

The CSIR NYENDA PROGRAMME: Traffic management R&D capacity building – balancing the opportunities and constraints

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ABSTRACT

The CSIR's NyendaWeb programme is developed to provide support to the road safety and traffic management fraternity particularly to efforts aimed at stopping the carnage on South African roads and then also to achieve sustainability in transport (SATC, 2008). NyendaWeb harnesses Intelligent Transport Systems (ITS) in its various forms of implementation and is developed as an open source instrument to facilitate improved collaboration among transport researchers, managers and operations, and to enhance reciprocal data accessibility. Concurrently, the NyendaWeb project, as part of the CSIR ITS Lab Collaboratory, is establishing an international platform for collaborative research and development as well as capacity building in ITS and Traffic Management. At the functional level it was to ultimately also provide a neutral transport data integrative and fusion platform that is particularly suitable for environments with disparate and incoherent ITS deployments.

The NyendaWeb has moved from just a concept to a practical tool of which the functionality can now be expanded. This paper deliberates NyendaWeb's potential to rapidly grow in its usefulness to the transport/ITS industry and the constraints on further development. On the one hand the industry consists of many disparate entities that are not naturally collaborative despite integrative transport policy intents. On the other hand, the implementation of ITS technologies creates data rich environments that can contribute significantly to improved transport management and operations from company level to the level of national government, including end-users. Utilising such data, presents a new paradigm of opportunities to the transport and traffic management fraternity – both technologically and institutionally.

The first part of this paper considers aspects of the need for the special skills required for this paradigm and then the role of the Nyenda Programme to increase current capacity to do the necessary R&D and to expand the collaborative effort towards a more inclusive stakeholder cadre. In the second part of the paper, an update of the NyendaWeb technological development is provided including a practical example of the NyendaWeb data integrative capability. The paper concludes with views on the way forward with the Nyenda Programme.

1 INTRODUCTION

The key ingredient to effectively manage road safety is arguably the availability of accurate, relevant and timely information that is appropriate to guide and inform strategies, policies and actions at all levels of transport/traffic planning, design, management and operations. Good data, information or intelligence is the first step to achieve success in

planning and implementing transport/traffic interventions in any of the 4E-disciplines (i.e. education, engineering, enforcement and evaluation). It is in this area where the CSIR's NyendaWeb programme is envisaged to provide an intervention that can ultimately serve as key support to the road safety and traffic management fraternity in efforts to stop the carnage and to achieve sustainability in transport. NyendaWeb intends harnessing Intelligent Transport Systems (ITS) in its various forms of implementation and to be an open source instrument to facilitate making data accessible to transport researchers, managers and operations.

ITS at its core is aimed at making transport systems more efficient and productive and to assist in moving more rapidly to higher levels of sustainability, which inherently must include making it safer for people to travel. The developed world is currently allocating huge budgets to embed transport systems with ITS functionalities and South Africa is following suit with some early beginnings in the major metropolitan areas.

The CSIR NyendaWeb project is part of the CSIR ITS Lab Collaboratory that is intended to be an international platform for collaborative research and development as well as capacity building in ITS and broad based traffic management. NyendaWeb is developed to provide a neutral transport data integrative and fusion platform particularly suitable for environments with disparate and incoherent ITS deployments.

The NyendaWeb platform will provide the means to give exposure to aspiring students/researchers to the science, engineering and technology (SET) developments in the fields of transport/traffic engineering, traffic management, electronic engineering and ITS. There are already undergraduates and graduates engaged in the research and development work to expand the NyendaWeb "sensor network" (Labuschagne, 2008) or to develop the science and technology aspects of the ITS Lab Collaboratory. The transport and ITS industries are key stakeholders to the successful expansion of the NyendaWeb and various players are being approached for collaborative agreements to achieve mutual benefit – ultimately also pursuing national benefits in terms of efficient, productive and safe transport services and appropriately skilled workforces. NyendaWeb aims to advance SET, including human capital development, in transport and ITS and to facilitate the strengthening and expansion of a globally competitive transport services sector with an appropriate focus on BEE growth within the sector.

The NyendaWeb philosophy is founded on the premise that the transport sector is a primary driver for future growth in the global economy, based on the increased degree of specialisation within corporations and national economies, leading to the increased importance of national and international trade. Mobility of people and productive and efficient logistics are also viewed as important differentiators between successful and less successful economies. The 'greening' of transport has also grown in pertinence and will be of increasing relevance in transport strategies, planning, policy making and operations management and control.

It is furthermore believed that ITS holds the key to improved performance and productivity in the transport sector. While the use of information, communication and automation technologies have been widespread in the mining and manufacturing sectors for several decades, the same technologies have not made similar inroads into the transport sector as yet. This is partially due to the fact that transportation systems are inherently distributed by nature, and are often not fully controlled by a single entity, but tend to be shared by many independent stakeholders. The effective utilisation of these technologies has been key to the improvement of transportation systems, specifically public transport systems, in the Developed World over the past two decades. The NyendaWeb initiative has an important contribution to make in terms of adapting these technologies to the needs of the Developing World and assisting public and private stakeholders to successfully deploy

such ITS systems as part of existing and new transportation infrastructure. A particular contribution would be towards the “shrinking” of deployment horizons and the enhancement of take-up through demonstrable collaborative R&D programmes.

The NyendaWeb project is founded on the belief that success in this field will rely not only on the availability of the required expertise and facilities, but also on the ability to effectively communicate with decision-makers within stakeholder organisations, and the ability to mobilise and equip the resources available from those organisations in order to achieve fundamental changes in the way that transportation systems in the Developing World are operated today. For this reason the education and training leg of the proposed Nyenda Programme strategy is as important to achieve as the set of long term objectives.

2 SECTOR NEEDS

Arguably, in the developing world, including South Africa, information and communication technologies have only achieved limited penetration. Systems that have been deployed (e.g. vehicle counting systems, CCTV camera systems, etc.) have in most cases been designed to operate in isolation, and the collected data is not readily available to be shared by other systems or users. Apart from the most important and overarching need for human skills development, there are needs within the transport sector in general and within this sector in developing economies specifically, that can be addressed by utilising ITS:

- The need to utilise available funding more effectively by expanding capacity where its impact on the overall efficiency of the transport system will be the biggest;
- The need to respond quickly to non-recurring events like crashes and other incidents requiring the closure of lanes to minimise the impact on service delivery;
- The need to identify suspect or non-compliant vehicles in the normal course of traffic flow, enabling effective law enforcement with minimum impact on travel times;
- The need for careful planning of the sequencing of construction work, in order to minimise the impact on available road network capacity within each metropolitan area;
- The need to regulate the flow of freight traffic to ensure that freight vehicles utilise highly congested roads when their impact can be accommodated and ensuring that such vehicles only utilise roads that were designed to carry the respective type and volumes of traffic;
- The need for open road electronic tolling systems that can accurately collect revenues with little or no impact on traffic flows. The e-tolling systems used in developed countries tend to be too expensive for the general population of private road users in developing countries, creating the need for a low cost e-tolling concept that is still sufficiently accurate and close to actual usage to support the concept;
- The need in metropolitan areas to control access of road traffic to central business districts and other densification nodes, either through tolling or through restricted access based on time-of-day or day-of-week;
- The need of public and private organisations, dependent upon fleets of vehicles that are deployed on a daily basis as part of service delivery (e.g. the police service, ambulance services, hauliers and taxi operators), for a variety of systems that must be available for tracking vehicles and measuring utilisation and service levels, based on affordability and the accuracy of information required, and
- The need is to influence driver behaviour to the better. The application of ITS technologies has great potential to contribute significantly to this.

Currently only a limited number of these needs are met by systems that are commercially available as such systems mostly cater for end-users that can afford to procure relatively

expensive systems and that can afford to operate them in isolation from the needs of other end-users. Many of these needs, especially those needs involving vehicles operated by the general public, will only be met once new generation ITS systems have been deployed that can address a variety of end-uses based on a common infrastructure.

In situations where a number of ITS systems have been deployed (e.g. traffic loggers, CCTV cameras, RFID spotting, roaming surveillance platforms, etc.) much more value can be derived from the combined utilisation of all such data compared to the use of each type of information in isolation. A typical example will be where the authorities want to determine what fraction of in-compliant vehicles (including drivers) are using which roads during specific times of day, and also want to differentiate between the typical road behaviour of “compliant” versus “non-compliant” vehicles. While all the required raw data may be available from the various types of systems mentioned, it will be virtually impossible to solve the problem without the ability to fuse the data coming from different sources into one system, allowing the end-user to draw conclusions from the combined data set.

3 BRIDGING CONSTRAINTS

NyendaWeb is establishing the capability to design and deploy open ICT technologies in order to enable ITS systems that will have a much bigger impact on the effective operation of transport infrastructure and the management of traffic. NyendaWeb plans to achieve this in cooperation with all important categories of stakeholders in the ITS domain, including the transport authorities, commercial service and solution providers, end-user organisations and academic institutions. By involving the entire spectrum of stakeholders, building partnerships where necessary and mobilising available resources amongst all partners, NyendaWeb will act as facilitator to achieve fundamental enhancements in the use of ITS within the transport sector, firstly in South Africa and subsequently in the rest of the developing world.

The CSIR, as a national research and development entity with the mandate to serve the South African industry, in the first instance, will play the role of independent and objective role-player that can act as the central platform for building capacity to serve the future needs of the local ITS industry. The CSIR can thus act as the independent data broker between various parties, managing access to data based on the both the provider of data and user of data requirements - allowing both raw and processed data to be provided in a controlled manner for research, operations and planning. The CSIR will thus facilitate interaction with all categories of end-users and customers, as well as commercial solution and service providers to make an accurate assessment of the needs of the transport sector for improved ITS systems.

Based on the outcome of this assessment, NyendaWeb will focus on the following parallel activities that take it towards its objectives:

- Creating awareness of the benefits offered by new generation ITS amongst authorities at all levels (central, provincial and municipal) through workshops, at the same time conducting market research to assess current perceptions amongst these stakeholders regarding the contribution that ITS can make towards improved infrastructure utilisation and better service delivery;
- Designing and building the NyendaWeb, NyendaView and NyendaBEe infrastructure (Labuschagne, 2008) to allow it to collect, process, analyse, manage and display transport data collected by the complete spectrum of ITS sensing equipment in the field;
- Training up its own manpower base of expertise regarding the nature and the needs of transport systems, the technology platforms required to implement ITS systems,

and the ability to intelligently mine and present the data in the form of useful management information;

- Building up a network of partnerships with governmental agencies, academic institutions, commercial technology vendors and system integrators and international centres of expertise that will provide it with the required skills base to research ITS problems and build prototype ITS solutions;
- Educating and training human resources within customer organisations responsible for the establishment and operation of transport infrastructure, as well as within commercial technology and service providers that play the role of deploying ITS systems, partly to create awareness of new generation ITS concepts and systems, as well as to establish the capacity to plan for, deploy and operate ITS infrastructure, at the same time contributing to the NyendaWeb income base, and
- Recruiting research and development projects from customers and successfully completing such R&D in order to address new challenges and solve ITS problems as they are identified to the benefit of the transport community, at the same time providing an on-going basis of income for the centre.

4 NYENDAWEB TECHNOLOGY DEVELOPMENT

4.1 Introduction

As mentioned, the focus of the NyendaWeb is to create a common and open platform which can bring about a high level of coordination among ITS stakeholders. Specifically, the NyendaWeb seeks to improve the accessibility of the variety of data that are applicable to ITS. These are the data that can assist service providers in the provisioning of quality road and transport services to transport users. Transport users may in turn be in a position to contribute to optimising transport infrastructure utilisation by appropriately responding to user information. NyendaWeb intends to serve as an up-to-date and accurate repository or data dictionary of ITS data. NyendaWeb is a web or network of distributed ITS databases, including data from the level of road sensors to the level of management information. Some of the functions of the NyendaWeb are:

- Creating a comprehensive distributed database that can be relied on to provide necessary data for strategic planning and management of road infrastructures. Stakeholders with access will ultimately be able to visualise and measure the impact of their decisions before they are implemented. It will become possible to predict the locations where problems are likely to occur, and then to prevent them through appropriate interventions before they actually occur. The stakeholders that can benefit from this NyendaWeb function include the road operators, road controllers and government (municipalities), public transport operators, etc.;
- Enabling the archiving, retrieval, and distribution of data generated by ITS applications and enables ITS applications that use archived information. Decision support systems, predictive control and performance monitoring are some ITS applications enabled by the NyendaWeb, and
- Assist in transportation planning and management, administration, policy evaluation, evaluation of transportation system operation, safety analysis, future investment decisions and research. It makes use of a variety of software, database, and electronic data storage technologies – with “open source” technologies as far as would be achievable.

4.2 NyendaWeb high level architecture

The scope of work includes the collection of available data, the generation of unavailable data, the archiving of generated data in an open repository and disseminating this data in

appropriate formats. The research also seeks to develop an emulator which will allow stakeholders such as researchers, road authorities etc to improve road safety, study user/driver behaviour, study the environment's impact on road safety, study policy impacts, and visualise road use in a "bird's eye" manner. The architecture defines the features of the NyendaWeb and how the NyendaWeb is supposed to operate. It provides a structured way of how users' requirements will be satisfied, of defining the applications available to users, of processing the variety of different data types, of the linking of the physical entities that supports data archiving, the operational lay out that enables the archiving and retrieval of data through the NyendaWeb.

Since the abovementioned stakeholders have diverse needs and requirements, the Nyenda data dictionary and repository provides access to a full range of data that is applicable to each respective user. The database framework is also scalable and flexible enough to accommodate users' future requirements. The functions and responsibilities of the respective stakeholders will determine their data application purpose and therefore their data requirements.

Transport (traffic) data types differ for different application contexts. Some applications may require real time or "near-real" time data for operational, safety or planning purpose. These data may be in text formats or in video formats as deemed to be fit. Such data categories and formats are taken into account in the NyendaWeb data framework. Some ITS data types and their area of application include:

- Environmental Information: Air pollution data (green-house gas e.g. CO and NO emissions, road transport weather data, current and forecast road conditions, weather information, air temperature, pavement moisture and temperature, precipitation and humidity, road surface condition, flooding, wind direction and speed, visibility on the road, etc.);
- Roadway information obtained through traffic monitoring devices (e.g. traffic volume, vehicle speed and speed differential, lane occupancy and utilisation, lane changes, vehicle classification, vehicle occupancy, vehicle's specific location, vehicle headways, traffic queue, traffic flow at road intersections, etc.), and
- Road way maintenance and construction information (Type of road construction and maintenance activity, work zone information, safety precautions such as speed limits, completed road infrastructure, new road infrastructure, etc.).

Figure 1 below shows the NyendaWeb database framework. The NyendaWeb distributed data architecture was specifically designed to facilitate the collaboration, integration and distribution of data collected from distributed sensors and data stores without the need for local storage or direct integration. By implementing XML layers and meta data definitions with regards the location, type and description of the data the system allows for the complete separation of user interfaces, data and viewers. Sensors/databases registered on the Nyenda platform allow users a common interface for locating and extracting relevant data without the need to conform to different interfaces or procedures. Although the NyendaWeb platform is the gateway to existing data stores, its design also allows it to act as a temporary storage facility for data that needs to be interpreted before it is utilised in any third party application. The platform thus allows viewers or visualisation tools to be developed or plugged into the platform to extract and interpret the data in a format as required by the user. The platform has been built on PostgreSQL open source object-relational database system which allows for open standards data storage as well as being highly scalable. The engine has been labelled "anyDB" as it allows the creation of derived tables and functions to correctly interpret the sensor information and to build single interfaces to the data. The design and architecture of "anyDB" allows developers to constantly adjust the engine to facilitate the integration of new data sources over time, thus

allowing the system to evolve as required and adapt to the different types and sources of data.

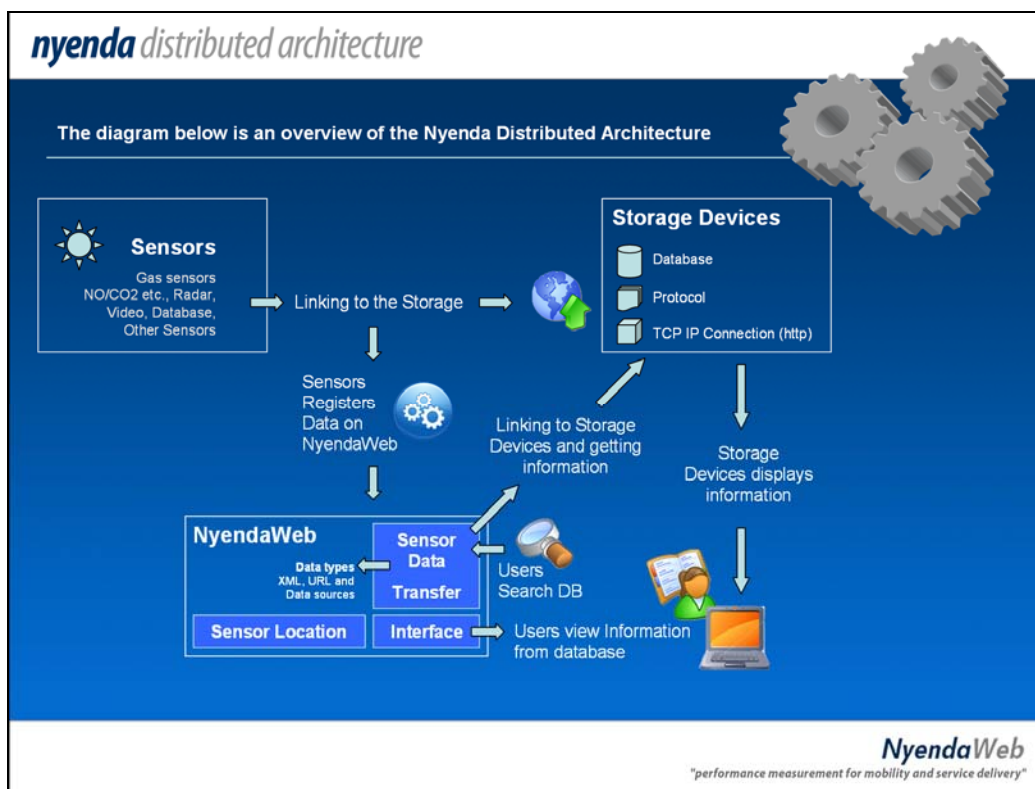


Figure 1: Diagrammatic representation of the NyendaWeb database framework

5 AN EXAMPLE APPLICATION OF NYENDAWEB

There is a growing emphasis on the greening of transport and specifically road transport. The management of processes and implementations towards “greener” road transport can be significantly enhanced if the contribution of road vehicles to pollutant levels can be determined with greater precision. This would generally be practically complex and also expensive to achieve with conventional direct measurement methods. The NyendaWeb-concept provides a methodology to utilise a combination of other sources of data to create a proxy “road emissions sensor”. To illustrate the functionality of the NyendaWeb-concept with respect to emissions measurement, three sets of data from different databases and sensors are combined to develop a completely unintended application: 1) Traffic engineering logger (TEL) data provide volumes and point speeds of vehicles by lane and by class of vehicle; 2) Freeway surveillance video data are processed to provide speed profiles of vehicles in the traffic stream and of the number plates of vehicles in the traffic stream, and 3) Number plate information that relate to the emissions profile of the vehicle (according to manufacturer, model, year of manufacture, engine capacity, etc.) under the prevailing operating conditions. The data are then viewed with a viewer that does background modelling and calculations that effectively converts each vehicle into a virtual emissions sensor. The application was developed as part of Project AQUILA¹.

The core focus of the system was to develop an application that could be used to measure and graphically illustrate the pollutants dispersed by vehicles along a road. This application had to take into account several inputs as factors that influence the extent of pollutants, as

¹ Project AQUILA is a project to develop an air quality assessment tool funded by the South African National Energy Research Institute.

well as the environmental variables that influence the movement/dispersal of such pollutants to the surrounding areas. A stand-alone MS Windows application was developed in Visual-C that formed the main AQUILA interface. The CALINE4² dispersion model was ported to C and a Visual-C-library was developed for it. This allowed its incorporation (including its functions) into the AQUILA frame. CALINE was originally developed by Caltrans to measure carbon monoxide dispersion and uses a Gaussian plume dispersion model. Satellite imagery or areal photographs are incorporated in the visualisation component of AQUILA. Geospatial Data Abstraction Library (GDAL) third party software is used to generate the isopleths over the imagery of the study area.

The AQUILA-application utilises the mentioned inputs above (see Figure 2 with Notes 1, 2, 3 & 4) along with an underlying grid of receptors to calculate the extent of dispersion over time. Isopleth contours (in thematic colour ranges) visually illustrate the dispersal values as calculated. Within the interface the user can specify monitor points – these are points that are placed on the spatial surface (along the road or some distance away). Results are calculated for these points based on the underlying (nearest) receptors. To ease interpretation, a rolling index is calculated for each result based on weights given to bands/ranges of emissions to indicate the risk of exposure.

Figure 3 below shows a typical AQUILA-application output. The output is dynamic and the application can be run in real-time depending on the availability of the required real-time data streams. The typical practical application will most probably be in post processing and analysis environments but a potential real-time application would be to generate warnings for the development of high health risk situations that may prompt the institution of access restrictions on certain sections of roads.

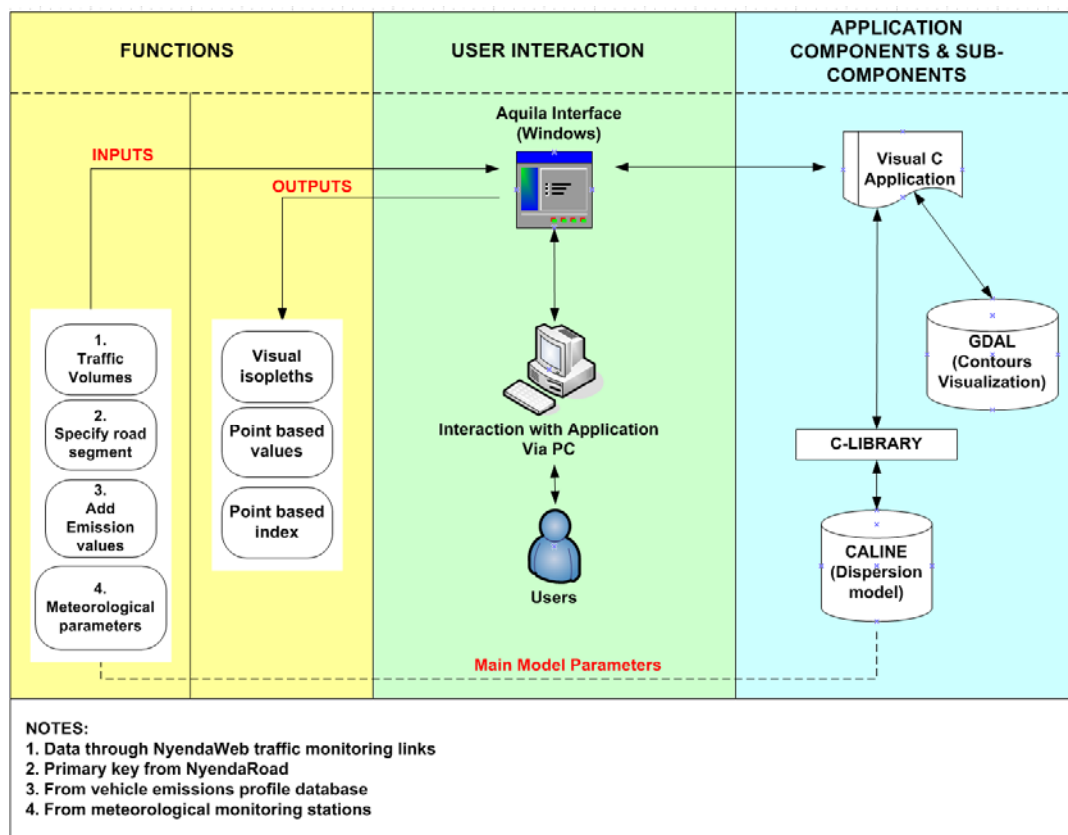


Figure 2: Technical design outlining the core element of the AQUILA-application and main functions

² CALINE (California Line Dispersion Model) - <http://www.weblakes.com/lakepa1.html#CALINE4>

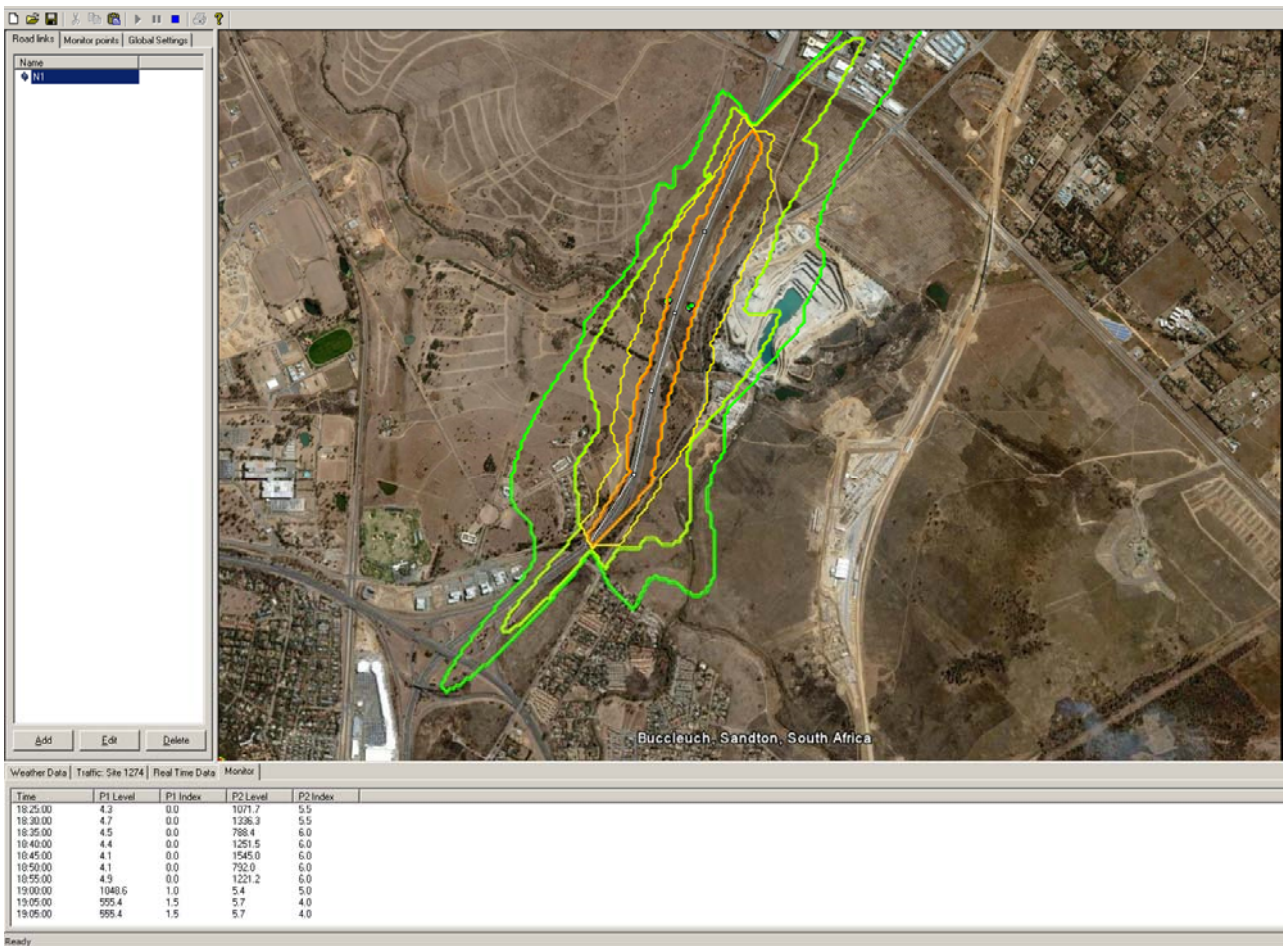


Figure 3: Screenshot of the dynamic graphical output of the AQUILA-application showing the isopleths for various CO concentration levels

6 CONCLUSIONS AND WAY FORWARD

The example AQUILA-application demonstrates how the availability of data from disparate data sources can contribute to the development of powerful analysis and visualisation tools including those useful for near real time tactical decision-making. NyendaWeb, through its database framework, is configured to overcome the constraints of non-uniformity and inconsistency of data granularity, data definitions and data structures. It provides a platform that encourages accessibility of all kinds of transport-relevant data and promotes data enrichment processes. It thus creates abundant opportunities to develop new applications and other tools that have been more typical for data rich environments. Some of these are:

- Visualisation of data and information can be applied as a powerful analysis tool. NyendaView (of which the AQUILA-application is an example), aims to transform blind data to contextualised information through the use of advanced geospatial presentation technologies. This is considered very useful in R&D, training and upskilling programmes in that the relationships between data (or theory) and reality (or practice) can be demonstrated more clearly.
- NyendaWeb provides a neutral platform that encourages the development of a much wider scope of traffic management and traffic engineering applications and decision support systems. This is possible through enhanced access to transport-relevant data and the availability of tools for analysis and presentation.
- The development of the tools (to analyse and view) itself is the object of NyendaWeb R&D. NyendaWeb provides the structure with definable building blocks

to progressively establish a national resource to improve transport management and accountable service delivery capabilities. It relies on multi-disciplinary R&D collaboration at all levels, from undergraduate to post-doctoral – something that is direly needed in the traffic safety management domain.

NyendaWeb's data integration premise, and thus the way forward, is focused on the many transport-related systems that are already generating very useful transport management-, operations- and research-relevant data. These systems generate performance measurement and management data that may duly serve the management needs of road authorities.

The NyendaWeb Programme is aimed at facilitating improved collaboration between transport providers and the transport users. Transport users with handheld devices, like cell phones, and other vehicle-bound devices have the opportunity to assist transport providers by providing anonymous data to improve transport services that will benefit the South African economy and reduce transport costs for individuals and companies. Transport service providers will also be able to provide more predictable service levels and to optimally utilise available transport system capacity. Transport authorities may also be more proactive in detecting and clearing incidents and preventing transport incidents may even become possible.

The transport and ITS industry is key to the successful expansion of the NyendaWeb and various players are being approached for collaborative agreements to achieve mutual benefits in terms of efficient, productive and safe transport services. NyendaWeb aims to advance SET, including human capital development, in transport and ITS and to facilitate the strengthening and expansion of a globally-competitive transport services sector with an appropriate focus on growing BEE within the sector.

7 REFERENCES

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