3-9 and include: Java, Adobe Flex, Microsoft SharePoint, .NET and Silverlight.

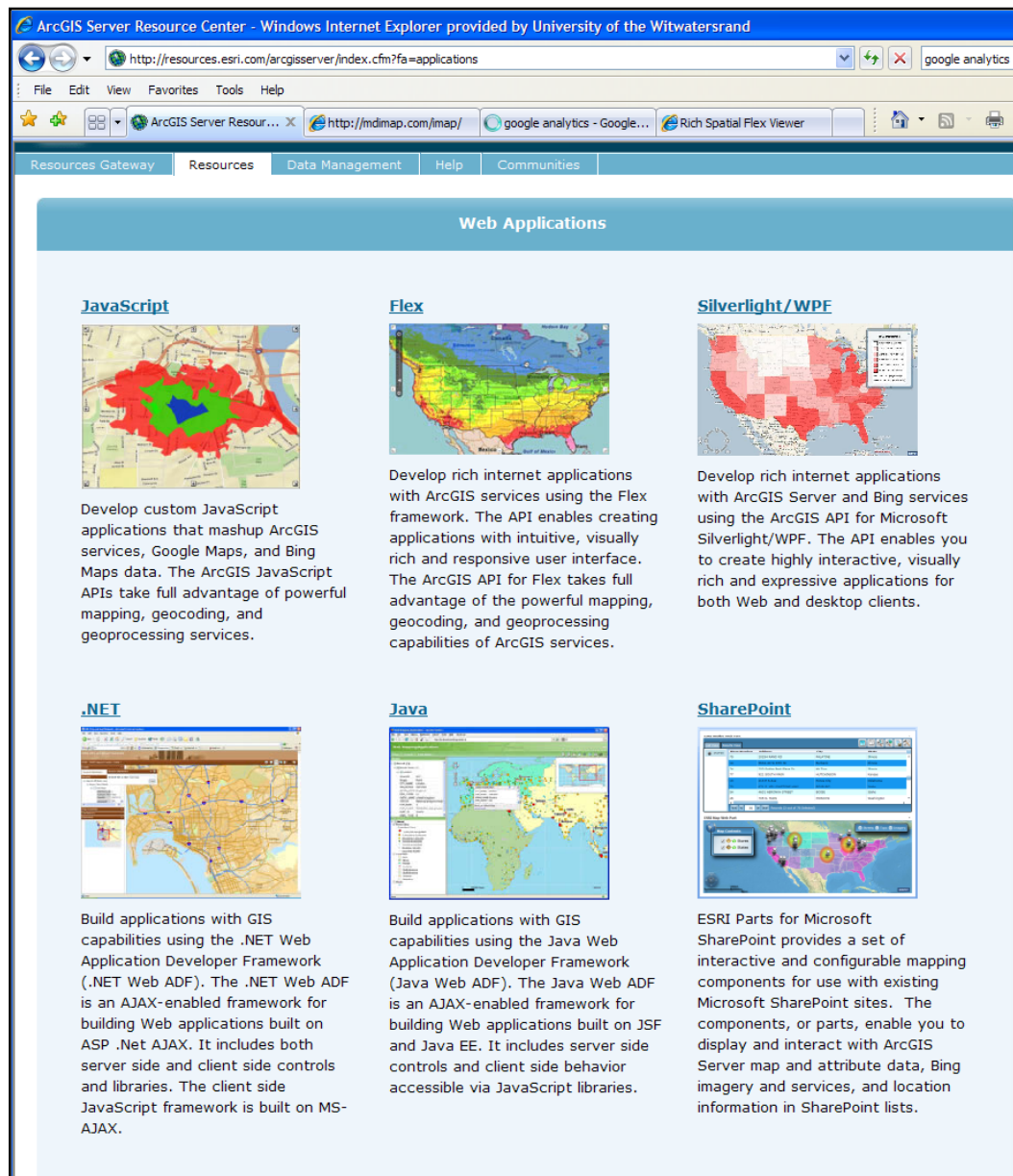


Figure 3-9: ArcGIS Server Web APIs [95]

The availability of programming skills is the most important factor to consider when deciding on which software and APIs to use to develop a GIS website [76]. The GIS viewer was developed by two student interns from the JCSE (Johannesburg Centre for Software Engineering) based at WITS [96]. As an increasing number of ESRI Adobe Flex websites were being developed and deployed, including the MD iMap website, it was decided to develop using the ESRI Adobe Flex sample viewer. Flex is based on an “open source framework for building expressive web applications that deploy consistently on all major browsers, desktops, and operating systems by leveraging the Adobe® Flash® Player and Adobe AIR® runtimes” [97] and deploys across all browsers and operating systems.

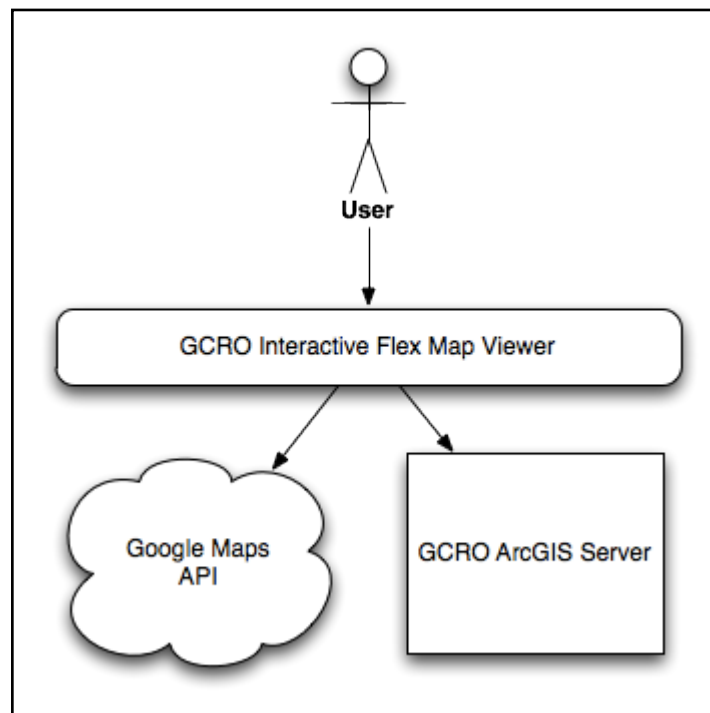


Figure 3-10: Structure of the GCRO GIS web application

The basic structure of the GCRO GIS web application is illustrated in Figure 3-10. Although Flex is open source, development is enhanced using a software development environment. Flash Builder 4 with the Flex 3.5 SDK was purchased

for use on this project. Mercurial open source version control software was also used to provide the functionality of merging different versions of code while keeping track of old versions, allowing the developers to work independently.

As the student developers had no prior knowledge of Adobe Flex or GIS web application development, a simplified prototype specification (Appendix B) was written by the author to test their development skills and ensure a basic prototype viewer could be built within the project time frame. The prototype specification, which focused on the integration of Google Maps and three GCRO themes (GCRO administrative base layers, demographics and 2009 Quality of Life) with dynamic graphs within the ESRI Flex viewer, formed the basis for the prototype design document prepared by the JCSE interns (Appendix C and Figure 3-11).

The GCRO GIS website was therefore developed by customising ESRI Flex sample viewer version 1.3 with the ESRI Flex API version 1.3 and Google Maps API for Flash, to incorporate the GCRO design and functionality detailed in the specification. An advantage of customising the sample viewer is that all the base functionality and tools such as navigation tools, basic searches and drawing tools were already included. Only the additional tools that the GCRO required, such as dynamic themes and graphs, had to be developed. However, a cautionary note is provided by Noyle and Bouwman [69] that with the wealth of development tools, developers should consider only including the essential tools from sample viewers and design them to be intuitively obvious to the user.

The prototype design document detailed the system design and divided the web application in four categories or layers. It lists the main widgets selected from the sample viewer to be included in the GCRO GIS web application:

- **Google Maps base layer** – to replace the ESRI base maps included in the sample viewer.
- **GCRO administrative layer** – an ArcGIS Server web mapping service to be included within the base layers.

- **GCRO dynamic data layers** – dynamic themes published as ArcGIS Server web mapping services with additional functionality of pop up graphs linked to the maps.
- **Application widgets** – existing widgets from the sample viewer to be configured, including a graphing, search, drawing and bookmark widget.

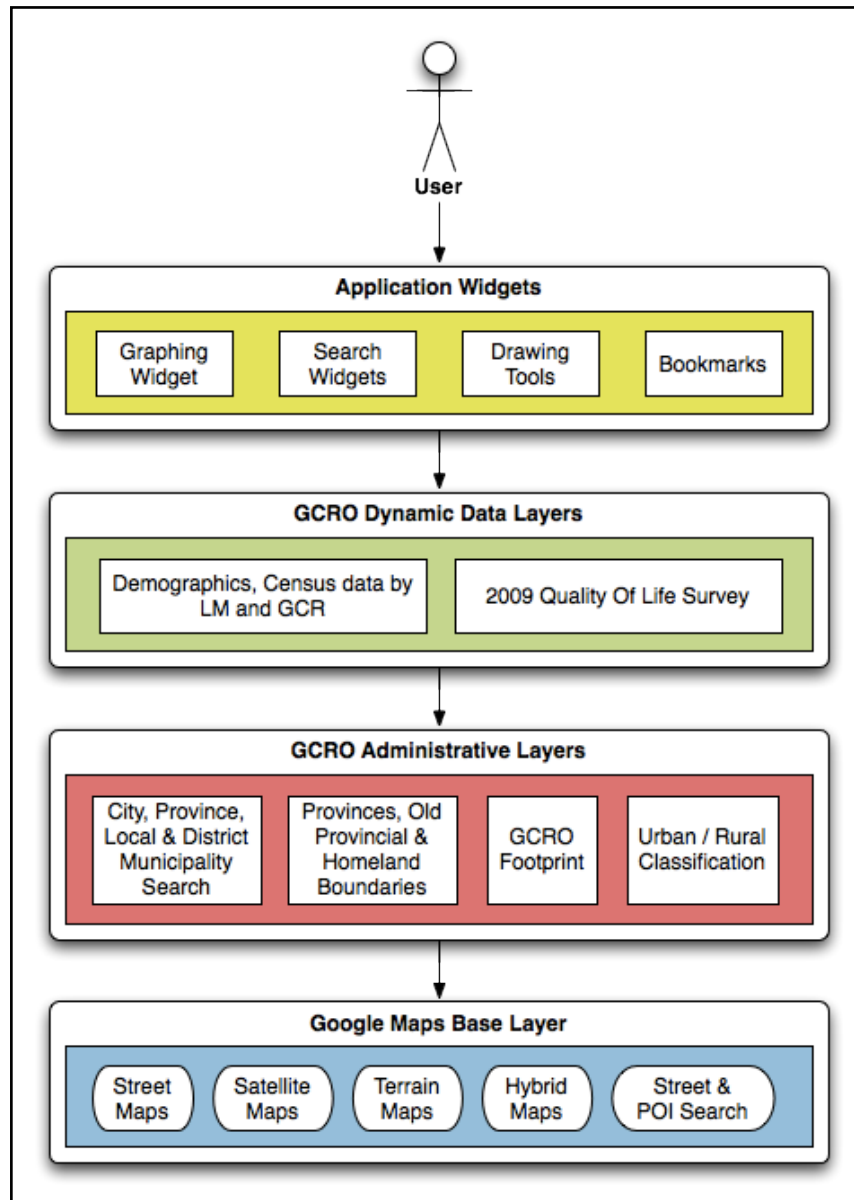


Figure 3-11: Detailed layering structure of the GCRO GIS prototype web application

The prototype development was completed by June 2010 and presented to GCRO and GPG staff.

### **3.2 Measuring user acceptance using TAM**

The success of the GCRO GIS website can be determined by measuring user acceptance. The most widely employed model of IT adoption that can be utilised to measure user acceptance, is TAM. Various TAM models including TAM2, UTAUT and TAM3, and alternatives such as the WAMMI questionnaire, were introduced in the previous chapter. These models explored in more detail the key determinants of user acceptance, with the TAM3 model presenting a complete model of the determinants of individuals' IT adoption and use [79]. A TAM questionnaire had been successfully used in a Wits research project which investigated minimising the effect of user obstruction to the deployment of Information Technologies for mobile computing applications in Africa [117], and it was decided to use a similar TAM methodology deployed in the research project to test the acceptability of the GCRO GIS website during its development. This dissertation, however, was mainly concerned with measuring whether the Web 2.0 g-government technology would be accepted by the GCRO staff and local and provincial government, and not the measurement of which variables influence user acceptance. Therefore the three main constructs – perceived usefulness, perceived ease of use and behavioural intention – from the original TAM presented by Davis [20], adapted by Davis and Venkatesh [85] in pre-prototype user acceptance testing and Venkatesh and Bala [79] in the TAM3 model, were used to develop a questionnaire to measure user acceptance of the GCRO GIS website.

#### **3.2.1 GCRO GIS website TAM questionnaire**

The TAM section of the questionnaire consisted of four questions to measure perceived usefulness, four questions to measure perceived ease of use and one question measuring behavioural intention (see Table 3-3 below). A further question adapted from TAM3 measuring the output quality, was also included to measure the user's ranking of the quality of GCRO GIS data in the website.

The responses were measured using a 7-point Likert scale where 1: strongly disagree, 2: moderately disagree, 3: slightly disagree, 4: neutral, 5: slightly agree,

6: moderately agree and 7: strongly agree. This is a slight variation from Likert scale used in TAM3, where 3: somewhat disagree and 5: somewhat agree was used [79], as it was felt that the term ‘slightly’ was a greater differentiator between points 2 and 3, and 5 and 6 in the 7-point scale, than the term ‘somewhat’. The two GCRO questionnaires are provided in Appendices D and E.

Table 3-3: TAM constructs and questions utilised in the GCRO GIS website questionnaire

|                                     |                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Perceived usefulness</b>         | <ul style="list-style-type: none"> <li>• Using the GCRO GIS interactive website will improve my performance in my job.</li> <li>• Using the GCRO GIS interactive website will increase my productivity.</li> <li>• Using the GCRO GIS interactive website will enhance my effectiveness in my job.</li> <li>• I would find the GCRO GIS interactive website useful in my job.</li> </ul>                                  |
| <b>Perceived ease of use</b>        | <ul style="list-style-type: none"> <li>• My interaction with the GCRO GIS interactive website will be clear and understandable.</li> <li>• Interacting with the GCRO GIS interactive website will be free from a lot of mental effort.</li> <li>• I will find the GCRO GIS interactive website easy to use.</li> <li>• I will find it easy to get the GCRO GIS interactive website to do what I want it to do.</li> </ul> |
| <b>Output quality</b>               | <ul style="list-style-type: none"> <li>• The quality of the output I will get from GCRO GIS interactive website will be high.</li> </ul>                                                                                                                                                                                                                                                                                  |
| <b>Behavioural intention to use</b> | <ul style="list-style-type: none"> <li>• Given that I will have access to the GCRO GIS interactive website, I predict I will use it.</li> </ul>                                                                                                                                                                                                                                                                           |

The GCRO GIS website user acceptance TAM survey did not require ethical clearance from the WITS Human Research Ethics Committee, as it was exempt in

terms of the Office for Human Research Protections' decision charts, under 45 CFR 46.101(b)(2) [98, 99].

### 3.2.2 Sampling

User acceptance was measured at two stages during the project. Firstly, at the prototype stage, following a brief presentation to GCRO staff at the GCRO offices and a small group of management staff from the GPG Department of Economic Development at their offices. The presentation explained the background to the development and business need for the GIS website and was followed by a short 5 minute live demonstration of the key features of the GCRO prototype. All attendees were then requested to complete a user review of the GCRO GIS interactive website. This early TAM measurement provided an opportunity to test the questionnaire and gauge user acceptance of the proposed GIS website, prior to the finalisation of the design and implementation of the GIS website. It also provided a chance for users to provide comments and input that were used to alter the final design.

A second TAM measurement was performed at the official launch of the GCRO GIS website to determine user acceptance of the final implemented GCRO GIS website. Users interacting with the GIS website are depicted in Figure 3-12.



Figure 3-12: Pictures from the launch showing users interacting with the GIS website

The launch/training sessions were held over three days from 1-3 September 2010 at the WITS School of Electrical Engineering's PC lab, with each session focusing on a different group of users, i.e.

- GIS specialists from all spheres of government
- Local and provincial government officials involved in planning in the GCR
- GPG Heads of Departments.

After a short introduction explaining the business need for the GIS website and development process, an interactive demo of the website was presented by the author, with participants able to interact and learn the various tools and datasets available using the engineering lab PCs. Attendees then evaluated the website by filling in the online TAM questionnaire.

The GCRO prototype TAM questionnaire was adjusted for the second measurement to include additional questions such as how often the user will use the system and what the website would mainly be used for, e.g. to learn about the GCR or access data. The questionnaire was completed by the potential users after a live demonstration/training session that was designed to allow the users to fully interact with the GIS website (described in more detail in the TAM3 post-implementation interventions section below).

Although the research by Davis and Venkatesh [85] established that a user's intentions to use a system could be measured at the pre-prototype or proof of concept stage of software development, it is still important to measure user acceptance of the final implemented system. The TAM responses captured at the launch therefore represent the users' perceived usefulness, perceived ease of use and behavioural intention based on their initial use of the system.

In order to evaluate how the GCRO GIS website's perceived usefulness and ease of use compared to an existing government GIS website and to generally test the TAM as a tool to measure user acceptance of GIS websites, the identical TAM

questions utilised in the GCRO GIS website questionnaire were also included in a user survey of a successful local government GIS website, the CoJ's online maps application.

The data from the various TAM questionnaires described above were imported into the statistical software PASW Statistics (SPSS) version 18.0 to run the statistical analysis.

### **3.2.3 TAM3 Pre-implementation interventions**

The sampling procedure was influenced by several pre- and post-implementation methods proposed by Venkatesh and Bala [79] described in the Literature Review chapter. The pre-implementation interventions that take place during system development and deployment are designed to minimise the initial resistance to new applications and provide a realistic preview of the system for the potential users [79]. They include: design characteristics, user participation, management support and incentive alignment. As the GCRO GIS website was developed for use within the research and government environment, incentive alignment was not considered an appropriate intervention.

The design characteristics of a system are comprised of the information-related and system-related characteristics [79]. The information-related components in a GIS web application consist of the spatial data and how it is visualised with maps, graphs and charts. Venkatesh and Bala [79] propose that the information-related characteristics will influence perceived usefulness, i.e. if a system can provide the relevant information in a timely, accurate understandable format that can help make better decisions; users are more likely to accept and use the system. There was therefore a focus to ensure the data included in the GIS website was relevant and understandable with visually appealing dynamic maps and graphs.

The system-related characteristics are the actual web application and Web 2.0 tools. If the system can be characterised as reliable, flexible and user friendly, then users will have a high degree of perceived ease of use and have less stress-

related anxiety [79]. These characteristics were key components of the GCRO GIS website specification and the developers were briefed in detail about the importance of reliability, flexibility and user friendliness in the implemented GIS website.

User participation in the system development and implementation activities assists the potential users to generate a better understanding of the system features, organisation resources and management's support of the new application, which may lead to reduced anxiety about the new system and a higher level of perceived usefulness from the user [79]. User participation was encouraged initially with input from the GCRO staff at the initial conceptualisation of the project and development of the GCRO GIS website specification. Once the prototype was developed, both the GCRO and key staff members and management of the GPG Department of Economic Development were given the opportunity to view and comment on the proposed GIS website.

Management support directly influences both perceived usefulness and ease of use and is critical to the system success and adoption [79]. Fortunately support from the GCRO Executive Director and senior management from the GPG Department of Economic Development and Gauteng Planning Commission, was secured early on in the project and management played an instrumental role in arranging and ensuring attendance from the GPG Head of Departments at the third launch session.

#### **3.2.4 TAM3 Post-implementation interventions**

Post-implementation procedures, listed as training, organisational support and peer support, occur after the deployment of a new system and represent organisational, managerial and support activities to enhance the user acceptance of the system [79]. The procedures should make users feel the new system is an opportunity to enhance their job performance and that they have the necessary support and resources.

The main post-implementation method utilised in this research was training, as it is considered to be one of the most important post-implementation interventions that can lead to greater user acceptance and system success [100]. The official launch was therefore arranged at a venue that had online access to the GCRO GIS website for each attendee. While a live demonstration was presented, users could follow the demo on their PC or generally experiment with the website. This provided each attendee with a unique opportunity to personally interact with the website and obtain a full understanding of the functionality and data available in the website.

### **3.3 Conclusion**

A Web 2.0 GIS website design methodology, which includes a number of techniques and methods that should be implemented to ensure an optimised GIS application, discussed in this chapter, was utilised to develop the GCRO GIS website. Various pre- and post-implementation interventions proposed in the TAM3 model were also employed to minimise user resistance and maximise user acceptance of the new GIS website. Finally, TAM, as a methodology to measure user acceptance and determine the success of the GIS website development, was used to design a questionnaire and measure user acceptance of the GCRO GIS website and provide a perceived usefulness and ease of use comparison to an existing government GIS website.

## 4. RESULTS AND ANALYSIS

Version 1.0 of the GCRO GIS website was released and publically launched on 1 September 2010. A brief description of the website's main functionality and available data is provided in the first section of this chapter. This followed by an analysis of the GCRO TAM questionnaires to determine the success of the website development by measuring user acceptance. Finally a comparison between the GCRO TAM results and TAM questions in the CoJ Online GIS user survey is reviewed.

### 4.1 The GCRO GIS website

The GCRO GIS website is viewable in all the main Internet browsers (such as Internet Explorer, Safari, Firefox and Google Chrome), but does require a reasonable broadband Internet connection and the Adobe Flash Player plug-in (version 9) to be installed. It is accessed from the GCRO website ([www.gcro.ac.za](http://www.gcro.ac.za)), depicted in Figure 4-1, by selecting the Interactive GIS link and clicking on the map image.



Figure 4-1: GCRO website with links to the GCRO GIS website

The user is presented with a disclaimer screen which provides a brief description of the viewer and basic steps of interaction with the data, i.e. changing the Google Maps base layers and interacting with the various GCRO themes and dynamic graph functionality. The user then has the choice of accepting the disclaimer and entering the site, opening the site and a tutorial, or returning to the GCRO home page.

The website consists of the mapping window that utilises the full extent of the browser window, the main user interface in the top left corner, and tools and themes which pop up on the right hand side (Figure 4-2). The website tools are depicted in Figure 4-3 and grouped into: base data, dynamic themes, navigation tools (which are also easily accessible on the main interface), website tools and help.

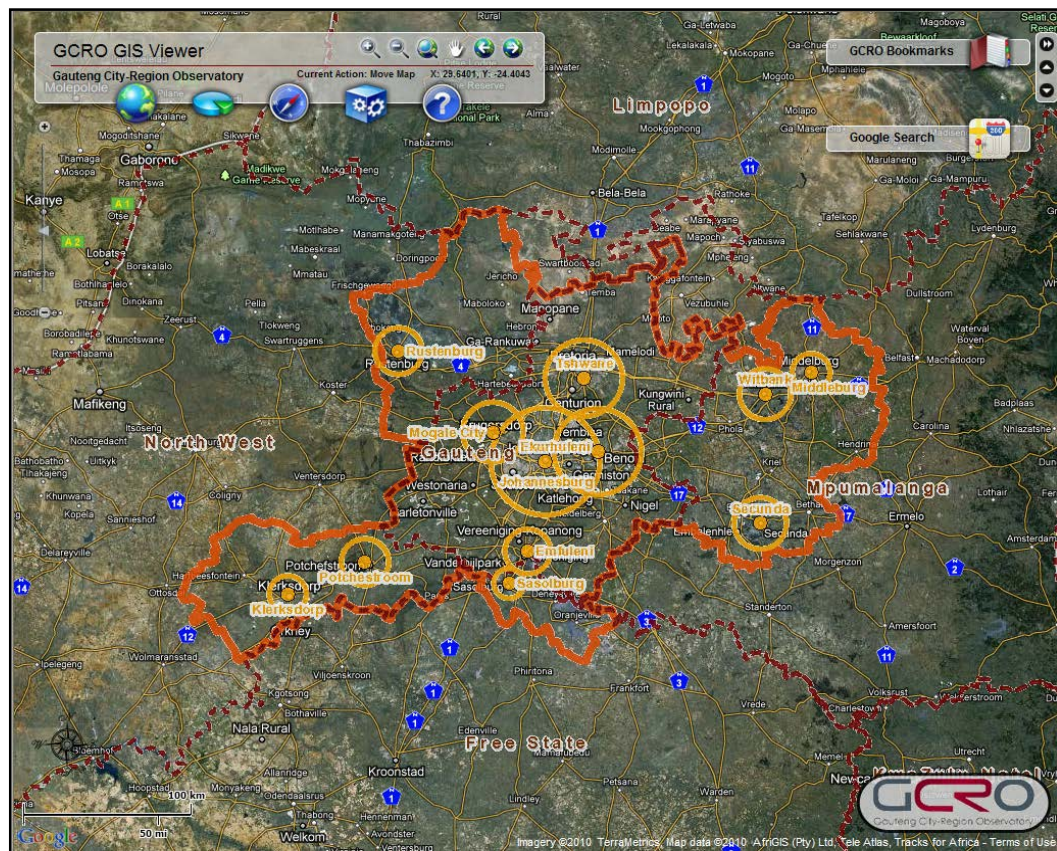


Figure 4-2: GCRO GIS website

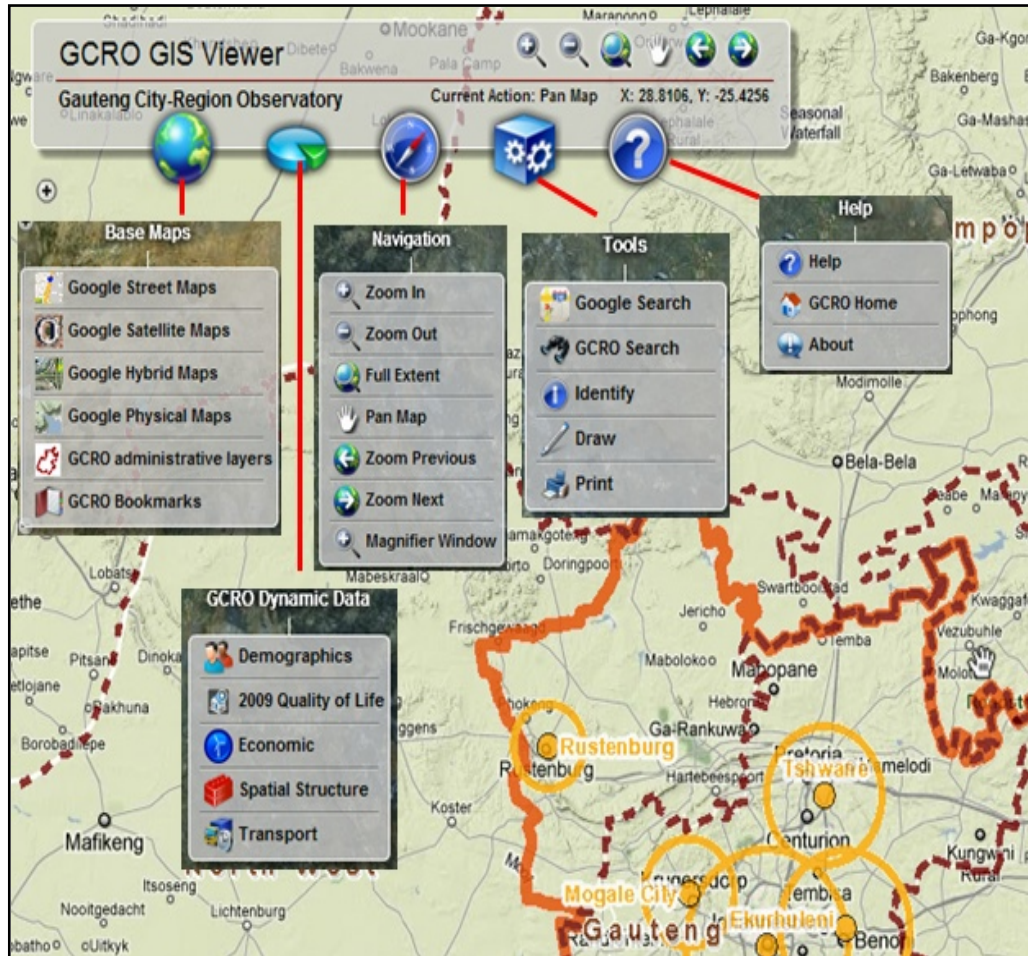


Figure 4-3: GCRO GIS website: base data, GCRO themes and tools

After accepting the disclaimer, the user selects the appropriate base data layers by choosing a Google Maps layer to display (hybrid maps are the default base map). Figure 4-4 indicates the four Google Maps layers that provide seamless imagery, transportation information and main points of interest, across the entire GCR and neighbouring areas. The advantage of using mapping layers, such as Google Maps, is that the user has access to an entire worldwide base map, and as they are cached, the Google Maps base maps are downloaded and drawn quickly. The download speed is dependent on the user's network connection, but if a user can access the Google Maps websites, they can utilise the GCRO website.

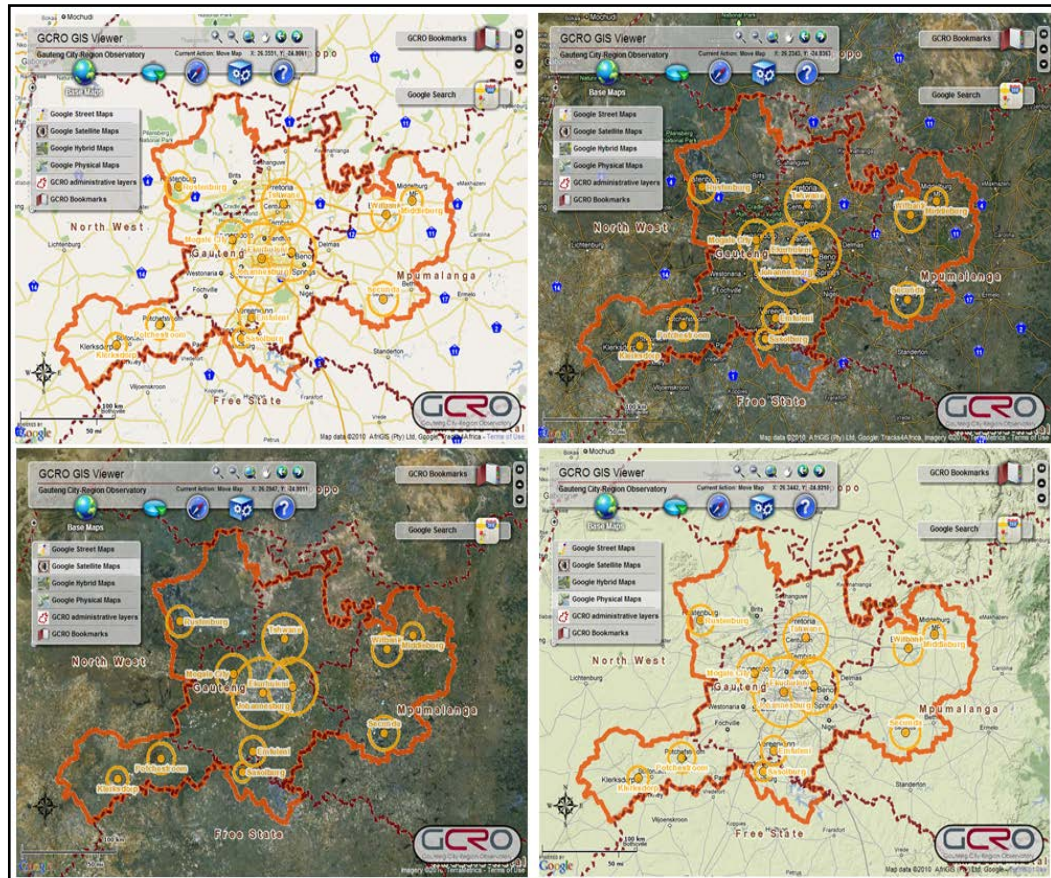


Figure 4-4: Google Maps base map layers: street, satellite, hybrid and physical

The next step is for the user to define what GCRO administrative layers are to be shown by opening the GCRO Administrative layers theme widget. The individual layers can be switched on and off, although some layers are only visible at various scales. The other tools available include adjusting the transparency of the layers, chart statistics or graphs, metadata for each layer, a legend (shown in Figure 4-5) and an option to lock the transparency of the theme window.

Once the base map layers are selected, the user can interact with the various GCRO dynamic themes which contain categorised layers focused on specific themes. The tools available in the Administrative layers theme described above are available in the GCRO dynamic themes, with a few of the GCRO dynamic theme layers also offering dynamic graphs with the chart statistics tool.

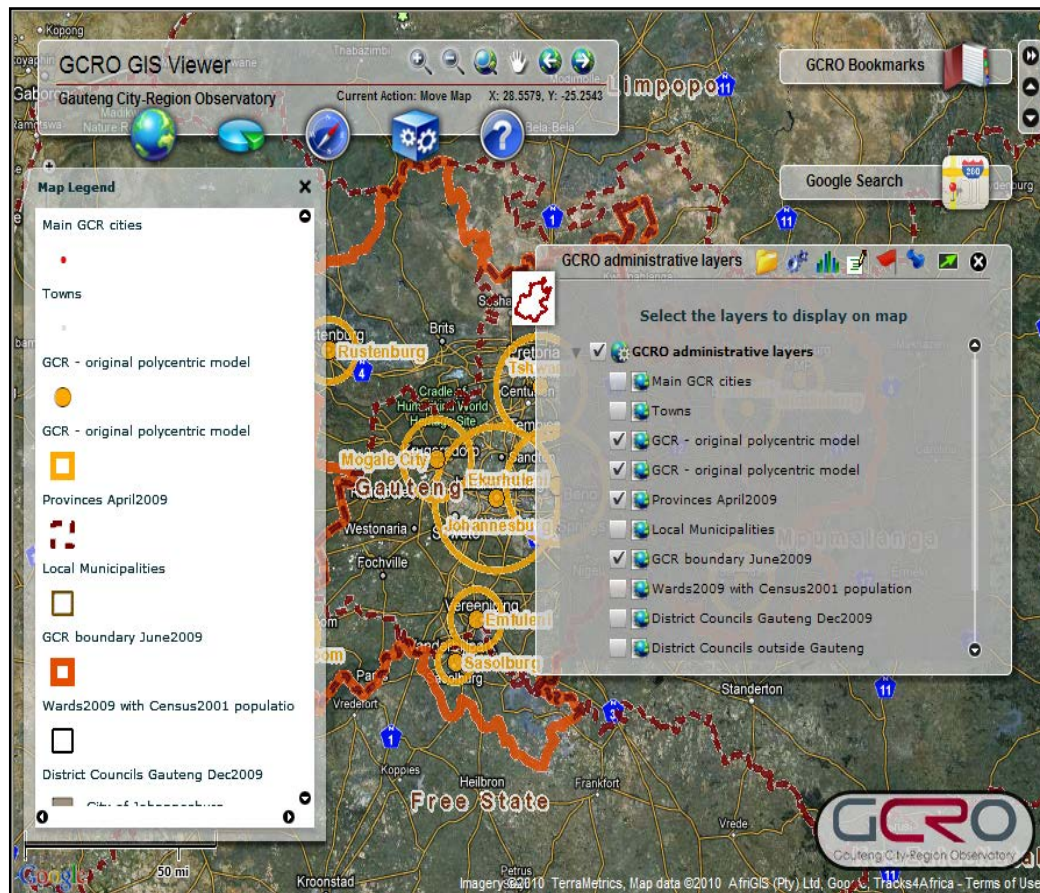


Figure 4-5: GCRO Administrative layers theme widget with map legend

An example of dynamic Web 2.0 RIA functionality is provided in Figure 4-6, which depicts the visualisation of the 2009 Quality of Life survey, with the satisfaction with local government layer displayed on the map and dissatisfaction with government drawn in the graph. The chart statistics tool has a further option that may be selected – to dynamically link the graph to the map. In this case, when the information in the graph is moused over, the corresponding area on the map is highlighted. When the bar chart in the graph is clicked, the corresponding area on the map is zoomed into. Figure 4-7 depicts the local municipality of Westonaria with a rating of 36% dissatisfaction with national government highlighted on the map.

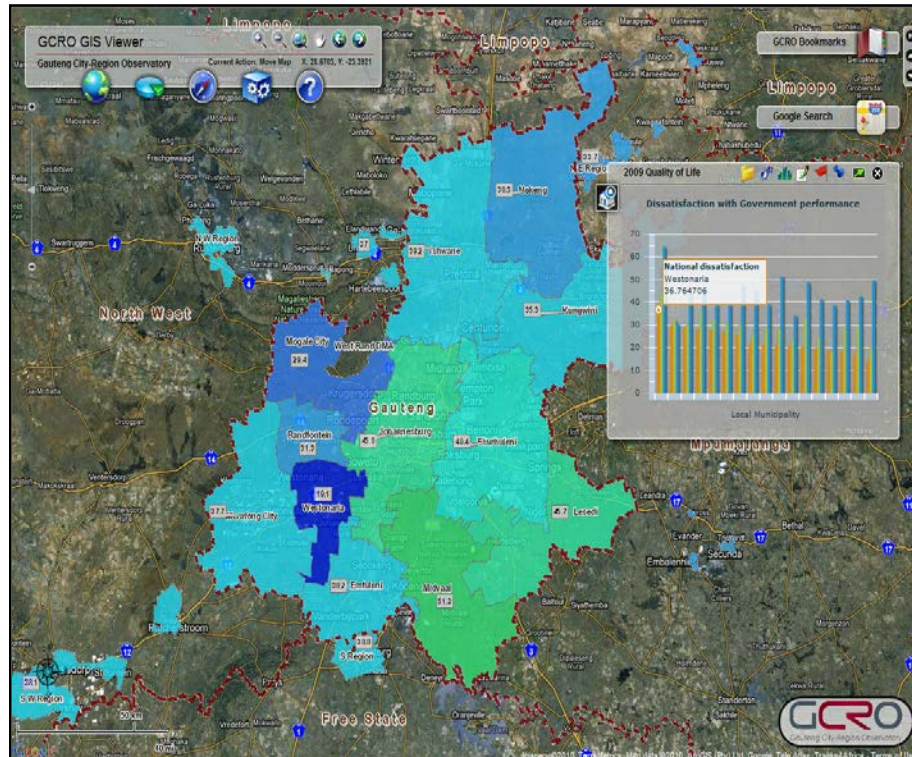


Figure 4-6: 2009 Quality of Life dynamic theme with graph

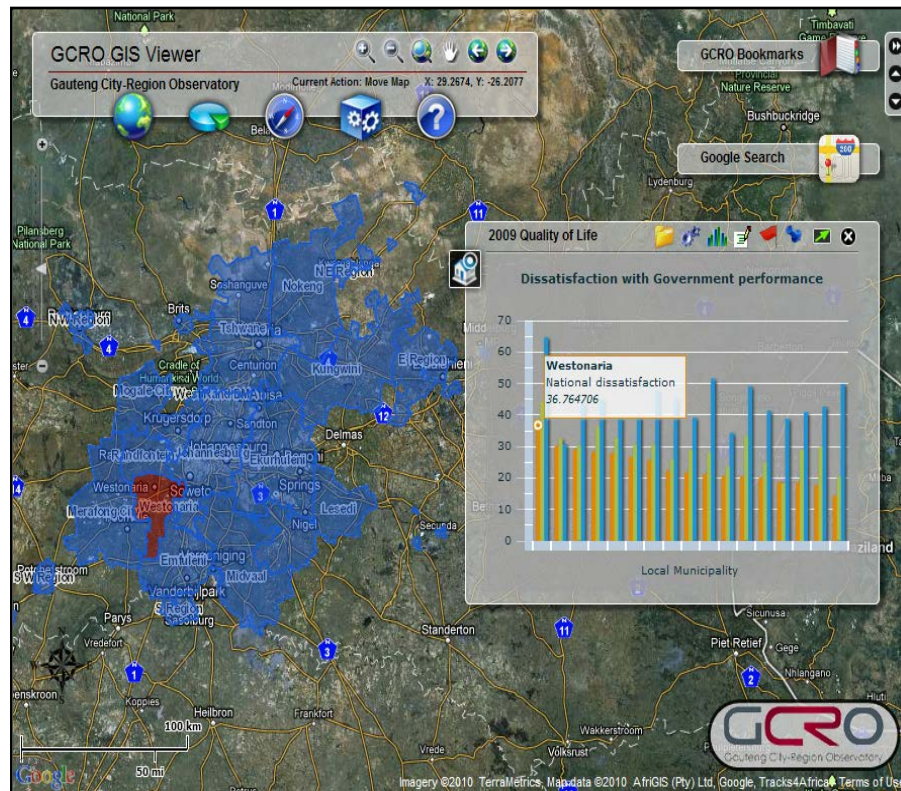


Figure 4-7: Graphs dynamically linked to the map

Two different search tools are available. The first is a Google search which utilises the power of the Google Maps search engine and allows the user to search for a point of interest, street address or any other feature stored in the Google Maps database. The GCRO search provides for searches on specific GCRO layers such as the local municipality or wards. There is also an identify, draw and printing tool, which allows the user to choose a base layer and print to an A4 landscape or pdf file. Finally, a comprehensive help page is provided that explains each tool in detail.

User experience is defined by Fu, Yin and Sun [93] as “the level of satisfaction a person gets from using a product or a service”, with a pleasant user experience conveying the three main principles of user experience design – the web application should be fast, easy and fun to use. The next section will show that this has been achieved.

#### **4.2 GCRO TAM analysis**

User acceptance of the GCRO GIS website was tested at the prototype and implementation/launch stages of the project using the TAM questions adapted from Davis and Venkatesh [85] and Venkatesh and Bala [79], to measure perceived usefulness, perceived ease of use, output quality and behavioural intention to use. The perceived usefulness variable was computed from the average of the four perceived usefulness questions. Similarly, the perceived ease of use variable was computed from the average of the four perceived ease of use questions. The output quality and behavioural intention to use variables were determined from the output quality and behavioural intention to use questions respectively. All the TAM questions were measured with a 7-point Likert scale with the perceived usefulness, perceived ease of use and behavioural intention scores ranging from 1 (extremely unlikely to use the website) to 7 (extremely likely to use the website). A high score in the output quality represents a high rating of the data quality.

#### **4.2.1 GCRO GIS website prototype user review**

The GCRO GIS website prototype user review questionnaire sample consisted of 3 GCRO staff and 3 senior planning officials from the GPG Department of Economic Development. This is a statistically small sample, but the results displayed in Table 4-1 are significant as they indicate high user acceptance scores, with low standard deviations across all of the TAM constructs, and 100% of the users sampled predicting they would use the implemented website. This provided confirmation of the proposed design and user acceptance of the new technology at the prototype stage, with some of the user comments influencing the functionality incorporated in the final viewer. However, as the website was slow during the demo using the GPG network at the GPG Department of Economic Development's offices, the staff did raise a concern with slow GPG network connections perhaps affecting the response and usability of the final implemented website.

Table 4-1: GCRO GIS prototype TAM scores

| <b>TAM variables</b>  | <b>Average</b> | <b>Std deviation</b> |
|-----------------------|----------------|----------------------|
| Perceived usefulness  | 6.58           | 0.41                 |
| Perceived ease of use | 6.25           | 0.45                 |
| Output quality (data) | 6.50           | 0.55                 |
| Behavioural intention | 7.00           | 0.00                 |

#### **4.2.2 GCRO GIS website launch questionnaire analysis**

The GCRO GIS website launch evaluation questionnaire sample consisted of 4 staff from the GCRO (11%), 12 from GPG (32%), 15 from local government (40%) and 7 individuals, grouped as "other" in the database, from the National Department of Human Settlements, UJ, WITS, CSIR (Council for Scientific and

Industrial Research) and Development Bank of Southern Africa (DBSA). The total sample survey was 38 respondents and is representative of the GCRO stakeholders for whom the GIS website was developed. These potential users were surveyed at the launch/training sessions following a short presentation and live demonstration, with attendees able to follow the demo and interact with the website and data using the venue's computers. The GCRO GIS website is hosted on the same network as the launch venue which provided optimal performance. Lower TAM scores may be expected with users accessing the website through slow connections.

There was an almost even split between managers (including GPG department heads and directors) and specialist/research staff of 53% and 47% respectively. A wide range of GPG departments were represented, such as Economic Development, Development Planning, Local Government and Housing, and Roads and Transport. The local government attendees were mainly from GIS, planning or land use management departments, with one attendee from a central strategy unit. In terms of qualifications and experience, 95% of the respondents had a minimum of a diploma, with 26% stating that they had no formal GIS experience. However an indication of the growth of online maps and GIS on the Internet is provided by the statistics that 92 % of the attendees had previously used an online GIS website.

The TAM analysis of the total sample is presented in Table 4-2 and Figure 4-8, with high user acceptance scores for all of the TAM constructs and the behavioural intention to use average, scoring a possible 6.82 out of 7. The standard deviations are all below 1 and medians greater than the mean<sup>3</sup>, indicating the data is clustered around the high end (7) of the Likert scale. This is visible in Figure 4-9, a histogram of behavioural intention to use, which is skewed to the left with a few outliers on the lower end. It is also significant that there were no negative responses, i.e. the minimum scores were a few neutral rankings scoring 4

---

<sup>3</sup> A mean is the average of a numerical dataset, whereas a median is "the point at which there are an equal number of data points whose values lie above and below the median value"[101]

on the Likert scale. Therefore all respondents on average agreed that the GCRO website would be useful in their jobs, that it was easy to use, the quality of the data was high, and that given they had access to the website, intended to use it.

Table 4-2: GCRO GIS website launch TAM analysis results for all respondents

| <b>TAM construct</b>         | <b>Minimum</b> | <b>Maximum</b> | <b>Average/<br/>mean</b> | <b>Median</b> | <b>Std.<br/>Deviation</b> |
|------------------------------|----------------|----------------|--------------------------|---------------|---------------------------|
| Perceived usefulness         | 4              | 7              | 6.36                     | 7.00          | 0.91                      |
| Perceived Ease of Use        | 4              | 7              | 6.23                     | 6.25          | 0.83                      |
| Quality of output            | 4              | 7              | 6.47                     | 7.00          | 0.76                      |
| Behavioural intention to use | 5              | 7              | 6.82                     | 7.00          | 0.46                      |

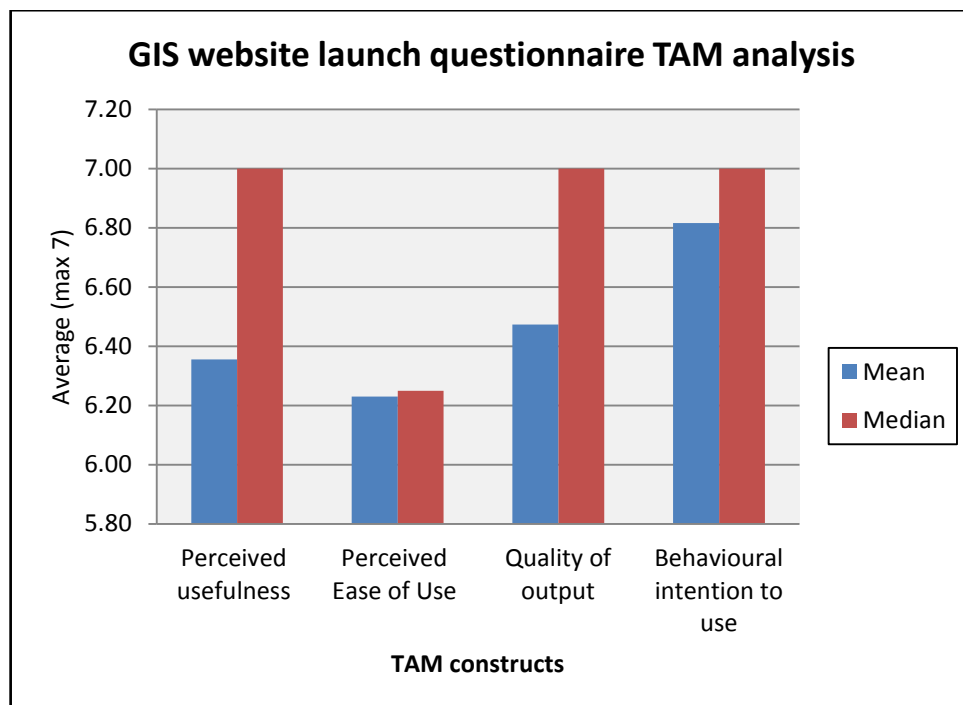


Figure 4-8: Graph of GCRO GIS website launch questionnaire TAM analysis

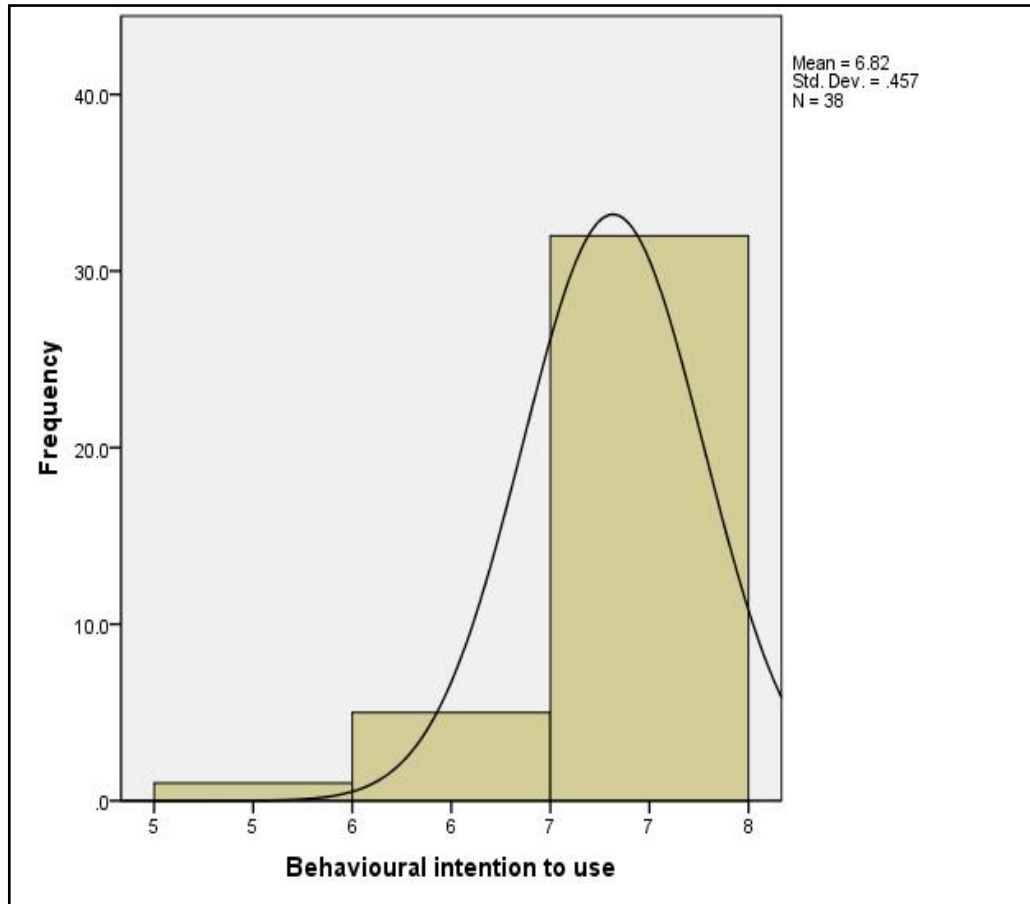


Figure 4-9: Histogram with normal distribution curve of the GCRO GIS website launch sample – behavioural intention to use TAM variable

This is supported by the comments from the questionnaire. In the perceived usefulness section, comments ranged from a more neutral: “The website would not be useful specifically for the nature of my job” to “Our district does not have access or rather developed systems to access some geographical data, therefore this website will definitely help us access some of this information and improve the effectiveness in our tasks” and “Extremely useful tool and very user friendly”. In terms of the perceived ease of use comments, some respondents were impressed with the user friendliness: “Very user friendly – even to a novice like me”. Other respondents were overwhelmed at first but after the live demo/training session gained confidence, for example: “Website is very easy to use once one gets the hang of things” and “On first impression it looked complicated, but after

30 minutes, the layout made it easy to use the site”. This highlights the importance training has in positively influencing user acceptance of a new technology, as identified by Venkatesh and Bala [79] as a vital post-implementation intervention. Other users noted that their interaction would improve with further use.

Comments in the quality of output section of the questionnaire ranged from “Very good” to “Excellent”, with respondents impressed with the quality and clarity of the Google Maps imagery and one user even noting: “I have never seen such clear photos”. All of the behavioural intention to use comments confirmed that they would use the GCRO GIS website as an additional tool in their work.

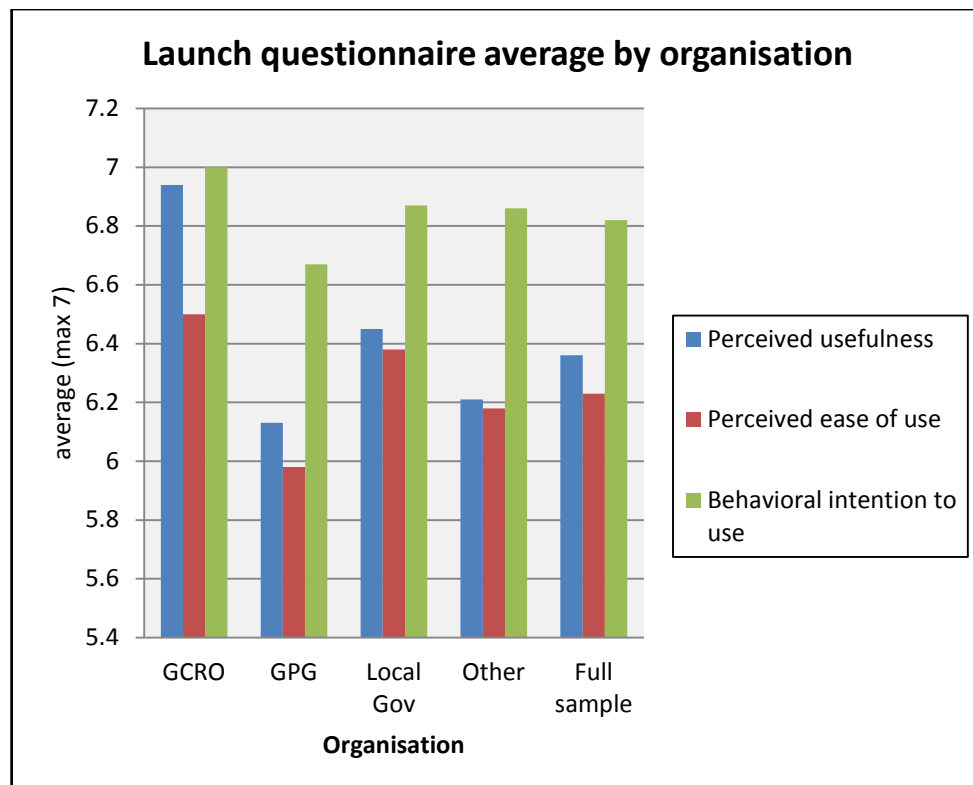


Figure 4-10: Graph showing the results of the GCRO GIS website launch TAM analysis by organisation

Analysing the launch questionnaire by the different organisations or spheres of government (Figure 4-10), reflects high user acceptance across all the different organisations, illustrating a definite need from both provincial and local

government to access to Web GIS data and tools for the GCR. As is clearly visible in Figure 4-11, GIS experience was not a prerequisite to be able to utilise the GCRO GIS website, as those with no prior GIS experience (10 individuals) scored in the same range as those with GIS experience (28 individuals) . This confirms that the user friendly development specification, with use by both policy-makers and specialists, was achieved. As identified by one of the respondents, training and good descriptive help files are also important factors to aid non-GIS users: “As someone who is not familiar with GIS-based websites, or GIS itself, I think the help function is an excellent tool to facilitate easy understanding of the website and how best to use it. I have learned a lot from Chris’ tutorial”.

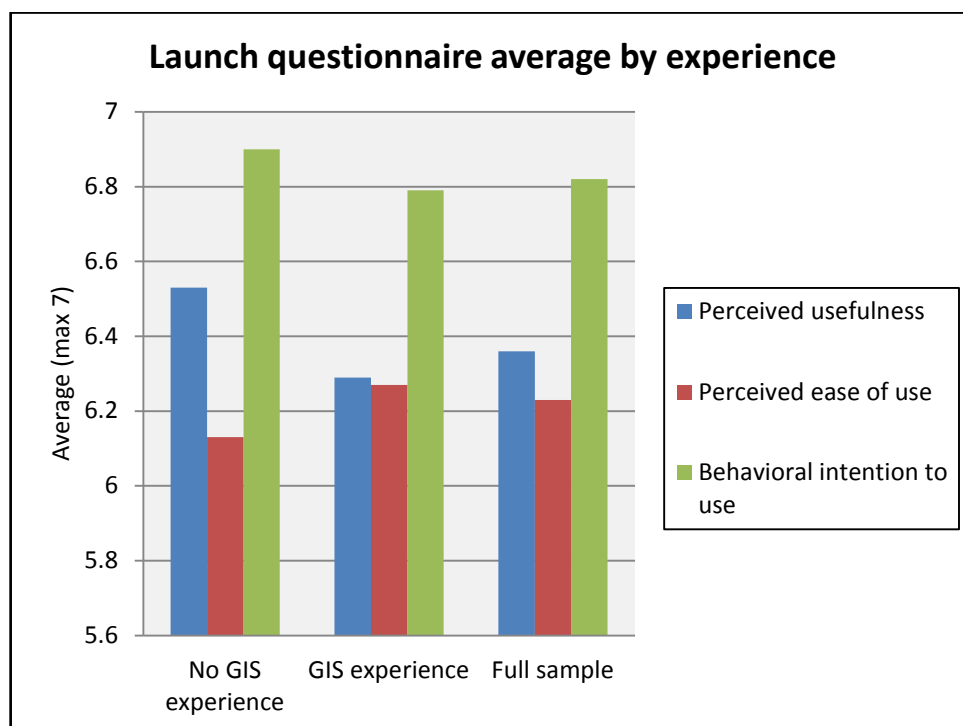


Figure 4-11: Graph showing the results of the GCRO GIS website launch TAM analysis by GIS experience

It is recognised that launch questionnaire samples are small when grouped by organisation or experience, i.e. less than the generally statistically accepted

sample population of 30 [101], but the results were all in a similar range with population samples clustered around the high end of the Likert scale and therefore were considered to be valid.

In terms of usage, two thirds of the respondents (68.4%) replied that they would use the website on a daily or weekly basis, with the main use of the website identified as accessing GCR data (87%), followed by 71% of respondents intending to use the website to assist with planning (refer to Figure 4-12). As one of the respondents commented: “This is a perfect tool for planning and implementation”. Other uses identified by the respondents included a decision support tool, monitoring tool for changes in land use and environmental patterns and for writing, teaching and presentations.

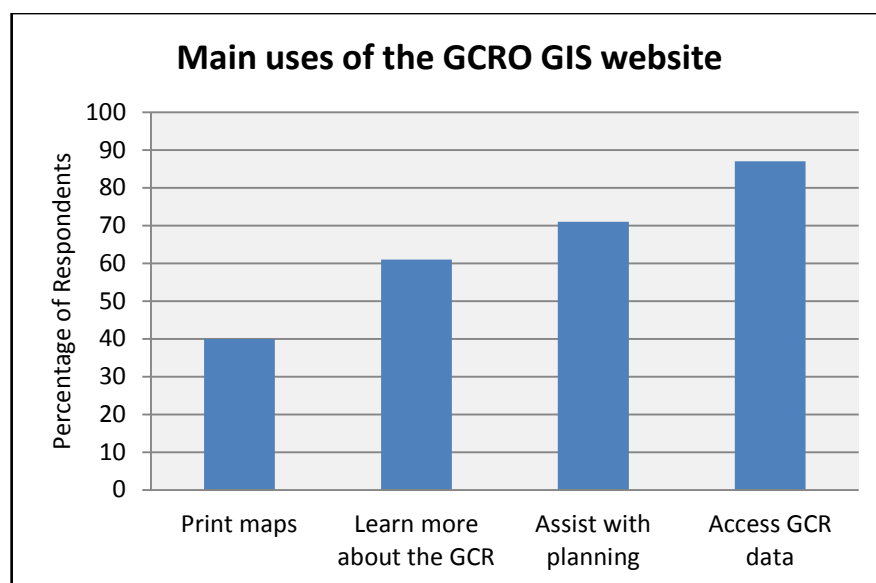


Figure 4-12: Graph depicting the main uses of the website

The above results have indicated that the g-government website development was a success with user acceptance of the new technology confirmed by the TAM results.

### 4.3 Comparison to CoJ Online GIS website

In order to place the GCRO TAM results in perspective, the TAM scores were benchmarked against an existing online government GIS website, the CoJ Corporate Geo-Informatics (CGIS) online maps website.

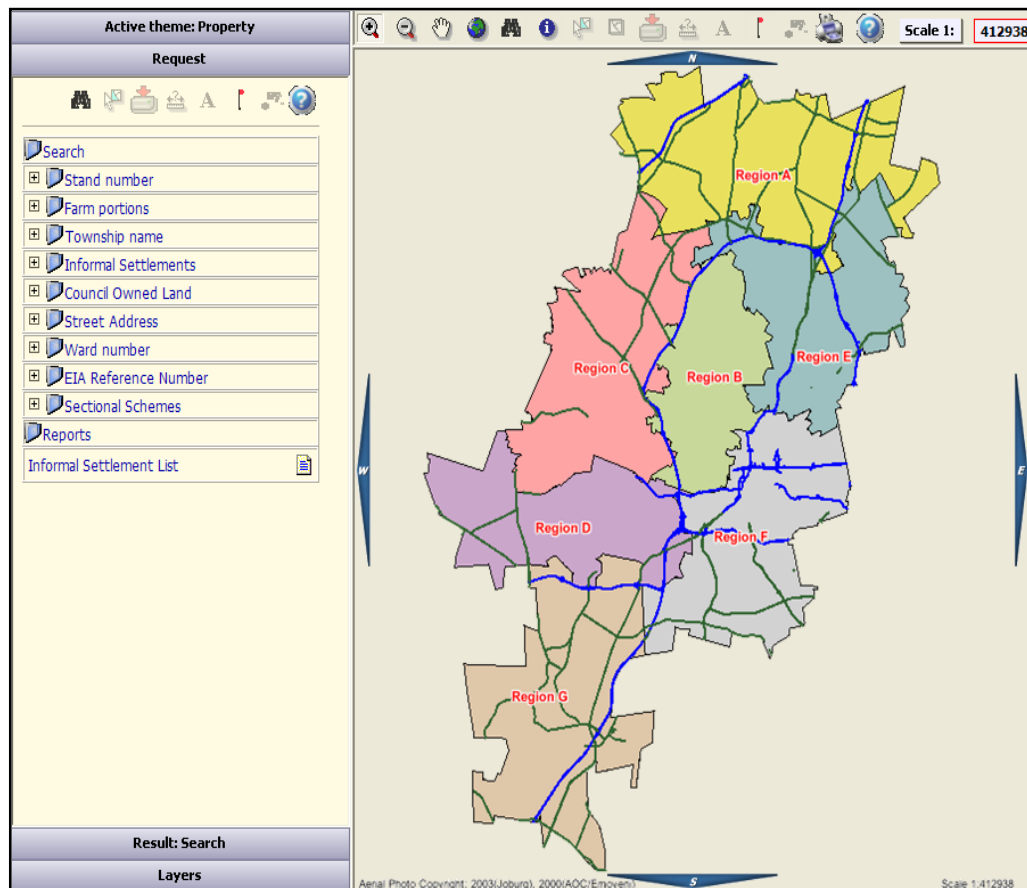


Figure 4-13: CoJ CGIS online maps website [102]

The CoJ CGIS website, depicted in Figure 4-13, was one of the first publically accessible government GIS websites in South Africa, serving GIS through the web since 2001. The CGIS department originally developed the website for internal CoJ departments and utilities on the ESRI ArcIMS 3.x software platform. It was soon expanded to the Internet in January 2004 when it was integrated into the CoJ electronic services portal, offering two levels of access to data and

functionality: a free site and more detailed paid subscription website. July 2005 saw the re-launch following a Microsoft .NET viewer development focusing on improved user friendliness for non-GIS users, enhanced functionality and additional data grouped into various themes [103]. The CoJ GIS website has been recognised for its innovation and advancement of Web GIS through numerous awards such as an ESRI special achievement award in 2002 [104] and selection as a finalist in the Centre for Public Innovation Awards in 2006, finishing runner up in the innovative use of IT for effective service delivery category [105].

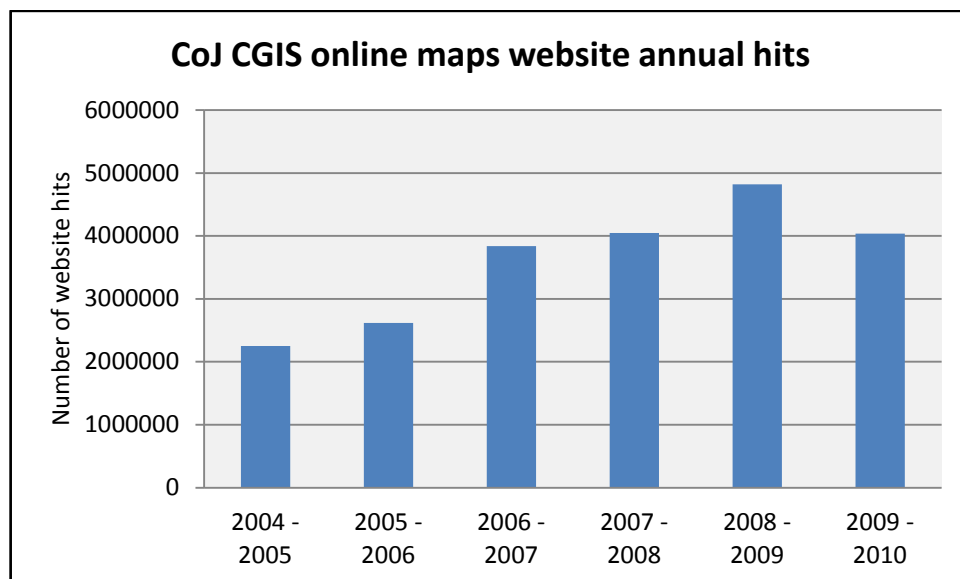


Figure 4-14: CoJ GIS website annual hits

The success of the CoJ GIS website is evident from the enormous growth it has experienced over a five year period (Figure 4-14), with a 114% increase from 2 251 563 hits in the 2004/2005 financial year, to 4 818 691 hits in the 2008/2009 financial year [106]. The number of hits dipped in the last financial year (2009/2010) as a result of the termination of a number of data capture projects within the City of Johannesburg that utilised the website. However, a figure of over four million hits per year averaging 336 000 per month, is still a phenomenal achievement. The users range from the general public accessing the free site to

obtain information on their stand, such as street address, zoning or current valuation, to paying subscribers such as property developers accessing zoning certificates and full resolution aerial photography. The Internet website had a total of 1 695 subscribers with 162 active subscribers in 2009 [107].

The CGIS department is embarking on an upgrade project to migrate the GIS website to the ESRI ArcGIS server software platform. To assist with the design process, a user review of the current website was completed in October 2010, with a questionnaire developed to gauge: the website's most frequently utilised data and tools, determine how users access the website (i.e. the network connections and browsers used) and measure the website support rating. After consultation with the CGIS management, it was agreed to include a section of the questionnaire which measured the current users' perceived usefulness, perceived ease of use, output quality and behavioural intention to continue using the website. The same TAM questions and 7-point measurement scale from the GCRO GIS website launch questionnaire were utilised, with the verb tenses modified to reflect the CGIS online maps website measurement.

A total of 124 fully completed questionnaires were analysed with the type of user consisting of 54% (67 respondents) external free users, 23.4% (29 respondents) external subscription users and 22.6% (28 respondents) internal users. The CoJ TAM scores in Table 4-3 indicate a good user acceptance score for perceived usefulness and behavioural intention to use, and lower but still acceptable scores for perceived ease of use. The standard deviation values show a greater variation in the sample than the GCRO GIS website TAM survey, which is highlighted with a minimum score of 1. The median scores were higher than the mean scores in each case, indicating a clustering of values around the high end of the measurement scale.

Table 4-3: CoJ CGIS online maps 2010 user questionnaire TAM analysis results for all respondents

| <b>TAM variable</b>          | <b>Minimum</b> | <b>Maximum</b> | <b>Average/<br/>Mean</b> | <b>Median</b> | <b>Std.<br/>Deviation</b> |
|------------------------------|----------------|----------------|--------------------------|---------------|---------------------------|
| Perceived usefulness         | 1              | 7              | 6.05                     | 6.50          | 1.26                      |
| Perceived ease of use        | 1              | 7              | 5.36                     | 5.75          | 1.42                      |
| Quality of output            | 1              | 7              | 5.59                     | 6.00          | 1.37                      |
| Behavioural intention to use | 1              | 7              | 6.35                     | 7.00          | 1.06                      |

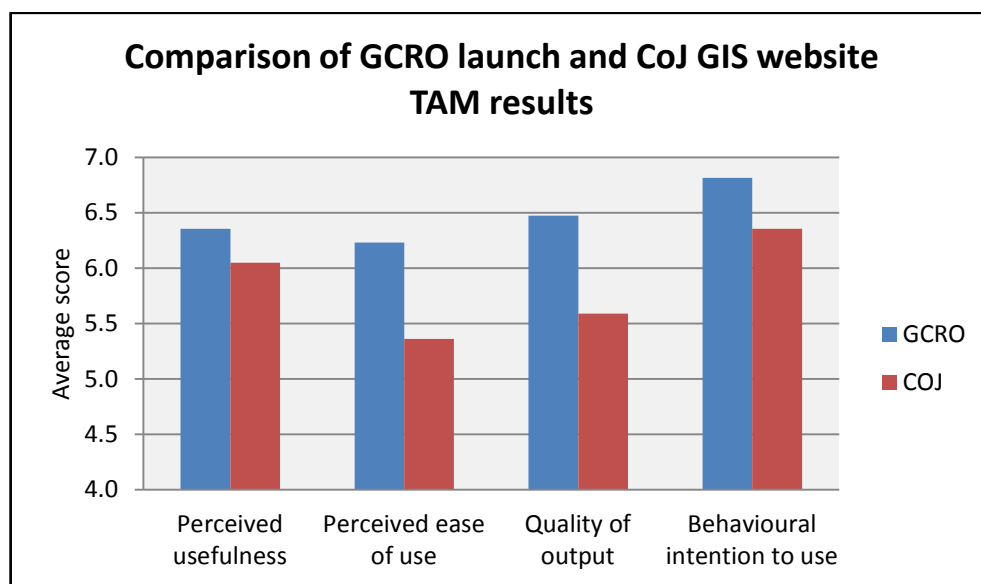


Figure 4-15: Graph comparing GCRO GIS website launch and CoJ CGIS online maps TAM results

Figure 4-15 comparing the GCRO GIS website and CoJ CGIS online maps TAM results, clearly indicates the user acceptance scores of the GCRO website were

higher than the CoJ website. The results are not directly comparable as the GCRO measurement measured potential use, whereas the CoJ TAM questionnaire measured real users. However, the higher GCRO scores confirm potential user acceptance and usage by the GCRO stakeholders.

A more detailed analysis of the CoJ TAM scores reveals some interesting results in terms of the different types of users (Figure 4-16): external free (public access), external subscription (monthly subscription access) and internal subscribers (CoJ departments or Municipal Owned Entities). The external subscribers score higher on perceived usefulness (6.34), which is to be expected as the subscriber would only subscribe to the website to access the additional data (such as high resolution imagery and zoning) and functionality, if they considered the website to assist them with their job performance. However, the external subscribers scored the lowest on the perceived ease of use (4.99), with the highest, the internal subscribers, scoring 5.82.

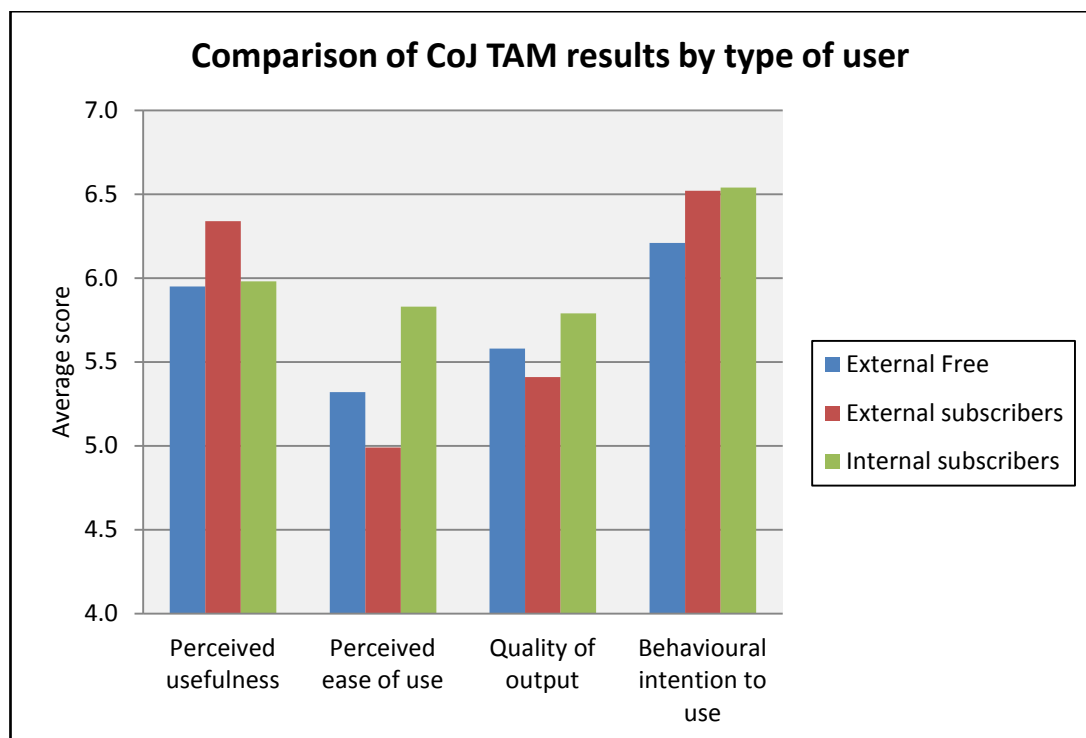


Figure 4-16: Graph depicting CoJ TAM results by type of user

The lower perceived ease of use scores can be explained by the fact that despite the continued growth, the GIS website has experienced a few problems and negative customer responses. The online bi-annual customer survey run by the CGIS department contains a number of questions measuring satisfaction with the website. Specifically, question 9.5 rates the overall quality of the Intranet/Internet mapping service which dropped from 92.7 % in the November 2008 survey, to 78.8% in the May 2009 survey [108]. A meeting with the CGIS ArcIMS team [109] revealed that the main two problems during this period which affected the stability and response times of the GIS application were:

- A database migration from Microsoft SQL Server to IBM DB2. Due to a lack of local DB2 GIS expertise, serious support delays and downtime were encountered over a period of a few months when the application was redeveloped for ArcIMS to access the data from the DB2 database environment.
- Stability and outdated hardware problems within the CoJ e-services portal. As the number of users accessing the CoJ portal has grown, the portal has slowed and is often unavailable after working hours. This environment is one that the GIS department has no direct control over, frustrating users that have to access the GIS websites through the e-services portal.

The latest customer surveys revealed that some of these problems had been addressed with overall quality of the Intranet/Internet mapping service recovering to 87.93% in November 2009, with a slightly lower rating once again in the May 2010 survey, of 84.57% [110]. However, a number of the respondents in the 2010 user questionnaire continued to comment about login problems, lack of availability after hours and slow response times, which may explain the lower perceived ease of use ratings. The external users who are not required to logon to the e-services portal and internal subscribers that access the website via the CoJ Intranet do not experience the same level of access problems as the external subscribers and therefore score higher on the ease of use.

To summarise, the CoJ CGIS website respondents perceive it to be a useful tool (as measured by the perceived usefulness and behavioural intention to continue use), but are perhaps frustrated at times with the slow website response times and e-services portal problems, i.e. ease of use. The ease of use problems must be addressed as part the project upgrade to ESRI ArcGIS Server 10 in order to address client concerns and improve user acceptance ratings.

#### **4.4 Summary of the results**

“Great system. I look forward to using it and seeing it develop and grow” -  
Comment from one of the GCRO GIS website launch attendees.

A number of research questions were introduced at the beginning of chapter 3. Firstly, what design methodology should be considered when developing a GIS Web 2.0 application? A five step sample methodology was used to develop the GCRO GIS website. Web 2.0 technologies such as the Google Maps mashups and the RIA tools available in the ESRI Flex sample viewer, have been combined with the dynamic maps and graphs of the GCRO government datasets to provide a g-government solution for the GCR with the GCRO GIS website. The website offers comprehensive base data and thematic layers covering the GCR, and is fast and easy to use, with a fun element of RIA popup windows and dynamic graphs.

Secondly, can TAM be used to measure the technology acceptance of a GIS website? TAM has proved to be not only a useful tool in measuring user acceptance of new GIS applications at both the prototype and implementation stages, but also provides a useful analysis of current GIS websites in terms of their usefulness and ease of use, assisting with identifying areas for future improvement.

Thirdly, how does the GCRO GIS website’s ease of use and usefulness compare to an existing local government GIS website? The GCRO TAM compared favourably to the popular local government GIS website, CoJ CGIS online maps,

with the user acceptance scores of the GCRO GIS website scoring significantly higher than the COJ online maps website.

Fourthly, is the g-government website development using Web 2.0 technology and the visualisation of spatial government data a success, in terms of sharing and opening access to public sector spatial data? The TAM analysis of the GCRO GIS website launch questionnaires has provided promising indications of the success of this development by measuring high user acceptance scores of the potential users of the website at both the prototype and launch stages of the project. The launch questionnaire respondents gave the perceived usefulness of the GCRO GIS website an average score of 6.36, confirming that the business needs and purpose of the website identified in the original development specification were met. The user-friendliness and use by both GIS specialists and GCR policy-makers with no GIS or online maps experience, was established with the average score of 6.23 for perceived ease of use. Respondents were also satisfied with the quality of the GIS data and maps, scoring the quality of the website output an average of 6.47. When asked whether they would make use of the website, the 38 respondents were unanimous in agreeing that they would utilise the website, with an average score of 6.82 for behavioural intention to use.

High user acceptance and possible usage of the website was confirmed by the respondents' comments, as discussed in section 4.2.2. Respondents were impressed by the data mashup capabilities of the website to serve as a government data integration tool providing online access to base maps and provincial data, and requested a range of additional GCR datasets to be included in the next release. The ability to add other data such as shp files (a popular ESRI GIS file format), or connect to other departments publishing WMS layers, was also mentioned by five of the respondents.

In conclusion, a Web 2.0 GIS g-government website site has been successfully developed for the GCRO and local and provincial government, by turning government data and GIS layers into dynamic interactive maps and graphs, easily accessible by both the policy-makers and citizens.

## 5. CONCLUSIONS

“Harnessing the power of Web GIS will greatly benefit, or even determine, the future of many organisations.” [111]

Web 2.0 has revolutionised the Internet and the way we interact with information and people, by offering new ways to collaborate and communicate, and providing exciting new Web GIS applications and sources of online spatial data. This presents governments with an opportunity to evolve towards a new form of connected e-government with enhanced value of services for all citizens through Government 2.0. According to O'Reilly, one of the pioneers of Web 2.0, not only is Government 2.0 the future of technology, but the future of democracy [55].

This research dissertation has focused on g-government, a subset of Government 2.0. By combining the use of GIS and Web 2.0 technologies, g-government uses Web GIS to promote collaboration within government and connect to its citizens through online maps and spatial data. An example, such as the MD iMap website, has proved to be an indispensable tool for the State of Maryland's agencies and government departments to collaborate and coordinate efforts, thus supporting “transparency and accountability and enhancing public's knowledge of how well government is operating and serving their needs” [57]. Other examples from around the world, including the Ordnance Survey's OS Opendata website and Geovation challenge competition, are opening access to government data and promoting new innovative ways to empower organisations and developers to develop spatial solutions and applications to meet the need of local communities.

South Africa, however, still faces many challenges with regard to g-government. The latest United Nations e-government survey 2010 report indicated a decline in South Africa's e-government development index ranking to 97 out of the 184 countries surveyed, highlighting the need to devote greater resources to enhancing online services and increasing access to ICT (Information Communication Technology) infrastructure [49]. Furthermore, the literature review in chapter 2

revealed that problems accessing government information still exist [13], with limited co-operation and institutions operating in silos [61]. It is promising, however, that there are attempts to rectify this with a number of Web GIS projects such as the CDNGI Intranet/Internet web mapping portal, the CUO's attempts to establish an MOU and regional SDI (with Western Cape provincial and local governments), and the GeoGCR initiative to provide a single gateway to Gauteng's spatial information.

The GCRO recognised the need to provide online spatial information and GIS tools to develop a better understanding of the GCR, assist the GCR policy-makers to make better informed decisions and open up public access to government datasets. This business need was met through the development of the GCRO GIS website that has provided a g-government solution for the GCRO and its provincial and local government stakeholders. It makes use of Web 2.0 technologies such as data mashups to integrate data from various sources and is one of the first government GIS websites in South Africa to utilise open datasets such as Google Maps to provide the base data and tap into the Google Maps' search engine to provide powerful searching capabilities. The website was built using RIA technology provided by the ESRI Adobe Flex viewer to offer an enhanced user experience with popup windows and dynamic graphs linked to the maps.

TAM was used to determine the success of the GCRO g-government website by measuring user acceptance at the prototype and implementation stages of the project. High acceptance scores were achieved for perceived usefulness, perceived ease of use and data quality across both professional technical and non-GIS management staff. An average score of 6.82 out of a maximum of 7.00 for behavioural intention to use, indicates that the GCRO and local and provincial government staff involved with the planning and development of the GCR, are ready to utilise g-government. The Wordle graphic<sup>4</sup> depicting the launch

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<sup>4</sup> Wordle is a free online application for generating "word clouds" from text with greater prominence given to words that appear more frequently in the source text [113]



GCRO will continue to develop the GCRO GIS website through the addition of new innovative datasets and tools such as Google Street View. The next phase of the GCRO GIS website development will focus on upgrading to the latest version of the ESRI Flex viewer and providing the functionality, as requested by the launch questionnaire respondents, for users to incorporate their own data (in ESRI shp file format or WMS) into the GCRO GIS website application. The applicability of Web 3.0 technologies, including multisite mashups and merged graphs for the GCRO GIS website, will be considered. With the growing availability of mobile phone Web GIS applications, such as Google Maps for mobile and ESRI mobile phone APIs, and increasing numbers of mobile phone users accessing the Internet through smart phones, further research consideration should be also given to the mobile platform for provision of g-government. Not only can information be served to mobile phone applications, but government employees and citizens can feed information back to government. Mobile phones can be used as locational devices, serving as valuable sensory input to government information systems as Volunteered Geographic Information.

Secondly, the pre- and post-implementation interventions proposed by Venkatesh and Bala [79] as part of TAM3, such as user involvement, management support and training, were followed to minimise user resistance to the new technology and enhance user acceptance.

The research conducted in this dissertation has concluded that TAM is a useful tool for measuring user acceptance of new GIS applications at the prototype and implementation stages of a Web 2.0 GIS website project. Future research work could include an extension of the initial TAM survey to measure user acceptance of the GCRO GIS website at the place of work where the users are accessing the website. This would provide an updated measurement of user acceptance at the actual usage stage and investigate whether factors, such as the slow government Internet connections identified by the GPG Department of Economic Development staff in the prototype questionnaire, may affect user acceptance and usage of g-government technology.

The author is also extending the TAM research with the CoJ online maps website that was used to benchmark the GCRO GIS website TAM results. The CoJ website is currently being redesigned and upgraded to ArcGIS Server 10 to improve its performance and introduce new functionality. The TAM survey will be re-run to measure user acceptance with a few selected users when the prototype is developed and again as part of the next CGIS online maps user survey once the newly redesigned website and GIS web server software is implemented. This will enable the CGIS department to determine whether the redesigned GIS website was successful in addressing the concerns raised by the users in the 2010 survey and measure user acceptance of the new GIS website and functionality.

The GCRO g-government website has an important role within the GCR as the GCRO, GPG and Gauteng Planning Commission attempt to improve the way government connects with its citizens and promote coordination between different departments within the Gauteng province and the different spheres of local and provincial government. It is hoped that the GCRO GIS website will serve as a prototype for the GeoGCR plan that the GPG is embarking on. Furthermore, as the success of the GCR is of national importance, it is also anticipated that the website will be a vital tool for the newly constituted National Planning Commission tasked with contributing towards the South African government's long term plans and strategic vision through the production of high quality, evidence-based research [112].

According to Williamson [61], "The need is to manage information spatially and not manage spatial information". G-government provides the technology to achieve this and the GCR governments and stakeholders are ready to embrace the GCRO GIS website.

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## **7. APPENDICES**

- A. GCRO GIS website specification
- B. GCRO GIS website prototype specification
- C. GCRO GIS website prototype design document
- D. GCRO GIS website prototype TAM questionnaire
- E. GCRO GIS website launch TAM questionnaire
- F. Published papers:

“Enabling successful g-government through the development of a Web 2.0 GIS website for the Gauteng Provincial Government”.

Wray, C. and van Olst, R. Map Africa 2010 conference proceedings, Cape Town, November 2010.

## GCRO GIS website development specification – February 2010

### 1. Introduction to the GCRO

The **Gauteng City Region Observatory (GCRO)** was established in 2008 as a partnership between the Gauteng Provincial Government (GPG), the University of Johannesburg (UJ) and the University of the Witwatersrand (Wits).

Behind the motivation for setting up the GCRO is a vision for a fast growing and dynamic urban Gauteng City Region (GCR) – South Africa’s economic heartland – that through better planning and management, and in particular through improved intergovernmental relations, will become more functionally integrated, spatially coherent, economically competitive, creative, innovative, environmentally sustainable and socially inclusive.

GCRO is charged with helping to build the knowledge base that government, business, labour, civil society and citizens all need in order to shape the strategies that will make this vision a reality. GCRO collects and benchmarks data, provides policy analysis and on-request policy support, undertakes applied research, and publishes critically reflective academic work.

### 2. GCRO GIS website

The GCRO’s current website ([www.gcro.ac.za](http://www.gcro.ac.za)) is a content management system, written in open source Drupal. It serves information about the GCR and GCRO and includes content such as downloadable reports, data (such as spreadsheets) and static pdf/jpeg maps. GCRO has acquired, created and mapped a range of GIS layers to produce these static pdf/jpeg maps. To ensure the biggest impact and usage of the GIS layers and maps, and to assist the GCR policy makers, the GIS maps and data need to be visualized in a **dynamic interactive GIS website**.

The GIS website should make use of the latest Web 2.0 tools such as GIS data mashups and rich Internet applications to provide both ease of use and usability, of dynamically visualized GIS maps. The application should display the latest, relevant GCR GIS layers and offer innovative GIS visualisation tools such as popup graphs linked to the map layers, in a simple, easy to use application directed at the GCR policy makers.

The website design, development and its subsequent usage forms part of Chris Wray’s Master’s thesis: “A Web 2.0 based g-government solution for the Gauteng City-Region Observatory (GCRO)” The Technology Acceptance Model (TAM) originally developed by Davis in 1989, will be used to measure the acceptance of the website by the main users.

### 3. Business need

The purpose of the GIS application will be to visualize GIS base data and themed layers offering different perspectives of the GCR, such as population distribution, poverty indexes and the latest 2009 Quality of life survey results as maps and graphs. The main aim being to create a better understanding of the GCR by providing GIS analysis tools for the users to make better informed decisions and policies regarding the GCR.

Government users will enter the site and require a quick overview of the main themes influencing the GCR.

#### **4. End Users:**

The main users the application will be developed for is the GCRO stakeholders – Gauteng Provincial Government (GPG) Planning commission, GPG Office of the Premier, Local government officials and other GCR government agencies. These users are responsible for planning the future development and direction of the GCR and are mainly high ranking government officials with no mapping or GIS experience. Hence the focus on a simple “Google maps”- like design.

The site will also be publically accessible through the Internet providing open access to the GCRO GIS data.

#### **5. Creating GIS map applications**

Creating a GIS web maps is based described in the following workflow:

- Step 1: Think about the application and its users
- Step 2: Design maps for the web application
- Step 3: Tune the maps to optimize request performance
- **Step 4: Develop the web application to visualize and interact the GIS layers**

This web mapping development proposal for the GCRO is focused on **step 4** – Developing the web application to visualize and interact the GIS layers.

#### **6. Current GCRO server environment**

GCRO has a single GIS and data server (hosting GCRO office documents), GCRO1 hosted at Wits server centre (gcro1.wits.ac.za). It will serve as the testing and production environment. There are however, spare PCS within the GCRO office that may be used as testing environments.

OS software: Windows Server 2008 with IIS

The GCRO website ([www.gcro.ac.za](http://www.gcro.ac.za)) is hosted offsite and will link to the GCRO GIS website application hosted on GCRO1.

#### **7. GIS software ESRI ArcGIS server**

The GIS data will be served from, and the application needs to be developed around the ESRI ArcGIS Server software. The GCRO has an ArcGIS Server Standard licence installed on the GCRO1 server. The main features of ArcGIS Server are summarized in the table below (<http://www.esri.com/software/arcgis/arcgisserver/key-features.html>). The development will focus on the GIS web services, mapping, spatial analysis, publishing to clients, image management and application development tools.

**Table 1: ArcGIS Server Key features:** Depending on what features you need, you can choose from among three editions of ArcGIS Server (Advanced, Standard, and Basic).

|                                                                                                                                                                                                                                                                                                                                                         | Advanced | Standard | Basic |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------|-------|
| <b>Data Management</b><br>Provides geodata services for data extraction, replication, and synchronization, as well as a framework and tools for managing large spatial datasets in an RDBMS such as IBM DB2, IBM Informix, Oracle, Microsoft Access, Microsoft SQL Server, and PostgreSQL. <a href="#">Learn about GIS data storage and management.</a> | ✓        | ✓        | ✓     |
| <b>GIS Web Services</b><br>Supports Web services including map, image, globe, locator, geoprocessing, KML, WMS, WCS, WFS, and WFS-T (REST and SOAP access are included with all editions.)                                                                                                                                                              | ✓        | ✓        |       |
| <b>Mapping</b><br>Includes tools for creating rich browser-based Web mapping applications                                                                                                                                                                                                                                                               | ✓        | ✓        |       |
| <b>Spatial Analysis</b><br>Supports server-based analysis and geoprocessing, including vector, raster, 3D, and network analytics as well as models, scripts, and tools                                                                                                                                                                                  | ✓        | ✓        |       |
| <b>Publishing to Clients</b><br>Supports a broad range of clients including <a href="#">ArcGIS Desktop</a> , <a href="#">ArcGIS Explorer</a> , <a href="#">ArcGIS for AutoCAD</a> , and browser-based applications                                                                                                                                      | ✓        | ✓        |       |
| <b>Image Management</b><br>Supports a complete <a href="#">image management system</a> for delivering large quantities of imagery that can be consumed in desktop, mobile, Web, and imagery clients                                                                                                                                                     | ✓        | ✓        |       |
| <b>Web Mapping Application</b><br>Provides an out-of-the-box, configurable mapping application with tools for map navigation, identifying features, measuring distances, finding addresses, and querying and searching attributes                                                                                                                       | ✓        | ✓        |       |
| <b>Application Developer Tools</b><br>Includes Application Development Frameworks (ADFs) for <a href="#">.NET</a> and <a href="#">Java</a> and Application Programming Interfaces (APIs) for <a href="#">JavaScript</a> , <a href="#">Flex</a> , and <a href="#">Microsoft Silverlight/WPF</a>                                                          | ✓        | ✓        |       |
| <b>Spatial Web Editing</b><br>Supports spatial editing tasks for applications, such as adding, modifying and deleting map features like points, lines, and polygons                                                                                                                                                                                     | ✓        | ✓        |       |
| <b>Advanced Spatial Analysis</b><br>3D Analyst, Geostatistical Analyst, Network Analyst, and Spatial Analyst                                                                                                                                                                                                                                            | ✓        |          |       |

|                                                                                                                                                                                                                                                                                                                                        | Advanced | Standard | Basic |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------|-------|
| extensions included at no extra cost                                                                                                                                                                                                                                                                                                   |          |          |       |
| <b>Mobile GIS Application</b><br>Provides an out-of-the-box, configurable mobile application that allows mobile workforces to dynamically query and update server data remotely—is administered from ArcGIS Server, is integrated with GPS, and fits seamlessly into the enterprise IT environment                                     | ✓        |          |       |
| <b>Mobile Application Developer Tools</b><br>Provides tools to manage and deploy custom applications for use on mobile devices including a software developer kit (SDK) (Mobile applications can be deployed on Windows CE or Windows Mobile devices with the .NET Compact Framework and Windows XP or Vista PCs with .NET Framework.) | ✓        |          |       |

ArcGIS server comes with out of the box Web application software, but does not meet the needs of the GCRO. Alternatively, GCRO will consider using the freely accessible ESRI API's to develop the customised GIS mapping applications. These resources are available on the ArcGIS server resources website: <http://resources.esri.com/arcgisserver/index.cfm?fa=applications>.

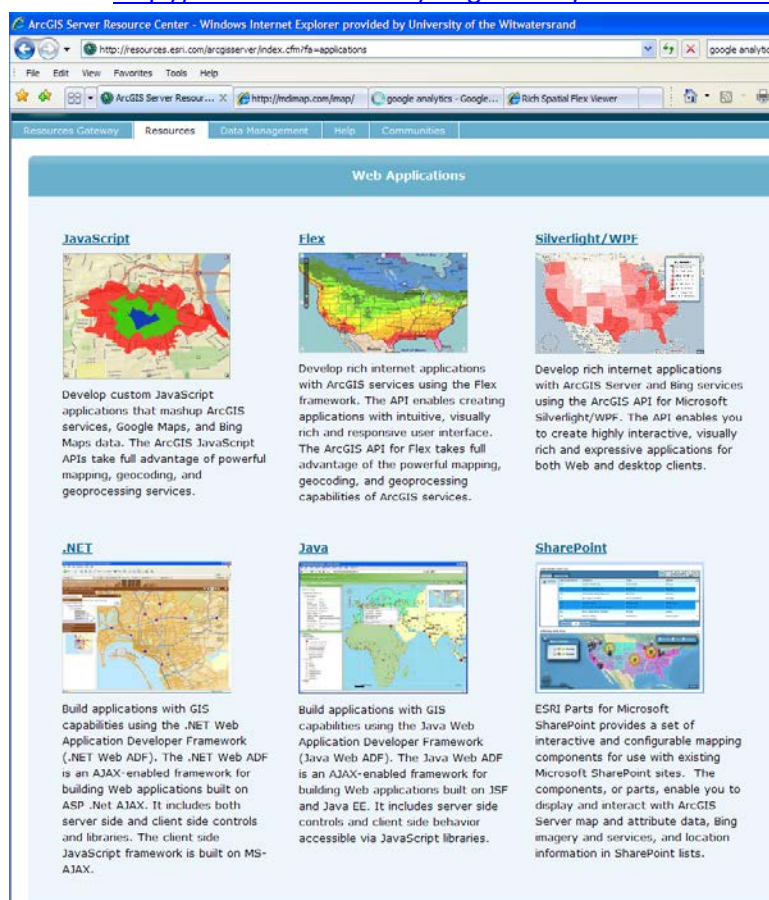


Figure 1: ArcGIS Server Web API's

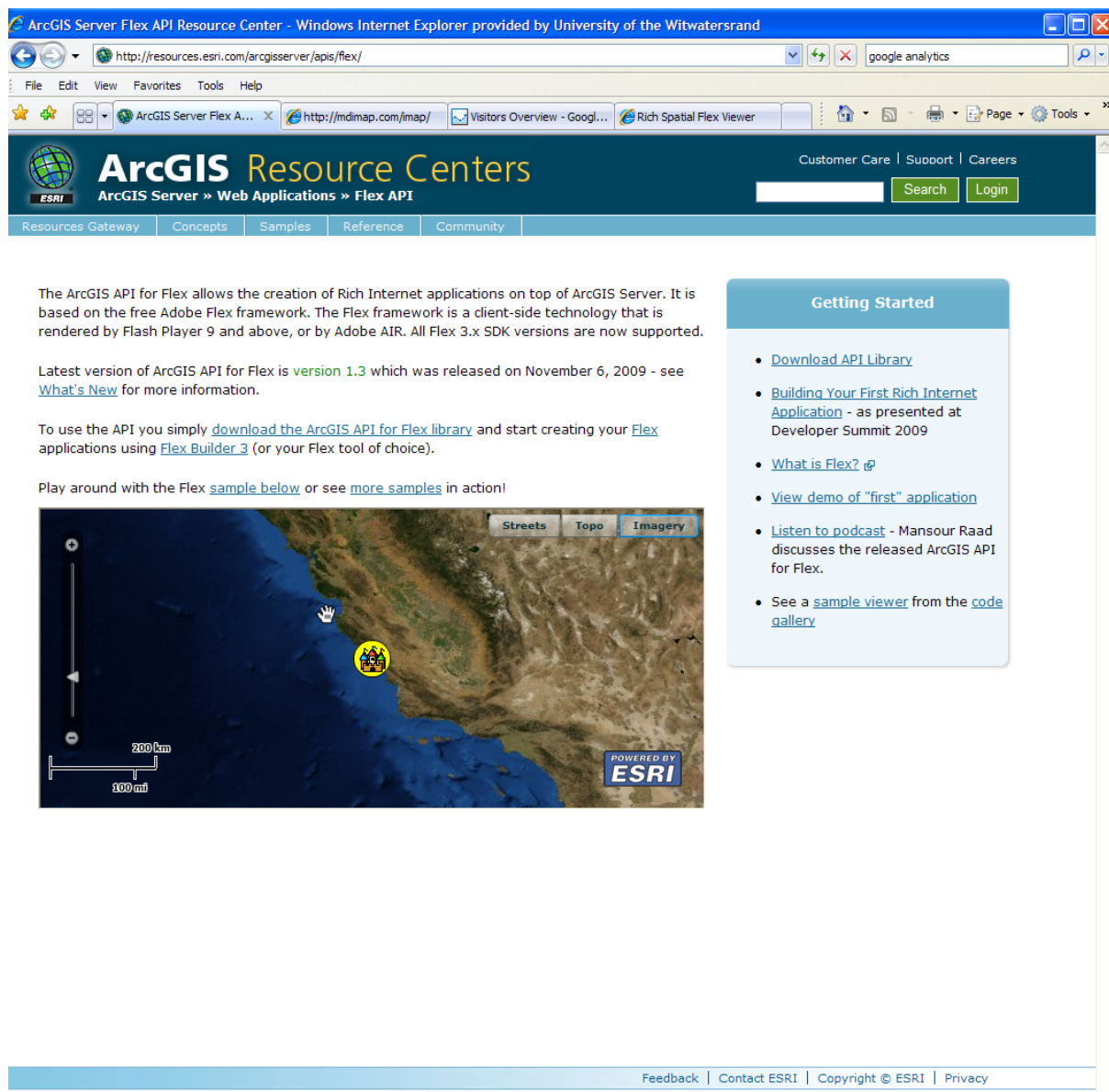


Figure 2 ESRI Flex API

The Flex API is one of the most widely used RIA and is the preferred application for this development. "Flex is a highly productive, free open source framework for building and maintaining expressive web applications that deploy consistently on all major browsers, desktops, and operating systems. While Flex applications can be built using only the free open source framework, developers can use Adobe® Flex® Builder™ software to dramatically accelerate development" (<http://www.adobe.com/products/flex/>). More information on Flex ESRI integration is available from: [http://www.adobe.com/cfusion/showcase/index.cfm?event=casestudydetail&casestudyid=580887&loc=en\\_us](http://www.adobe.com/cfusion/showcase/index.cfm?event=casestudydetail&casestudyid=580887&loc=en_us).

## 8. GIS mapping application example

An excellent example that the GCRO would like to use as the base application is the Mdimap (<http://mdimap.com/imap/>). It was developed for the State of Maryland in the USA to inform public users about the performance of government, by presenting government information and statistics in

a dynamic interesting format. It uses the Flex viewer to visualize GIS layers with RIA tools and dynamic graphs. The GCRO website will be modelled on this application.

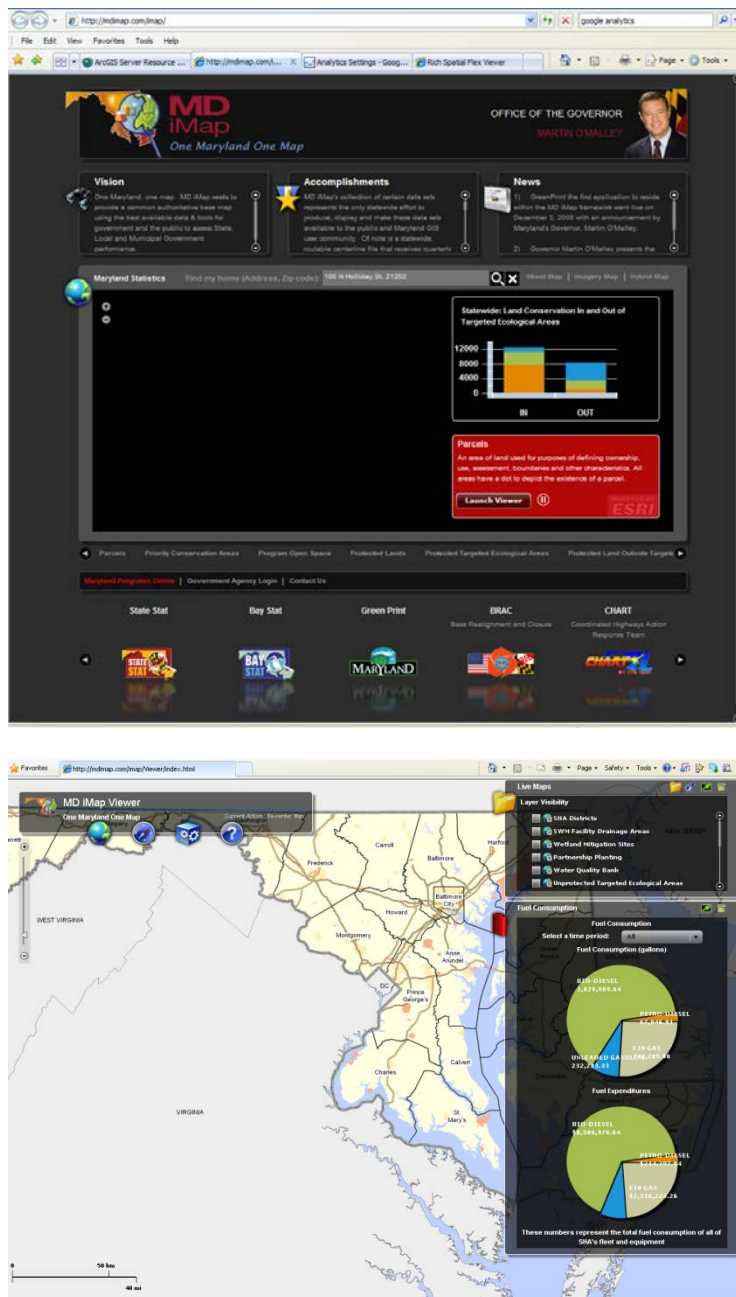


Figure 3: Mdimap ESRI Flex mapping application

## 9. GCRO GIS Website specifications

### 9.1. Website application platform

The GCRO GIS website application must be developed in Adobe FLEX 3 using the ArcGIS Server Flex viewer sample version 1.3, unless FLEX 4 becomes available and offers more functionality.

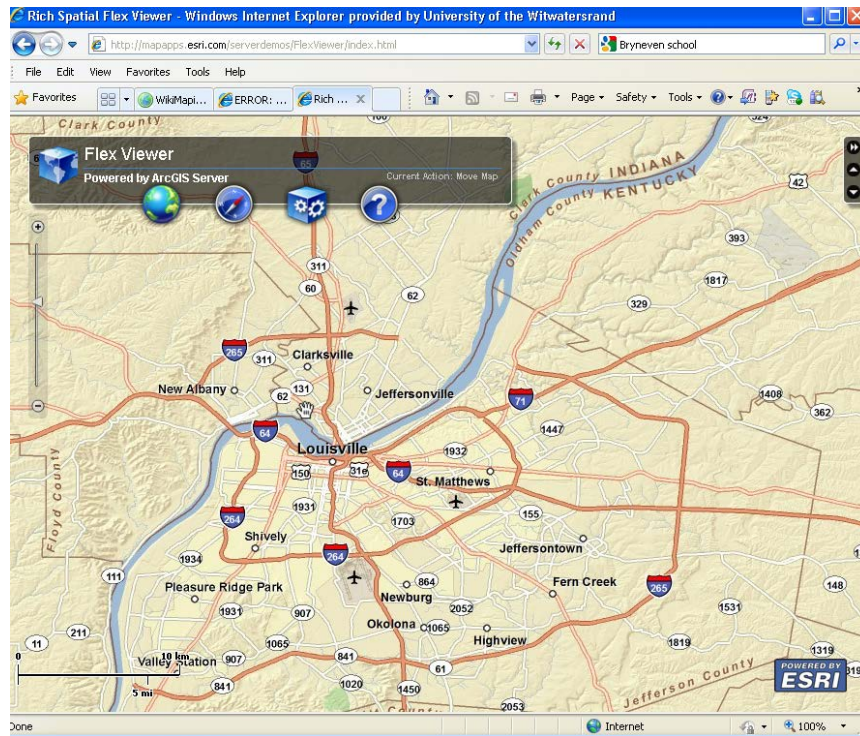


Figure 4 – FLEX viewer sample

## 9.2. Browser compatibility:

The application must be compatible with the main Internet browsers currently accessing the [www.gcro.ac.za](http://www.gcro.ac.za) site (Stats available from Google analytics):

- Internet explorer (IE 6+)
- Firefox
- Safari
- Opera
- Chrome

## 9.3. Website/GCRO1 Server security

The GCRO1 server online security must be evaluated and discussed with CNS to prepare a GCRO GIS website online security proposal. Once the proposal is agreed to by GCRO, it must be implemented in conjunction with CNS. ESRI ArcGIS Server white papers are available describing the recommended security implementations.

## 9.4. GIS website hits

Usage of the GIS website need to tracked, with Google analytics which is currently enabled on the GCRO website. A proposal for monitoring specific usage by provincial and local government must be investigated and implemented in order to monitor government usage of the application.

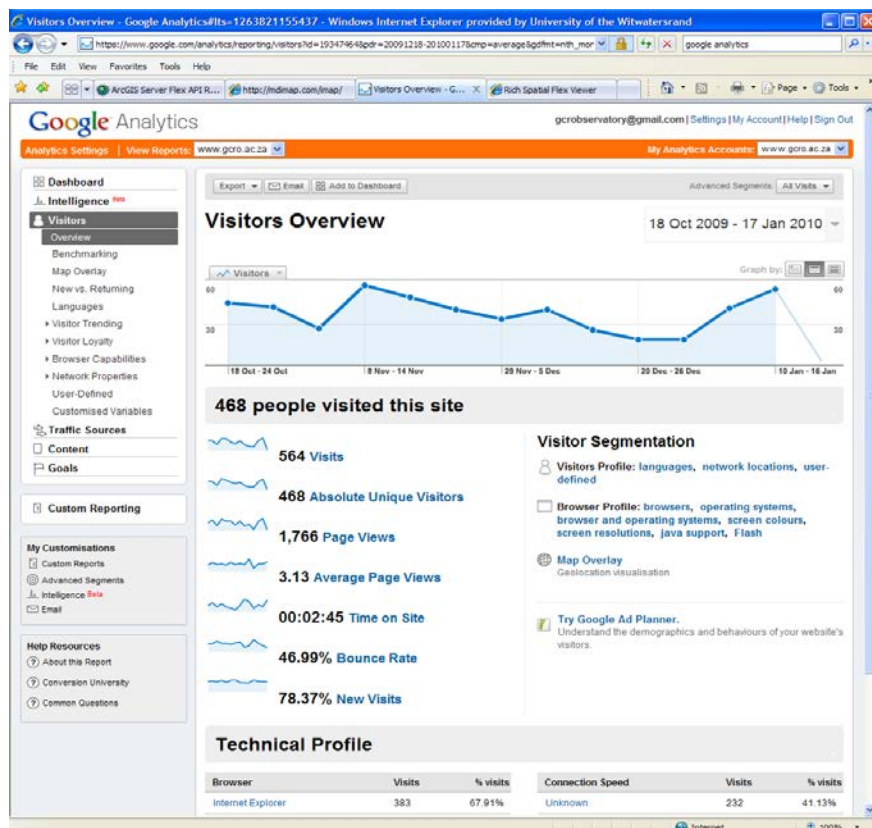


Figure 4: Google Analytics

## 9.5. GIS viewer basic design

The sample Flex application must be customized as follows:

### 9.5.1.Disclaimer/tutorial

The first page that opens should be a disclaimer page with 3 options: agree and enter the map application, agree and open the map and a basic tutorial, or return to GCRO home page. The application must open in the background while the user chooses an option (see [http://imap.mesacounty.us/food\\_service\\_map/index.html](http://imap.mesacounty.us/food_service_map/index.html)).

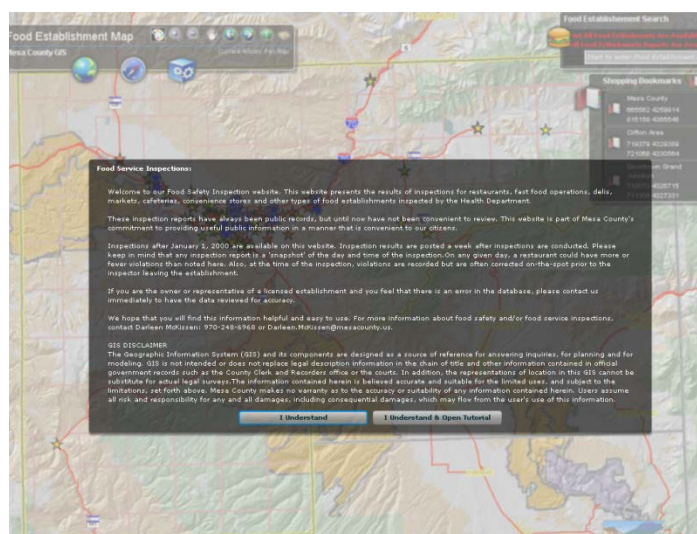


Figure 5: disclaimer page

### 9.5.2. Viewer design

- Name on main info panel to read Gauteng City-Region viewer



- GCRO logo to be present
- GCRO logo colours to be incorporated (burgundy and dark grey)
- Tools to be available on main info panel – zoom in, zoom out, pan, zoom previous, zoom next, print



### 9.6. Viewer Tools

Using the FLEX sample as an example, 5 tools must be available Base data, GCRO data, Navigation, Tools and Help as listed below. Logo and tool text must be displayed.

- Base data:
  - list of Base Google layers (described in 9.7.1) to change base map
  - GCRO Imagery layers – opens a new window with GCRO imagery layers
  - GCRO Administrative layers - opens a new window with GCRO layers and sets Base Google layer to satellite
  - Legend – opens a legend for current displayed layers and dynamically updates when layers switched off or on
  - Overview map – opens an overview map view current area on map highlighted with red box
  - GCRO bookmarks (list of predefined locations that user selects to zoom to)
  - Print – options to print basic A4 landscape/portrait map with title and option to print to pdf (flex map printing utility). If a theme/layer is switched on that has an associated graph, the user should have an option when printing the graph to include the graph.
- GCRO data (with GCRO logo):
  - Demographics layers - opens a new window with demographic layers
  - Economic layers - opens a new window with economic layers
  - 2009 Quality of Life survey - opens a new window with QoL layers
  - Spatial structure - opens a new window with spatial structure layers
  - Transport - opens a new window with transport layers
- Navigation
  - To contain following tools:



- o Should also contain Map Lens Widget for Sample Viewer
- Tools:
  - o Google Search – search for places and streets using Google maps search engine
  - o GCRO layer search – search on specific GCRO layers and fields
  - o Identify/Find – click and identify map features with attributes (enhanced identify widget) or selecting a polygon (see <http://maps.tnc.org/coredata/>)
  - o Measure/draw tool – user can draw on the map or make measurements (Enhanced Draw Widget for FlexViewer)
  - o Google Street view – to open window with Google® streetview panorama (see <http://gis.calhouncounty.org/FlexView/Index.html>) (dependent on availability of Google streetview for Gauteng).
- Help:
  - o Help file to be developed how to use the application
  - o Home – to return to GCRO home page [www.gcro.ac.za](http://www.gcro.ac.za)
  - o About – provide info on Flex versions and developers

## 9.7. GIS layers and functionality required

The web application will consist of 4 distinct groups of layers: freely available Google base layers, GCRO Imagery layers, GCRO Administrative layers and GCRO data layers (with dynamic functionality). The various layers and functionality that will be required for each layer is detailed below

### 9.7.1. Freely available Google maps base layers:

There are various online mapping sources of base layers: Google maps, Bing maps and ESRI online resources. Google maps offer the most up to date imagery and functionality such as Google street view. The application must test whether Google maps and street view layers can be incorporated within the GCRO Flex GIS application. An example of Google maps layers within a customized application is: <http://www.googis.de/paderborn/> and of a Flex viewer using Google street view is <http://gis.calhouncounty.org/FlexView/Index.html>. A blog post (<http://geochalkboard.wordpress.com/2008/08/29/integrating-the-google-maps-api-geocoder-with-arcgis-server/>) gives info on integrating the Google maps API geocoder with Arcgis server. Online courses such as: “ESRI - Programming the ArcGIS Server API for Flex”, are also available.

| Google maps | Functionality |
|-------------|---------------|
|-------------|---------------|

|                                               |                                     |
|-----------------------------------------------|-------------------------------------|
| Google Map (streets, points of interest etc.) | Switch on/off                       |
| Google satellite                              | Switch on/off + Imagery time slider |
| Google hybrid                                 | Switch on/off                       |
| Google Terrain                                | Switch on/off                       |
| Google Panoramio                              | Switch on/off                       |

### 9.7.2. GCRO Imagery layers

| GCRO Imagery layers                | Functionality                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| GCRO Landsat imagery 1989 and 2000 | <ol style="list-style-type: none"> <li>1) Must overlay imagery and present an image time slider – to view/fade GCR imagery from 1989 to 2000, and then switch to latest Google satellite imagery (**1965/1975 imagery to follow at a later stage) – see <a href="http://gis.greeleygov.com/origin/propinfo.html">http://gis.greeleygov.com/origin/propinfo.html</a></li> <li>2) Must open with GCRO administrative base layers overlaid</li> </ol> |

### 9.7.3. GCRO administrative base layers:

The GCRO administrative base layers have been sourced or mapped by GCRO and will be overlaid on the Google Satellite image base layers (when first selected the default Google layer must be set to Google Satellite) with basic functionality such as search and zoom, and change transparency to be available. The GCRO administrative base layers window should open when another theme for GCRO data (dynamic) layers is selected.

| GCRO base layers                    | Functionality                    |
|-------------------------------------|----------------------------------|
| Main cities                         | Search by name                   |
| Secondary cities                    | Search by name                   |
| Provinces                           |                                  |
| Old Provincial/ Homeland boundaries |                                  |
| District Municipalities             | Search by name                   |
| Local Municipalities                | Search by name                   |
| GCRO footprint                      | Set map extent to GCRO footprint |
| Latest wards                        | Search by ward number            |
| Urban rural classification          |                                  |

### 9.7.4. GCRO data (dynamic) layers

The dynamic GCRO layers will offer additional functionality such as popup graphs linked to the map (Charts and Statistics Widget for Sample Flex Viewer or ARRA Template: Simple Reporting Application (Version 1.3)).

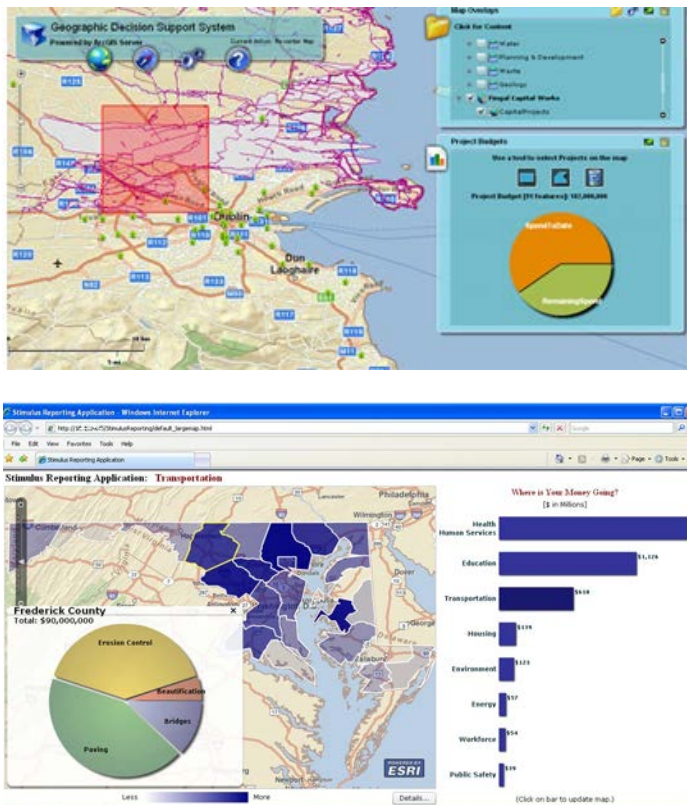


Figure 6 – interactive charting with Flex

These will be arranged in themes and provision must be made for GCRO to add themes or layers to the themes at a later stage. When a theme is selected, if not already open, the GCRO administrative layers window must open as well.

| Theme               | Theme Functionality                                                                                                                  | GCRO dynamic layers             | layer functionality                                                                                |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|----------------------------------------------------------------------------------------------------|
| <b>Demographics</b> | When theme switched on, opens Census graphs by LM and GCR. Click on bar graph and zooms/ highlights selected slightly transparent LM | Census 2001 dot density         | Standard                                                                                           |
|                     |                                                                                                                                      | Census 2001 dot density by race | Standard                                                                                           |
|                     |                                                                                                                                      | Population density by Ha        | Standard                                                                                           |
| <b>Economic</b>     |                                                                                                                                      | GVA per municipality (2008)     | When theme switched on, opens GVA Graph per LM which option to change year. Click on bar graph and |

|                                    |  |                                                                               |                                                                                                                                          |
|------------------------------------|--|-------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
|                                    |  |                                                                               | zooms/highlights selected LM                                                                                                             |
|                                    |  | Census 2001 Dot density unemployment map                                      | When theme switched on, opens unemployment Graph per LM which option to change year. Click on bar graph and zooms/highlights selected LM |
|                                    |  |                                                                               |                                                                                                                                          |
| <b>2009 Quality of Life survey</b> |  | Gov satisfaction and dissatisfaction indexes (National, provincial and local) | When layer switched on, opens graphs index per LM + Gauteng + GCR. Click on bar graph and zooms/highlights selected LM                   |
|                                    |  | Decent work index                                                             | Same as above                                                                                                                            |
|                                    |  | Poverty index                                                                 | Same as above                                                                                                                            |
|                                    |  | Movement**                                                                    | ** Animated flow into the City-Region (at a later stage)                                                                                 |
|                                    |  | Other indexes to be included as they become available                         | Same graphing functionality as indexes above                                                                                             |
|                                    |  |                                                                               |                                                                                                                                          |
| <b>Spatial structure</b>           |  | Land cover for Gauteng (GTI)                                                  | When layer switched on, opens graphs of % per land cover type                                                                            |
|                                    |  | Detailed urban land cover (GTI)                                               |                                                                                                                                          |
|                                    |  | Land use for urban areas 2001 - 2009 (GTI)                                    | When layer switched on, opens graphs of % per land use type                                                                              |
|                                    |  | Growth indicator 2001 -2009 (GTI)                                             |                                                                                                                                          |
|                                    |  | Eskom building count (Obtain permission from Eskom)                           |                                                                                                                                          |
|                                    |  | Eskom SBC Informal settlements (Obtain                                        |                                                                                                                                          |

|                  |  |                                                           |                                                                                                   |
|------------------|--|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------|
|                  |  | permission from Eskom)                                    |                                                                                                   |
|                  |  | Current Land use and land use change (dependent on Brian) | ** To be developed at a later stage – view animated change of landuse 1965 – 2008 + graph changes |
|                  |  |                                                           |                                                                                                   |
| <b>Transport</b> |  | Main roads and railways                                   |                                                                                                   |
|                  |  | BRT and Gautrain lines and stations                       | Search for stations                                                                               |
|                  |  | Transport survey zones                                    |                                                                                                   |
|                  |  | ANT congestion maps                                       | ** dependent on availability and form of the data                                                 |
|                  |  | Movement – CSIR 2001 desire lines                         | Animate main desire lines                                                                         |

#### 9.7.5. Standard functionality across all layers/tools

- The flex viewer must make use of the standard Flex windows from the Flex sample, for example - transparent and can be minimized.
- Transparency – must be able to change transparency of each layer (except Google maps base layers).
- Metadata – by clicking on the layer in the table of contents metadata for the layer must be displayed (except Google maps base layers).
- The application must allow for GCRO to add additional themes/layers (using the code and functionality already developed) without the need of additional programming.

#### 9.8. GIS website performance

The GIS website must be developed to offer optimum performance and stability. Maps should on average load within 5 seconds with a 3G/ADSL connection. At any stage when the application, map or task is loading, a progress bar or timer icon must be displayed until it is complete.

#### 10. Training/skills transfer/ ongoing maintenance?

During the project, provision must be made for basic Flex programming skills transfer and training for GCRO to enable basic changes to be made to the application to cater for new layers etc. New functionality may require further development from the JCSE on an ongoing basis

#### 11. Process and timelines

##### Process Overview:

The use of Flex viewer and ArcGIS Server API must be investigated with the Flex sample viewer. Students will work together with GCRO and Chris Wray to define the application based on the final layers and functionality, before a proof of concept/pre-prototype is presented to the GCRO stakeholders, and their acceptance and possible use of the application measured by TAM. These results will then guide the final development and implementation.

A number of project meetings are envisaged to engage with GCRO and JCSE students and projects at the various development stages.

The draft broad project timeline is proposed below. JCSE will be responsible for drawing up a detailed project plan with project meetings, milestones and deliverables that will be linked to invoice payments.

| <b>Task</b>                                  | <b>Description</b>                                                            | <b>Responsibility</b> | <b>Target date</b> |
|----------------------------------------------|-------------------------------------------------------------------------------|-----------------------|--------------------|
| Review Flex web 2.0 sites                    | Familiarise with flex builder 3 and review Flex websites and sample code      | PB and KN             | 24 Feb             |
| Define layers                                | Define layers and statistics to be mapped                                     | CW                    | 24 Feb             |
| Meet with JCSE project manager to            | finalise project spec, cost and project plan with milestones and deliverables | CW, PB, KN and JCSE   | 26 Feb             |
| Map layers and create web map service layers | Generate GIS layers and tables, and web map services                          | CW                    | 19 Mar             |
| Build application pilot                      | Develop pilot integrating Google layers + charts                              | PB and KN             | 26 Mar             |
| Present proposed design/pilot to GPG         | Measure initial acceptance using TAM                                          | CW                    | 31 Mar             |
| Review pilot design feedback                 | Make changes to design spec/ add additional layers                            | CW, PB and KN         | 1 Apr              |
| Final development                            |                                                                               | PB, KN and CW         | 21 May             |
| Final testing                                | Final testing on GCRO1 server across all browsers                             | PB, KN and CW         | 28 May             |
| Go Live                                      | Launch live viewer                                                            | PB, KN and CW         | 1 June             |
| Live demo/presentation to GPG/ training      | Present website to GPG and other stakeholders                                 | CW                    | June               |
| Flex training                                | Flex Training for CW                                                          | PB, KN and CW         | June               |
| Measure acceptance                           | Measure acceptance of site with TAM                                           | CS                    | July/Aug           |

## **Appendix A:**

A few more Flex viewer and code links and references.

<http://gis.calhouncounty.org/FlexView/Index.html>

<http://gis.ekurhuleni.gov.za/>

<http://maps.tnc.org/coredata/>

[http://imap.mesacounty.us/food\\_service\\_map/index.html](http://imap.mesacounty.us/food_service_map/index.html)

<http://www.flex888.com/>

Learn Flex in a week <http://www.adobe.com/devnet/flex/videotraining/>

<http://resources.esri.com/arcgisserver/apis/flex/index.cfm?fa=codeGallery>

[http://www.esri.com/software/mapping\\_for\\_everyone/api/code\\_gallery.html](http://www.esri.com/software/mapping_for_everyone/api/code_gallery.html)

[http://resources.esri.com/help/9.3/ArcGISServer/apis/javascript/gmaps/help/google\\_start.htm#topics/gmaps\\_addmap.html](http://resources.esri.com/help/9.3/ArcGISServer/apis/javascript/gmaps/help/google_start.htm#topics/gmaps_addmap.html)

## GCRO GIS website development February 2010 - Prototype/pilot specification

### 1. Business need

The purpose of the prototype GIS application will be prepare a pilot application to present to the GCRO stakeholders to test the GCRO GIS website application acceptance by the intended users. The pilot website will contain basic general functionality, base layers and a few dynamic layers to demonstrate the proof of concept.

### 2. Prototype GIS application environment

The Adobe Flex GIS application must be developed to run on a test environment established on the GCRO1 server hosted at Wits server centre (gcro1.wits.ac.za).

### 3. Prototype GIS functionality

The GIS application prototype must be based on the specification supplied to the JCSE entitled: *GCRO GIS website specification feb 2010 final verx.pdf*, with the functionality and layers listed below.

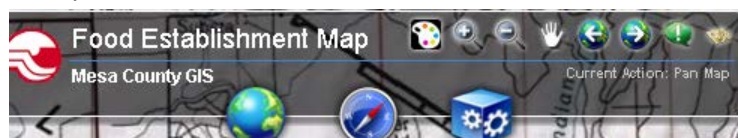
#### 3.1. Disclaimer/tutorial

The first page that opens should be a disclaimer page with 3 options: agree and enter the map application, agree and open the map and a basic tutorial example, or return to GCRO home page. The application must open in the background while the user chooses an option.

#### 3.2. Viewer design

- Name on main info panel to read Gauteng City-Region viewer

- GCRO logo to be present
- GCRO logo colours to be incorporated (burgundy and dark grey)
- Tools to be available on main info panel – zoom in, zoom out, pan, zoom previous, zoom next, print



#### 3.3. Viewer Tools

Using the FLEX sample as an example, 5 tools must be available Base data, GCRO data, Navigation, Tools and Help as listed below. Logo and tool text must be displayed.

- Base data:
  - list of Base Google layers (described in 9.7.1) to change base map

- o GCRO Administrative layers - opens a new window with GCRO layers and sets Base Google layer to satellite
- o Overview map – opens an overview map view current area on map highlighted with red box
- o GCRO bookmarks (list of predefined locations that user selects to zoom to)
- o Print – options to print basic A4 landscape/portrait map with title and option to print to pdf (flex map printing utility). If a theme/layer is switched on that has an associated graph, the user should have an option when printing the graph to include the graph.
- GCRO data (with GCRO logo):
  - o Demographics layers - opens a new window with demographic theme layers
  - o 2009 Quality of Life survey - opens a new window with QoL theme layers
- Navigation
  - o To contain following tools:
  - o Should also contain Mag Lens Widget for Sample Viewer
- Tools:
  - o Google Search – search for places and streets using Google maps search engine.
  - o GCRO layer search – search on specific GCRO layers and fields
  - o Identify/Find – click and identify map features with attributes (enhanced identify widget) or selecting a polygon
  - o Measure/draw tool – user can draw on the map or make measurements (Enhanced Draw Widget for FlexViewer)
- Help:
  - o Help file (1 page showing basic help)
  - o Home – to return to GCRO home page [www.gcro.ac.za](http://www.gcro.ac.za)
  - o About – provide info on Flex versions and developers

### 3.4. GIS layers and functionality required

The web application prototype will consist of 3 distinct groups of layers: freely available Google base layers, GCRO Administrative layers and GCRO data layers (with dynamic functionality). The various layers and functionality that will be required for each layer, is detailed below.

#### 3.4.1. Freely available Google maps base layers:

| Google maps                                   | Functionality          |
|-----------------------------------------------|------------------------|
| Google Map (streets, points of interest etc.) | Switch on/off + search |

|                  |                                                                           |
|------------------|---------------------------------------------------------------------------|
| Google satellite | Switch on/off + Imagery time slider (if possible within Internet browser) |
| Google hybrid    | Switch on/off                                                             |
| Google Terrain   | Switch on/off                                                             |
| Google Panoramio | Switch on/off                                                             |

### 3.4.2. GCRO administrative base layers:

The GCRO administrative base layers have been sourced or mapped by GCRO and will be overlaid on the Google Satellite image base layers (when GCRO administrative base layers first selected, the default Google layer must be set to Google Satellite) with basic functionality such as search and zoom, and change transparency to be available. The GCRO administrative base layers window should also open when another theme for GCRO data (dynamic) layers is selected.

| GCRO base layers                    | Functionality                    |
|-------------------------------------|----------------------------------|
| Main cities                         | Search by name                   |
| Secondary cities                    | Search by name                   |
| Provinces                           |                                  |
| Old Provincial/ Homeland boundaries |                                  |
| District Municipalities             | Search by name                   |
| Local Municipalities                | Search by name                   |
| GCRO footprint                      | Set map extent to GCRO footprint |
| Latest wards                        | Search by ward number            |
| Urban rural classification          |                                  |

### 3.4.3. GCRO data (dynamic) layers

The dynamic GCRO layers will offer additional functionality such as popup graphs linked to the map. These will be arranged in 2 themes and when a theme is selected, if not already open, the GCRO administrative layers window must open as well with Google Satellite layer switched on as well.

| Theme               | Theme Functionality                                                                                                                                                                           | GCRO dynamic layers             | layer functionality |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|---------------------|
| <b>Demographics</b> | When theme switched on, opens Census graphs by LM and GCR. Click on bar graph and zooms/ highlights selected slightly transparent LM. Option to change between 2001 Census and 2007 CS graphs | Census 2001 dot density         | Standard            |
|                     |                                                                                                                                                                                               | Census 2001 dot density by race | Standard            |
|                     |                                                                                                                                                                                               | Population density              | Standard            |

|                                    |  |                                                                               |                                                                                                                        |
|------------------------------------|--|-------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
|                                    |  | by Ha                                                                         |                                                                                                                        |
|                                    |  |                                                                               |                                                                                                                        |
| <b>2009 Quality of Life survey</b> |  | Gov satisfaction and dissatisfaction indexes (National, provincial and local) | When layer switched on, opens graphs index per LM + Gauteng + GCR. Click on bar graph and zooms/highlights selected LM |
|                                    |  | Decent work index                                                             | Same as above                                                                                                          |
|                                    |  | Poverty index                                                                 | Same as above                                                                                                          |

#### 3.4.4. Standard functionality across all layers/tools

- The flex viewer must make use of the standard Flex windows from the Flex sample, for example - transparent and can be minimized.
- Transparency – must be able to change transparency of each layer (except Google maps base layers).

#### 3.5. GIS website performance

The GIS website must be developed to offer optimum performance and stability. Maps should on average load within 5 seconds with a 3G/ADSL connection. At any stage when the application, map or task is loading, a progress bar or timer icon must be displayed until it is complete.

#### 4. Prototype development deadline

The website will be developed in conjunction with the web layer mapping to be completed by GCRO. **The prototype will be presented to the GCRO government stakeholders at a live demo workshop to be arranged towards the end of April 2010 (date still to be finalized) at the GCRO offices.** The users' acceptance and possible usage of the application will be evaluated using a TAM (technology acceptance model) questionnaire, focusing on ease of use and usability of the application. The responses will guide the remaining development.

# **GRCO GIS website prototype**

## **Design Document**

**March 2010**

**Designer 1: Peter Brookstein**

**Designer 2: Kirti Nathoo**

## **1. Project overview**

A prototype GIS web application called, Gauteng City-Region (GCR) Viewer will be designed and developed as per the GCRO Prototype / Pilot Specification document [?]. This application will be used to visualize GIS data and themed layers offering different perspectives of the GCR. Four distinct groups of layers will be implemented which include Google base layers, GCRO Administrative layers and GCRO theme layers. Students will be required to integrate these layers as base data in addition to other themed maps that will be provided. Graphical representations of base data will also be made available.

The application will be developed around the ESRI ArcGIS server software. All development and testing will be performed on the GCRO1 server hosted at WITS. Adobe Flex Builder 4 will be used as the application environment.

## **2. Goals and objectives**

The main functionality requirements for the prototype have been listed below:

- Disclaimer/ tutorial page
- Viewer design (i.e logo, icons, widgets, etc. )
- Viewer tools (i.e. navigation tools)
- GIS layer functionality
- Popup graphs linked to maps
- Website performance

## **3. Assumptions and constraints**

### **3.1 Assumptions**

- Main users are the GCRO and members of the Gauteng Economic Development: Development Planning department.

- Viewer tools and base widgets provided in Flex sample code and only custom functionality to be implemented
- The Flex viewer must utilize the standard Flex windows

## **3.2 Constraints**

- Trial version of Adobe to expire shortly
- The Flex sample application uses an ESRI base map instead of Google maps
- Mechanisms of monitoring user access to the website must be determined

# **4. Development environment**

## **4.1 Tools**

- Adobe Flash Builder 4 with Adobe Flex 3.5 Framework
- ESRI ArcGIS server software
- GCRO1 (server hosted at wits)
- Mercurial (Open source version control software)

## **4.2 Test environment**

The application will be designed and tested to be compatible with all major browsers that have been found accessing the current GCRO website as specified in the GCRO Proposal document [?].

# **5. Design**

## **5.1 Conceptual design**

The ArcGIS Sample Flexviewer will be used as the foundation of the web application. The Flexviewer is comprised of demo code that will be customised to meet the requirements of the GCR viewer.

The freely available Google maps will be incorporated and implemented as the base layer for the viewer. After which the GCRO Dynamic Data and Administrative layers will be deployed above the base layer. The functionality of existing tools and widgets will then be implemented to maximise the performance of the website.

## 5.2 Functional design

A dynamic interactive GIS web application will be designed for GCRO to visualize and interact GIS layers. The application will be developed using the Google maps API and the ESRI ArcGIS Server software.

The Google maps API allows the developer to use the existing Google maps functionality with the ability to modify and add additional features.

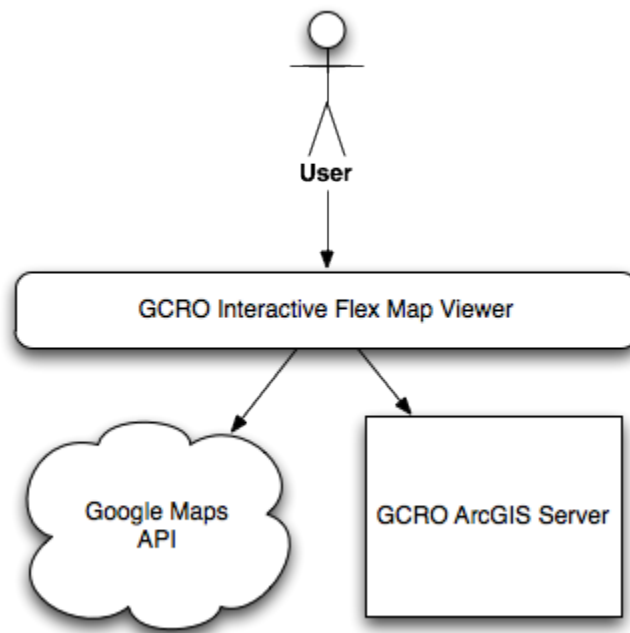


*Figure 1: Fundamental Structure*

The ESRI ArcGIS server software allows organizations to share mapping services and applications.

The interaction between the user and the web application has been illustrated in Figure 2. The web application has been abstracted into 4 distinct layers which illustrate the different functionality and services offered to the user.

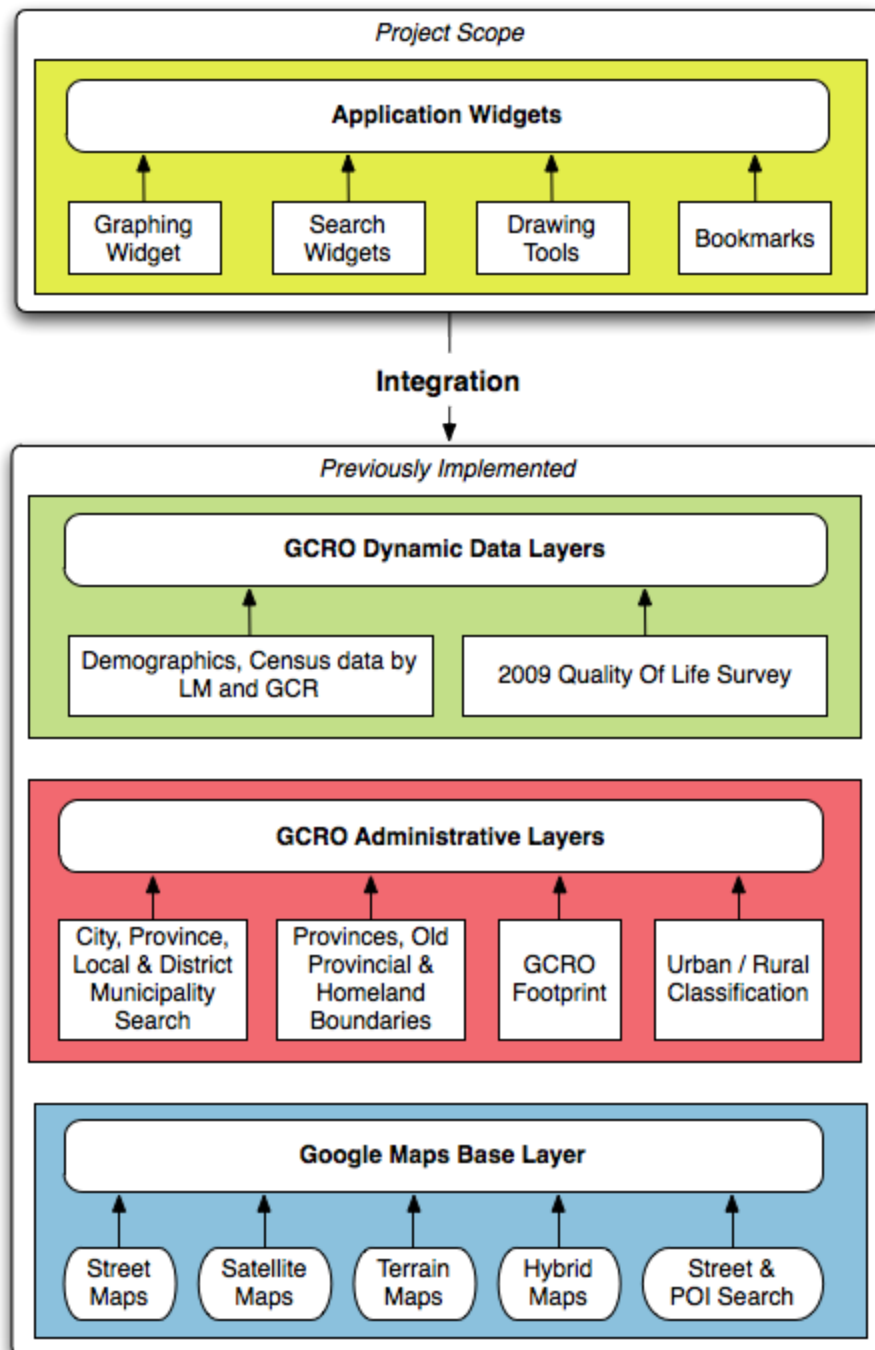


*Figure 2: Layers of the web application*

Various additional functionality will be incorporated into the application such as the search tool. This tool offers the user an option to either search the Google maps layer or the GCRO designed layers. There will be two search widgets, one to search the Google Maps base layer, and another which allows GCRO layer search. Wireframes of the two search widgets can be seen in Figure 3. The GCRO layer search allows the user to select which layers / themes they would like to restrict their search to.

The image displays two wireframe designs for search widgets, each within a blue rectangular container with a thin green border.

The top wireframe is titled "Google Maps Search" in bold black text. Below the title is a line of text: "Enter a search term to search the Google Maps Base Layer". Underneath this text is a large, empty white rectangular input field. In the bottom right corner of the container is a grey rectangular button with the word "Search" in white text.

The bottom wireframe is titled "GCRO Layer Search" in bold black text. Below the title is a line of text: "Please select the layers you are interested in searching, and then enter a search term." Below this text is a light blue rectangular box containing three search options, each preceded by a small white diamond icon:

- Administrative Layer Search
- Municipality Search
- Local Government Search

Below this selection box is a large, empty white rectangular input field. In the bottom right corner of the container is a grey rectangular button with the word "Search" in white text.

*Figure 3: Search Widget Wireframes*

A basic design of how the widget connects to the various back end search functions can be seen in Figure 4.

## Client / Server Search Interconnections

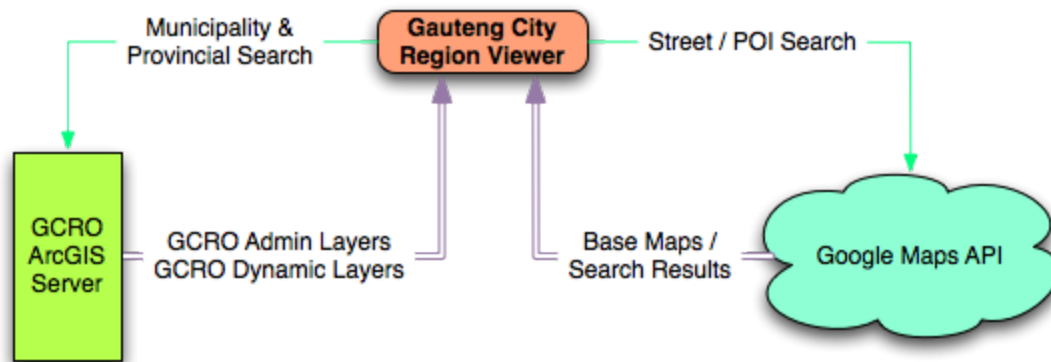


Figure 4: Client / Server Interconnection (Search)

### 5.3 Detailed system design

The web application can be subdivided into 4 categories/ layers as can be seen in figure 4:

- Google maps base layer

Google maps will replace the existing ESRI base map currently in the Sample Flex Viewer. Googles' satellite, hybrid, terrain and panoramio views will be implemented. The functionality of these views will include switching between views, panning the map and the option to zoom in and out.

Replacing of the base maps will be checked for compatibility with the Flex application and the accuracy of the map movements will be monitored.

- GCRO Administrative layer

This layer will be placed upon the Google maps base layer with basic functionality incorporated. The basic functionality will include searching, options to zoom and changing the transparency among layers. This layer was created to offer different themes that were designed by Chris Wray. Some of these themes include main cities, provinces, local and district municipalities, a GCRO footprint, etc.

- GCRO dynamic data layer

This layer offers pop up graphs linked to the above mentioned maps. Sample Flex Viewer does have a Charts and Statistics Widget which offers this functionality. These maps will consist of 2 themes, i.e Demographics and 2009 Quality of life survey.

## Application widgets

These widgets and tools are existing features in the Sample Flex Viewer designed to easily implement functionality to the web application. Each widget and its configurations will be added to the config.xml file.

**Graphing widget:** This widget will be used to create the pop up graphs. A basic, configurable graphing widget is provided with the ESRI FlexViewer 1.3 Demo codebase. This widget source code will be customized if required in order to provide the required functionality. Basic configuration of the widget is done within the site's Config.xml file.

**Search widget:** Existing search functionality will be extended to enable searching across the GCRO layers. These changes will all be made within the applets source code. Including any changes to the graphical appearance of the search widget.

**Drawing tools:** The drawing tools are already provided as a usable widget from within the demo code. No major changes to the widget are anticipated.

**Bookmarks:** Bookmarks are provided as a demo widget, and must be customized to remember a user so that they can return to their session at a later stage. It is understood that the majority of changes will occur within the applications Config.xml file.

Many of the other tools which include navigation, zooming and panning are built into the Sample Flex Viewer. The functionality of these existing tools must be implemented and will be incorporated with similar features offered by Google maps.

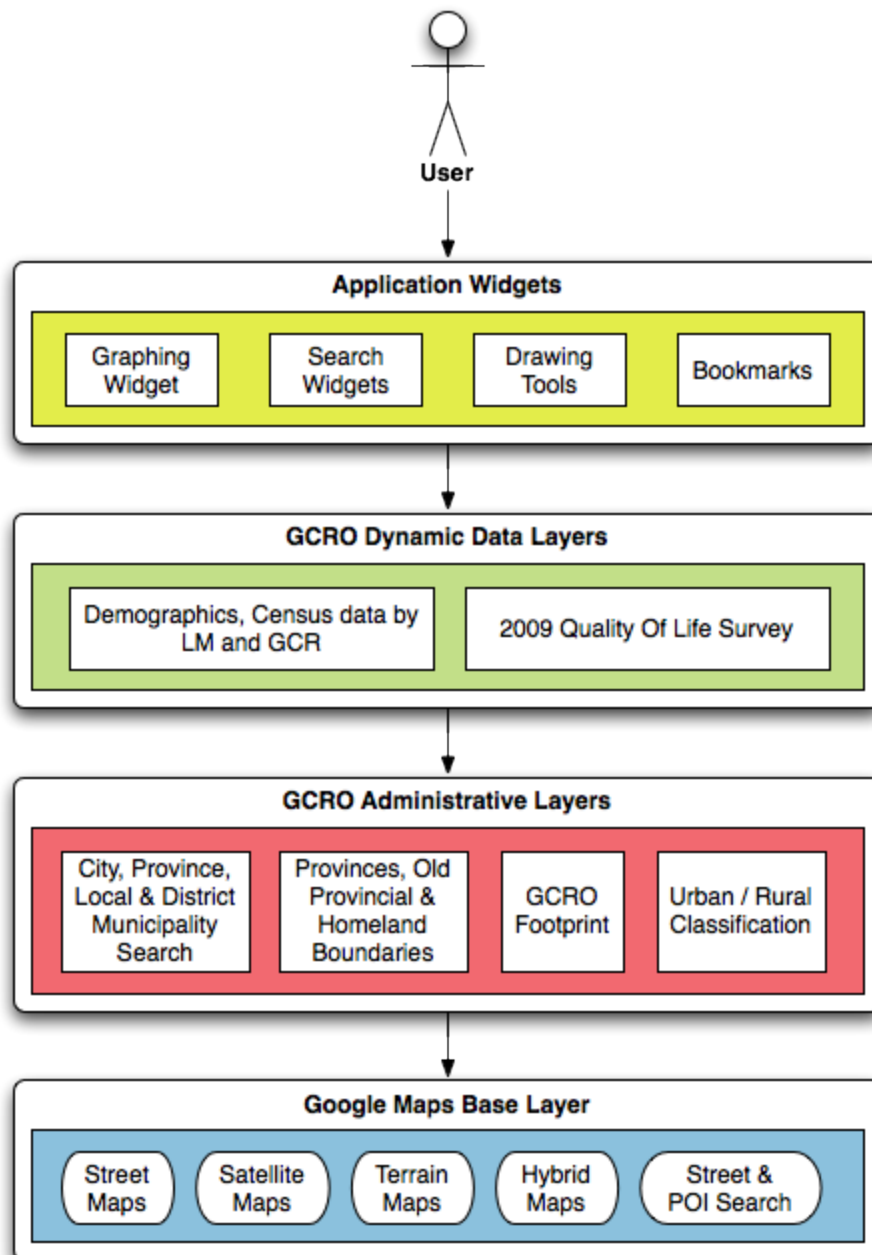


*Figure 4: Detailed layering structure of the GCR viewer*

The Flex Builder 4 application uses the ActionScript programming language.

The Flex sample code has already been divided into classes. The main classes and brief descriptions of each have been listed below:

- **AppEvent**: Used to send messages among components

- **BaseWidget:** All widgets and their functionality are derived from this class
- **ConfigManager:** A class used to parse the config.xml file
- **Controller:** Manages the user interface elements
- **DataManager:** Manages and stores data generated in a user session
- **EventBus:** Allows centralized communication among modules without point-to-point messaging
- **WidgetManager:** Defines the functionality and manages widgets
- **MapManager:** Manages base maps and live maps

Two freely available libraries will be used which enable the development of the web application with the Google maps API and the ESRI ArcGIS Server software:

- ArcGIS
- Google flex

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## Documentation Sign-off

---

### Document version control

**File name**

GCRO GIS website prototype

**Authors**

Peter Brookstein

Kirti Nathoo

**Comments**

| Version | Status   | Date       |
|---------|----------|------------|
| 1.0     | Draft    | 24-03-2010 |
| 1.1     | Revised  | 26-03-2010 |
| 2.0     | Sign-off | 29-03-2010 |

### Document sign-off list

**Publication date**

| Name       | Signature | Project Role                    | Date |
|------------|-----------|---------------------------------|------|
| Chris Wray |           | GCRO Project Owner /<br>Sponsor |      |

By signing this document the signatories acknowledge that they have (1) read this document, (2) understand the contents of this document and (3) agree that the content of this document is an accurate reflection of the information at the time of publication of the document.

## GCRO GIS interactive website prototype: user review

The **GCRO GIS website** being reviewed today is a prototype to demonstrate the basic functionality and a few of the GIS themes and layers to be made available online to assist decision makers in understanding the GCR. Please complete the questionnaire below to assist the GCRO to evaluate the functionality and usability of GIS website. Your comments will assist in the final design of the website, to be launched towards the end of July 2010.

Please read the statements below and select your response by **circling the corresponding number**, for example: circle 6 if you moderately agree with the statement. If there is not enough space to complete your comment under each question, continue the comments under the general comments at the end of the questionnaire.

1. Using the GCRO GIS interactive website will improve my performance in my job.

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

2. Using the GCRO GIS interactive website will increase my productivity.

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

3. Using the GCRO GIS interactive website will enhance my effectiveness in my job.

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

4. I would find the GCRO GIS interactive website useful in my job.

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

5. My interaction with the GCRO GIS interactive website will be clear and understandable.

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

6. Interacting with the GCRO GIS interactive website will be free from a lot of mental effort

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

7. I will find the GCRO GIS interactive website easy to use

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

8. I will find it easy to get the GCRO GIS interactive website to do what I want it to do

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

9. The quality of the output I will get from GCRO GIS interactive website will be high

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

10. Given that I will have access to the GCRO GIS interactive website, I predict I will use it

| Strongly agree | Moderately agree | Slightly agree | Neutral | Slightly disagree | Moderately disagree | Strongly disagree |
|----------------|------------------|----------------|---------|-------------------|---------------------|-------------------|
| 7              | 6                | 5              | 4       | 3                 | 2                   | 1                 |

Comments:

11. Have you used an online GIS website (such as Google maps) before?

|   |   |
|---|---|
| Y | N |
|---|---|

12. Is there any additional functionality you would like to be available in the GCRO GIS viewer?

Comments:

13. Are there any other GIS layers you feel are missing and should be added to the website?

Comments:

14. General comments

Comments:

# GCRO GIS website launch

## 1. GCRO GIS website evaluation: general information

Thank you for participating in the live GCRO GIS website demo and hands-on session.

Please complete the questionnaire below to assist the GCRO evaluate the functionality and usability of this first phase of the GIS website development, and add your comments regarding additional functionality or data you would like to see become available.

Personal details (on page 1 of the survey) will be kept confidential, but the general survey results and analysis will be made available.

**\* 1. Title**


**\* 2. Name:**

**\* 3. Job title:**

**\* 4. Organisation**


**\* 5. Department**

**\* 6. Age**

**\* 7. Highest qualification**


**\* 8. Do you have any formal GIS (Geographical Information Systems) expertise?**

☐

None

☐

Hands on GIS experience (self taught)

☐

Attended a GIS course

☐

GIS diploma

☐

GIS degree

☐

Other (please specify)

5

6

## GCRO GIS website launch

\* 9. Have you used an online Internet GIS website (such as Google maps) before?

☐ Yes

☐ No

# GCRO GIS website launch

## 2. GCRO GIS website evaluation: usefulness

**\* 10. Please evaluate the usefulness of the GCRO GIS website by reading the statements below and selecting your response by clicking on the appropriate button. For example, click on "6 moderately agree", if you moderately agree with the statement.**

|                                                                                | 7 strongly agree      | 6 moderately agree    | 5 slightly agree      | 4 neutral             | 3 slightly disagree   | 2 moderately disagree | 1 strongly disagree   |
|--------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Using the GCRO GIS interactive website will improve my performance in my job   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Using the GCRO GIS interactive website will increase my productivity           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Using the GCRO GIS interactive website will enhance my effectiveness in my job | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I would find the GCRO GIS interactive website useful in my job                 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Comments (optional) on all or any of the above

5

6

# GCRO GIS website launch

## 3. GCRO GIS website evaluation: ease of use

**\* 11. Please evaluate the ease of use of the GCRO GIS website by reading the statements below and selecting your response by clicking on the appropriate button. For example, click on "6 moderately agree", if you moderately agree with the statement.**

|                                                                                       | 7 strongly agree      | 6 moderately agree    | 5 slightly agree      | 4 neutral             | 3 slightly disagree   | 2 moderately disagree | 1 strongly disagree   |
|---------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| My interaction with the GCRO GIS interactive website is clear and understandable      | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Interacting with the GCRO GIS interactive website is free from a lot of mental effort | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I find the GCRO GIS interactive website easy to use                                   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I find it easy to get the GCRO GIS interactive website to do what I want it to do     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Comments (optional) on all or any of the above

5

6

# GCRO GIS website launch

## 4. GCRO GIS website evaluation: quality and use

- \* **12. Please evaluate the quality of the output (data) of the GIS website by reading the statements below and selecting your response clicking on the appropriate button. For example, click on "6 moderately agree", if you moderately agree with the statement.**

|                                                                           | 7 strongly agree      | 6 moderately agree    | 5 slightly agree      | 4 neutral             | 3 slightly disagree   | 2 moderately disagree | 1 strongly disagree   |
|---------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| The quality of the output I get from GCRO GIS interactive website is high | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Comments

5

6

- \* **13. Please evaluate the statement below, i.e. whether you will use the GCRO GIS website.**

|                                                                                       | 7 strongly agree      | 6 moderately agree    | 5 slightly agree      | 4 neutral             | 3 slightly disagree   | 2 moderately disagree | 1 strongly disagree   |
|---------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Given that I have access to the GCRO GIS interactive website, I predict I will use it | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Comments

5

6

### 14. If you predict you will use it, how often?

### 15. What will you use the GCRO GIS interactive website for?

☐ Learn more about the Gauteng City-Region (GCR)

☐ To access data about the GCR

☐ To print maps

☐ To assist with planning

☐ Other (please specify)

5

6

# GCRO GIS website launch

## 5. GCRO GIS website evaluation: final comments (optional)

**16. Is there any additional functionality you would like to be available in the GCRO GIS viewer?**

|  |   |
|--|---|
|  | 5 |
|  | 6 |

**17. Are there any other GIS layers you feel are missing and should be added to the website?**

|  |   |
|--|---|
|  | 5 |
|  | 6 |

**18. General comments**

|  |   |
|--|---|
|  | 5 |
|  | 6 |

Thank you for completing the questionnaire!

## Enabling successful g-Government through the development of a Web 2.0 GIS website for the Gauteng Provincial Government<sup>1</sup>

Chris Wray, Gauteng City-Region Observatory (GCRO), [chris.wray@gcro.ac.za](mailto:chris.wray@gcro.ac.za)

Professor Rex van Olst, University of the Witwatersrand, School of Electrical and Information Engineering, [rex.vanolst@wits.ac.za](mailto:rex.vanolst@wits.ac.za)

### 1 Introduction

Worldwide, increasingly connected citizens and stakeholders are demanding that governments deliver services more effectively and efficiently as conventional governmental systems fail to address the current challenges of increasing globalisation, crime, poverty, pandemics and service delivery failure [1]. Governments need to respond to these new challenges and redefine how they manage and share information, make policies, and deliver services.

Web 2.0 is proposed as the latest technological initiative to assist in bringing governments closer to their citizens [2]. It represents the second generation of web development and design with new web applications that enable improved interaction, communication, interoperability and sharing on the web [3]. Web 2.0 is therefore a usage paradigm shift centred on more interactive and collaborative applications that facilitate flexible web design, updates and creative reuse; resulting in better, faster, and richer user interfaces combining information from different sources [4]. Internet users have embraced public Web 2.0 applications such as MySpace, Flickr, You Tube, Facebook, and more recently the social networking and micro blogging application Twitter. The statistics are staggering with over 500 million active users on Facebook [5], and 190 million users tweeting 65 million times a day on Twitter [6]. Businesses and enterprises have also realised the benefits of Web 2.0 with companies using social networking applications such as Facebook, blogs and wikis to actively engage with customers and staff [7].

Web 2.0 is becoming a key component of an evolving approach to public service delivery. The initial shift from traditional government and modes of delivery, to e-Government and e-Services, has been replaced by a new paradigm shift towards a fully connected government committed to enhancing the value of services available for all citizens [8]. This new form of collaborative government, when enabled by Web 2.0, is termed Government 2.0.

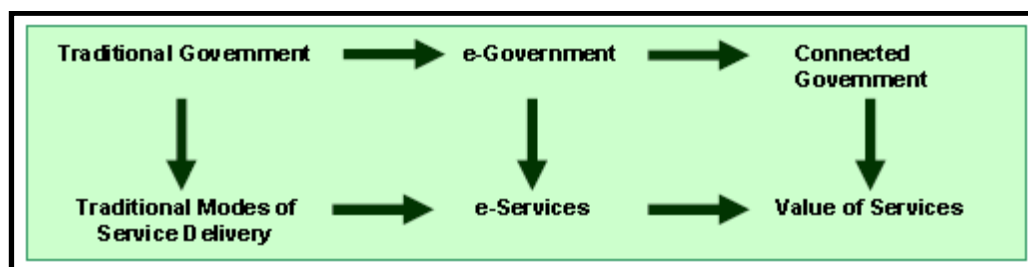


**Figure 1: Evolving approach to Public service delivery [8]**

<sup>1</sup> Proceedings of the Map Africa 2010 Conference, 23-35 November 2010, Cape Town.  
Accessible: [http://mapafrica.gisdevelopment.net/2010/proceeding/ts\\_LG.htm](http://mapafrica.gisdevelopment.net/2010/proceeding/ts_LG.htm)

g-Government is defined as using the Internet and Geographical Information Systems (GIS) to create more effective government [9]. This definition has been recently updated by defining the use of GIS and new Web 2.0 technology as g-Government [10]. According to Jack Dangermond, ESRI president, it is all about web GIS extending the vision of e-Government [11]. The majority of government data is spatially based and can be best visualised and interpreted using a GIS web mapping application, and therefore Tickner [10] states that g-Government can improve the way governments connect with its citizens by hosting map web portals to organise and display the vast government data resources. As Web 2.0 applications such as Google Earth have revolutionised public access to spatial data and GIS technology, governments need to spatially enable their data and systems with fresh innovative mapping applications.

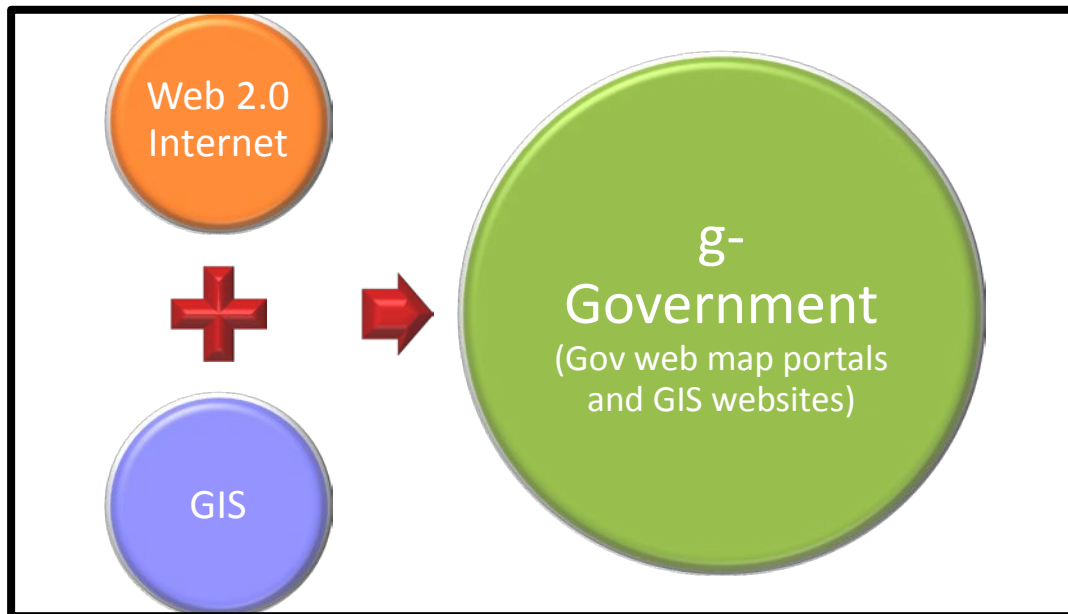


**Figure 2: g-Government definition**

However, despite all the spatial data policies and legislation in place, preliminary findings from R Sharif's doctoral research indicate that there are still problems accessing government information in South Africa [12], such as:

- Open availability of information
- Lack of systematic approach to collect, manage and store the data
- Institutional and socio-cultural barriers
- Poor quality and quantity of data and information at municipal levels
- Timeliness of information
- Reliability of information (use of private external consultants and the difficulty to verify and trust the methodologies used in these consultant reports)
- Lack of the culture of appreciating the value of public sector information (PSI) [12].

Sharif [12] argues that it is not the policies that are the problem, but rather the implementation of PSI policy. For example, it has taken 7 years from the promulgation of the Spatial Data Infrastructure (SDI) Act (Act 54 of 2003), to the formation and first meeting of Committee for Spatial Information (CSI), a committee responsible for the successful implementation of South Africa's SDI, and ensuring that South Africa makes effective use of its geospatial data for the benefit of all its citizens [13].

Government 2.0 and g-Government remain a challenge in South Africa.

## **2 GCRO GIS website business need and users**

The Gauteng City-Region Observatory (GCRO) was established in 2008 as a partnership between the Gauteng Provincial Government (GPG), the University of Johannesburg, and University of the Witwatersrand, Johannesburg (Wits). Behind the motivation for setting up the GCRO is a vision for a fast growing and dynamic Gauteng City-Region (GCR) that through better planning and management, and in particular improved co-operative government relations between all spheres of government, will become more functionally integrated, spatially coherent, globally competitive, economically productive, environmentally sustainable and socially inclusive.

Better planning, management and co-operative government relies on improved data, information, analysis and reflective evaluation. There was therefore an initial focus by the GCRO to collect existing government base datasets and generate new datasets, to be used to map and research the city-region. Various maps were prepared and made available as pdf/jpeg downloads on the GCRO website ([www.gcro.ac.za](http://www.gcro.ac.za)). However, the GCRO recognized that in order to ensure that the GCR information was fully utilised, the GIS maps and data needed to be visualized in a dynamic interactive GIS website. This website would enable the users to have a better understanding of the GCR by providing base data and themed layers offering different perspectives of the GCR, such as population distribution, poverty and the latest 2009 Quality of life survey results as maps and dynamic graphs; and GIS analysis tools for the user to make better informed decisions and policies regarding the future development of the GCR.

The main users of the application were identified as the GCRO stakeholders, namely: the GPG Planning Commission, GPG Office of the Premier, GPG Department of Economic Development (DED), local government officials and other GCR government agencies. These users are responsible for planning the future development and direction of the GCR and are mainly high ranking government officials with no mapping or GIS experience. Hence the need for a simple “Google Maps-like” online GIS design. Public access was also a requirement, ensuring open access to information about the GCR through the Internet to all GCR citizens.

## **3 GCRO GIS website development**

### **3.1 Specification**

The GCRO GIS website specification required the use of the latest Web 2.0 tools such as GIS data mashups<sup>2</sup>, Application Programming Interfaces (API) and rich Internet applications (RIA). ESRI software, which GCRO has deployed (ArcGIS Server 9.3.1), provides a range of RIA Web 2.0 sample viewers and APIs to build dynamic applications that access the ArcGIS Server services, including Java, Javascript, Flex, Microsoft Sharepoint, .NET and Silverlight. The ESRI Adobe Flex sample viewer version 1.3 was specified as the base application to build the GCRO GIS website, as the Flex API is one of the most widely used dynamic cross-platform RIA. Flex is based on an “open source framework for building expressive web applications that deploy

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<sup>2</sup> A data mashup is a web page or web site that combines data, information and services from multiple sources on the web [4].

consistently on all major browsers, desktops, and operating systems by leveraging the Adobe® Flash® Player and Adobe AIR® runtimes” [14].

### 3.2 Data

The GCR is an integrated cluster of cities, towns and urban nodes that together make up the economic heartland of South Africa. To obtain datasets and maintain data from the local and district municipalities and provincial governments constituting the GCR, would require a dedicated fulltime effort. Data availability, accuracy and currency would also vary across the different authorities. Frustratingly, freely available mapping websites such as Google Maps often serve more up to date imagery and base layers, such as streets, than the data available within many government departments. GCRO recognised that online spatial datasets can offer a viable alternative to sourcing base datasets, including imagery and streets, and provide a seamless coverage across a wide area. Web 2.0 technologies such as data mashups and APIs, provide the tools to access these online datasets.

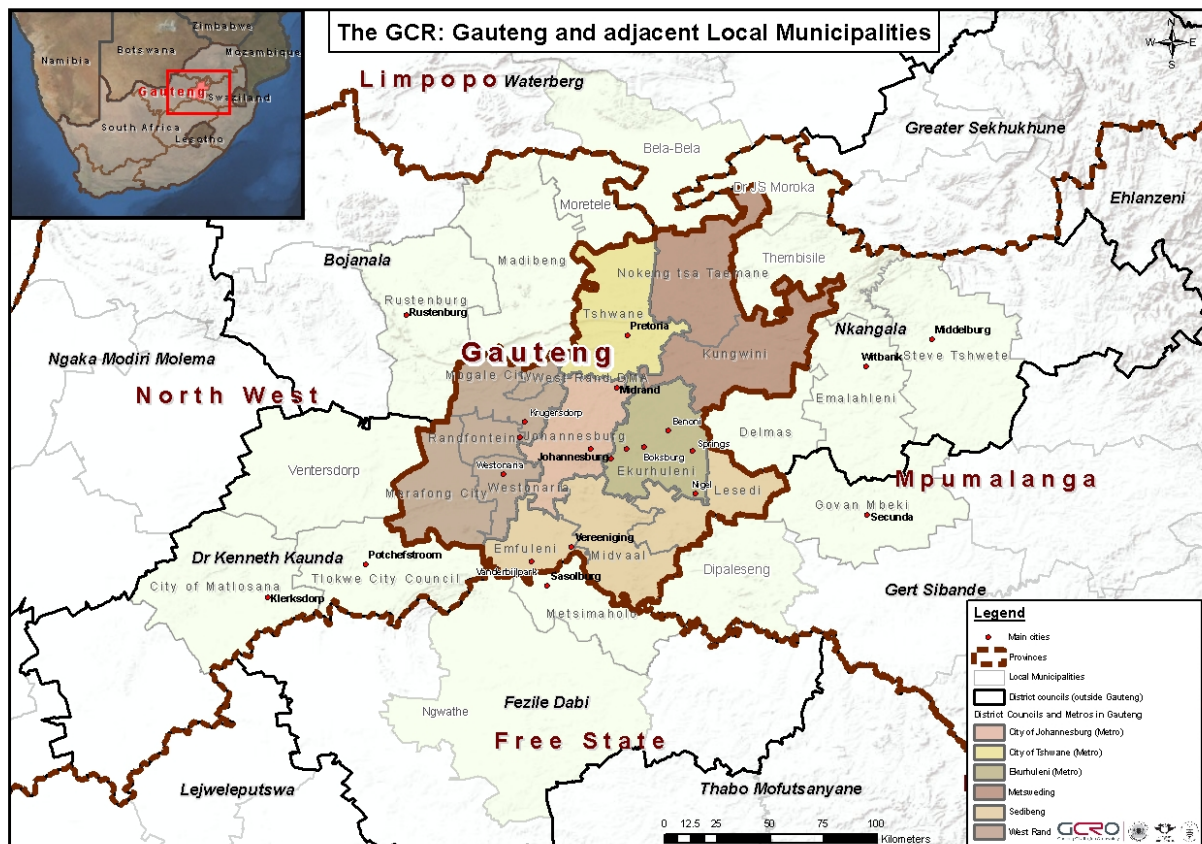


**Figure 3: The Gauteng City-Region (GCR)**

There are various sources of online base datasets: Google maps, Bing maps and ESRI online resources. Another source is open data initiatives such as OpenStreetMap, which offer free (licensed under the terms of the Creative Commons Attribution Share-Alike 2.0 license) downloadable street datasets for the world [15]. Google Maps was found to offer the most up to date imagery and dynamic functionality such as Google street view, and was therefore selected to provide the base layers in the GCRO GIS website application.

With regard to the various GCRO GIS layers that had been assembled, the data was divided into various themes that users could interact with individually, or overlay layers from different themes. The six themes mapped for the first release of the viewer include: GCRO administrative

layers, demographics, GCRO 2009 Quality of life survey, economic, spatial structure and transport. The development of these data themes will be an ongoing process as more GCR data becomes available or is generated from GIS data projects or analysis.

### **3.3 Website development**

The development of a prototype viewer kicked off in February 2010 and used the following ESRI methodology to build the GIS website [16]:

- Step 1: Think about the application and its users
- Step 2: Design maps for the web application
- Step 3: Tune the maps to optimize request performance
- Step 4: Develop the web application to visualize and interact with the GIS layers

The GCRO was accountable for the first three steps. The various GCRO data themes listed above were mapped in ArcView 9.3.1, optimised for web server performance using the Map Service Publishing toolbar and published in an optimised map service (.msd) format, which according to ESRI, significantly boosts the performance of dynamic layers [16]. Two of the themes had to be published as mxds (ArcGIS desktop project file format) due to the dynamic cartographic symbology used to visually represent the Census 2001 population and unemployment data as dot density maps. The published mxd themes however still provided acceptable drawing response times.

Two Joburg Centre for Software Engineering (JCSE) interns were assigned to complete step 4: the development of the GIS website. The JCSE based at Wits, is a three way partnership between government, academia and industry focused on developing software engineering capacity and skills [17].

The GIS viewer was developed by using the ESRI Flex API version 1.3 to customise the ESRI Flex Sample viewer version 1.3. Although Flex is open source, development is enhanced using a software development environment and Flash Builder 4 with the Flex 3.5 SDK (software development kit) was purchased for use on this project. An advantage of customising the sample viewer is that all the base functionality and tools such as navigation tools, basic searches and drawing tools were already included, and only the additional tools that the GCRO required, such as dynamic themes and graphs had to be developed. However a key challenge was the integration of the Google Maps layers using the Google Maps API for Flash, which took a number of months to achieve.

The prototype development was completed by June 2010 when it was presented to the GCRO and GPG DED staff. The response was extremely favourable and the prototype viewer specification was refined to include enhancements and staff suggestions made during the prototype presentation.

## **4 The GCRO GIS website**

The GCRO GIS website is viewable in all the main Internet browsers but does require the Adobe Flash Player plugin (version 9) to be installed. The website consists of the mapping window that utilises the full extent of the browser window, the main user interface in the top left corner, and tools and themes which pop up on the right hand side. The website tools are depicted in Figure 5, and include base data, dynamic themes, navigation tools (which are also easily accessible on the main interface), website tools and help. A user enters the site after accepting the disclaimer and selects the base data layers by choosing the Google Maps layer to display and defining what GCRO administrative layers are to be shown. The next step is to interact with the GCRO

dynamic themes that provide categorised layers focused on specific themes, with some of the layers also providing dynamic graphs.

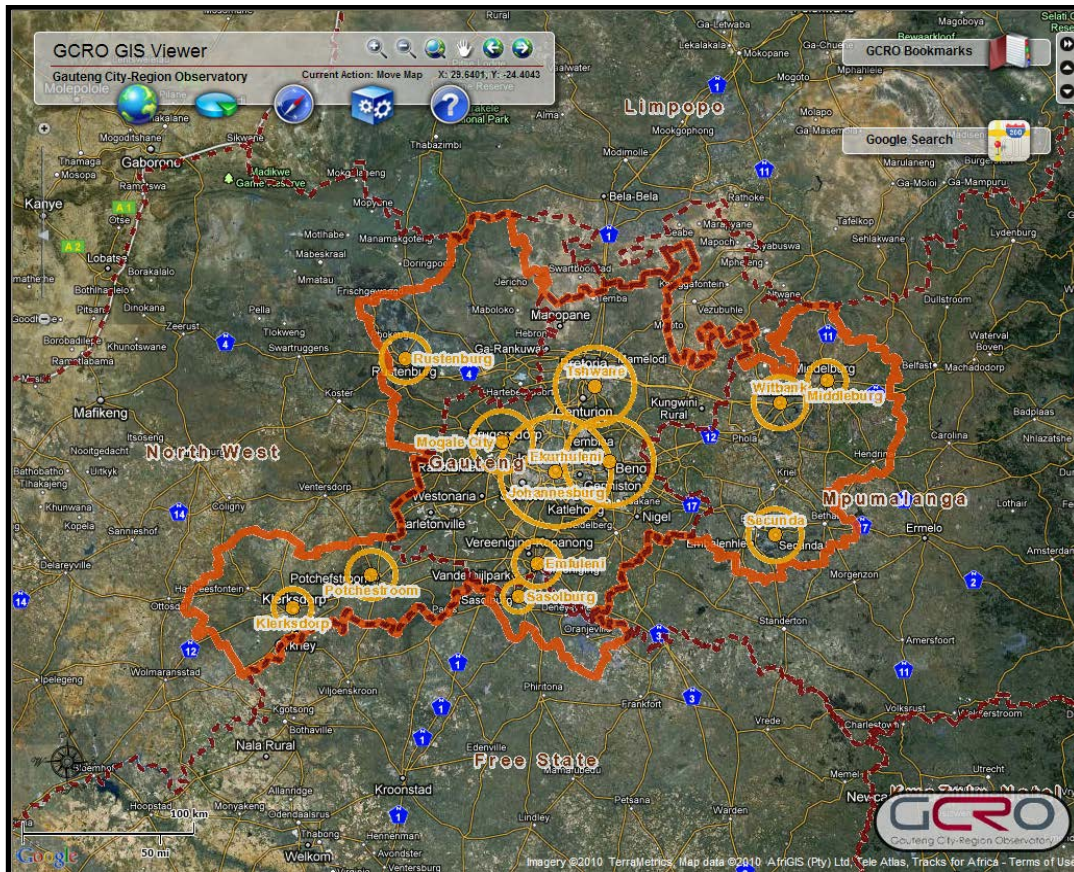


Figure 4: GCRO GIS website

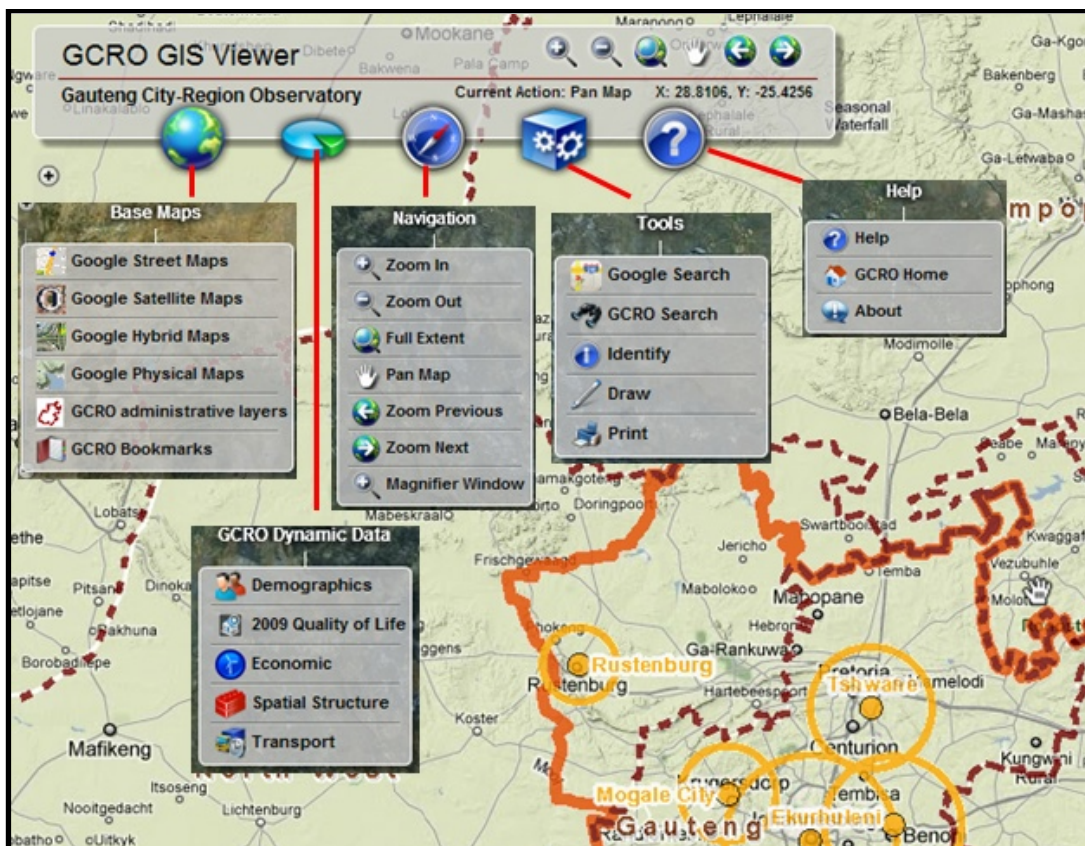


**Figure 5: GCRO GIS website base data, GCRO themes and tools**

An example is provided in Figure 6 with the GCRO 2009 Quality of Life survey satisfaction with local government layer shown on the map, and dissatisfaction with government performance drawn in the graph. Full metadata on all the layers is provided with the metadata tool on the theme toolbar.

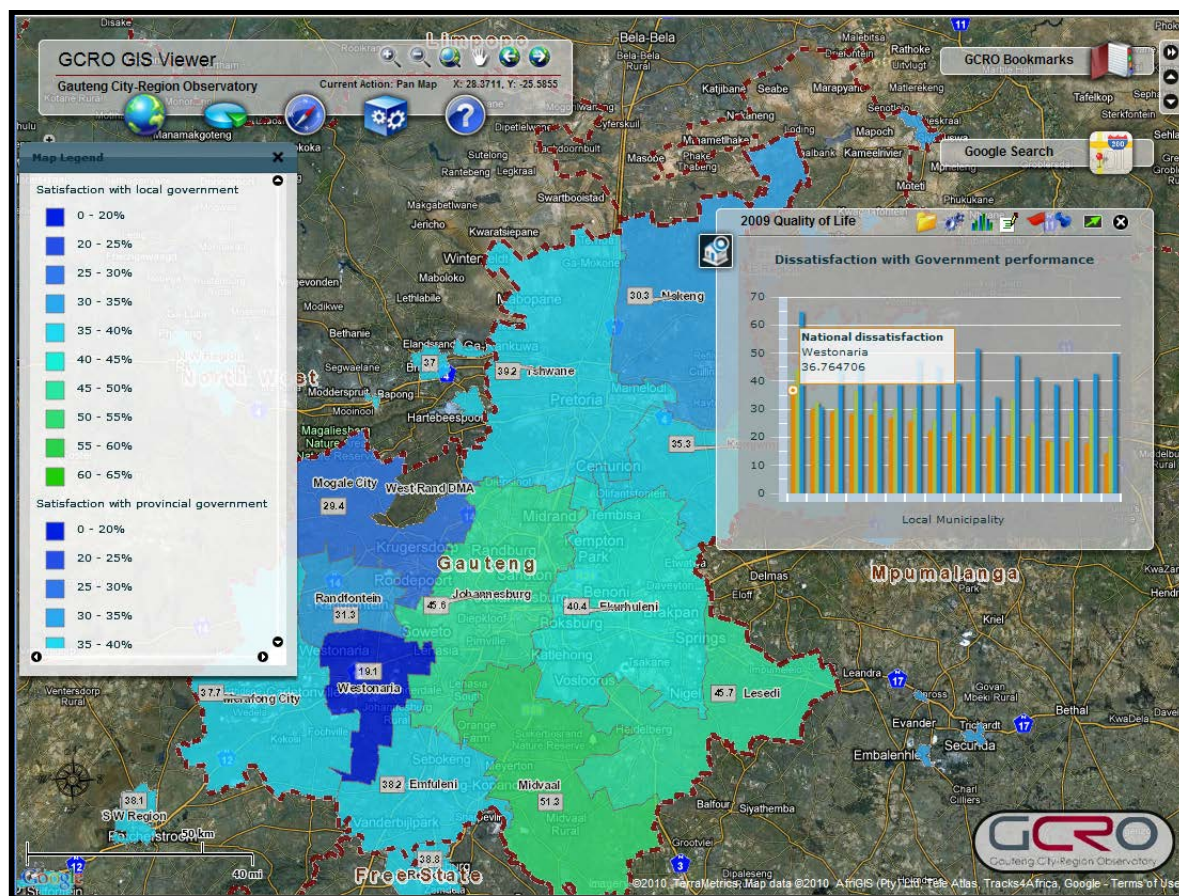


**Figure 6: QoL dynamic theme with graph**

Two different search tools are available. The first is a Google search which utilises the power of the Google Maps search engine and allows the user to search for a point of interest, street address or any feature that is featured in the Google Maps database. The GCRO search provides for searches on specific GCRO layers such as the local municipality or wards. There is also an identify, draw and printing tool, which allows the user to choose a base layer and print to pdf.

## 5 GCRO GIS website launch and response

The GCRO GIS website was formally launched on 1 September 2010, with launch sessions held over three days at the Wits Chamber of Mines engineering PC lab. Each session focused on a different group of users, i.e. government GIS specialists, local and government officials involved in planning, and GPG Heads of Departments. After a short introduction explaining the business need for the GIS website and development process, an interactive demo of the website was presented, with participants able to actively interact with the various tools and datasets using the engineering lab PCs. Attendees then evaluated the website by filling in an online questionnaire designed to measure user acceptance of the new application, using the Technology Acceptance



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