

THE CSIR NYENDAWEB INSTRUMENT OF THE ITS LAB® COLLABORATORY, AND RESEARCH AND DEVELOPMENT PLATFORM

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ABSTRACT

The improved access to transport and traffic data by researchers will greatly benefit general Research & Development (R&D) in the fields of road traffic and safety engineering, and traffic management. Obtaining historic data for transport and traffic related research work is generally found to be cumbersome and frustrating. Commensurate validity and verification concerns as well as incoherencies and uncertainties vested in available transport/traffic data, inevitably add to the complexity of analyses and the level of innovative contextualisation required to apply said towards inferences intended to guide transport/traffic management policy- and decision-making. Amidst government's imperative of accessible information, in this era where many transport and traffic related transactions are digitised in some way, and arguably where digitised data do indeed exist in large quantities, it remains *fait accompli* that it is very difficult and time consuming if not impossible to source validated, verified data for not only purposes of R&D but also for the intelligence required for transport policy-making, operation and management. Against this backdrop, CSIR has launched a flagship project, NyendaWeb based on the "sensor network" concept. NyendaWeb's underpinning theme is the promotion of Intelligent Transport Systems (ITS) in transport. The paper describes the NyendaWeb technical development concept, the role of NyendaWeb within the ITS Lab Collaboratory® as an international ITS R&D platform, and how the "demonstrator" functionality of NyendaWeb is envisaged to contribute to raising the awareness and interest of the engineering and associated disciplines at school, under-graduate and post-graduate levels in traffic engineering, ITS, traffic management, and other built environment sciences, engineering, technology and management fields.

1. INTRODUCTION

In April 2007 CSIR Built Environment launched an ambitious research platform development programme, the ITS Lab Collaboratory (ITS Lab), aimed at boosting research and development (R&D), inclusive of human capital development elements, in the field of intelligent transport systems (ITS). The programme is spearheaded by a project named "NyendaWeb: Developing Intelligent Systems for a High Performance Transport Network". NyendaWeb is developed as the main instrument of the ITS Lab to create a virtual ubiquitously-sensed built environment, with an initial focus on transport. NyendaWeb is envisaged as an open, universally accessible data collation and integration resource to facilitate more intensive R&D on ITS, traffic/transport engineering and traffic management, which includes road safety and other environmental aspects.

The need for a NyendaWeb development initiative stems from a number of needs:

- the need for improved access to transport- and traffic-related data, particularly for research and development purposes, but also for transport planning, and traffic operations and management;
- the need for greater integration of data with specific reference to data across-cutting functional lines, e.g. housing, health, education, etc.;
- the need to better utilise the vast amounts of data that is becoming available as a result of the ICT driven economies and processes;
- the need to unlock in-process generated data that could become useful information if appropriately processed and integrated, e.g. fleet management, cellphone data, etc.;
- the need to design work flow processes for the specific purpose of automating data capturing for monitoring and evaluation.

The envisaged NyendaWeb project impacts include:

- a platform for advanced transport, traffic and safety engineering, and traffic management research and development;
- greater awareness, insight and collaboration of transport users of the economic, social and environmental drivers in mobility provision;
- cost and time savings through more efficient road traffic operations;
- promotion of seamless connections among all transport modes;
- lower freight logistics costs;
- the management of mobility demand and supply through appropriate technical and policy measures that complement optimal capacity utilisation of the road network and transport ;
- the availability of real-time traffic and road data in an integrated information infrastructure to assist traffic management and improve transport network management, with due consideration to economic, social and environmental impacts;
- intrinsic performance measurement to evaluate the impact of policy and intervention implementation as well as holistic transport efficiency benchmarking, analysis and evaluation;
- greater transparency of traffic management functions and transport systems performance impacts;
- virtual transport/traffic policy and intervention evaluation and accreditation;
- bandwidth efficient technologies to collect and collate transport data for optimal intelligence dedicated to inform policy-making, managing and operating transport facilities, etc.

2. NYENDAWEB RATIONALE AND OBJECTIVES

“Nyenda” is a Venda (an indigenous language) word that can be associated with the mobility concept. NyendaWeb is a derivative of the Sensor Web. A sensor network is a computer accessible network of many, spatially distributed devices using sensors to monitor conditions at different locations, such as temperature, sound, vibration, pressure,

motion or pollutants. A Sensor Web refers to web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and interfaces (or application program interfaces).

In an Open Geospatial Consortium Inc. (OGC) initiative called Sensor Web Enablement (SWE), members of the OGC are building frameworks of open standards for exploiting Web-connected sensors and sensor systems of all types: flood gauges, air pollution monitors, stress gauges on bridges, mobile heart monitors, webcams, satellite-borne earth imaging devices and countless others (see <http://www.opengeospatial.org/legal>).

SWE presents many opportunities for adding a real-time sensor dimension to the Internet and the Web. This has extraordinary significance for science, environmental monitoring, transportation management, public safety, facility security, disaster management, utilities' SCADA operations, industrial controls, facilities management and many other domains of activity. The OGC voluntary consensus standards setting process, coupled with strong international industry and government support in domains that depend on sensors, will result in SWE specifications that will quickly become established in all application areas where such standards are of use.

Within the SWE initiative, the enabling of such sensor webs and networks is being pursued through the establishment of several encodings for describing sensors and sensor observations, and through several standard interface definitions for web services. The SWE development path is almost evolutionary of nature with vaguely defined objectives and timeframes. As such the progressive development is largely dependent on global consensus achievements through the efforts of the OGC and other collaborators. The NyendaWeb Project is intended to harness the SWE processes but such that it could aid in pushing technological development forward by delivering Sensor Web-type applications in a much shorter timeframe. NyendaWeb embraces transport technology foresight with the establishment of a technologically advanced research platform that will achieve optimal relevancy in transport and traffic engineering and management in 3 to 5 years' time. The current CSIR research agenda is thus driven by an interim deliverables range that will serve as building blocks for various technological platforms or applications with the potential to deliver short term impacts.

In this regard the Science, Engineering and Technology (SET) development focus of the respective Research Area (RA) of the CSIR Built Environment and some of the pertinent issues or needs that emerged from previous research were:

- improved intelligence for impact assessment and operational efficiency,
- informed decision-making based on the above improve intelligence,
- human capital development, and
- the development of science to deal with Information and Communications Technology (ICT) driven transport systems and associated economies.

These issues/needs culminated in the mission of the RA, i.e. to affirm the importance and relevance of scientific traffic engineering and traffic management research, engineering and technology through the creation of relevant research platforms and the development and/or application of advanced ICT-based technologies for more sophisticated transport management. Three thematic components have been identified to describe the approach to scientific research, namely:

1. Developing and/or unlocking of multi-disciplinary transport relevant detectors/sensors/databases – i.e. sensing transport infrastructure;
2. Development of an ICT-based open source platform for collaborative, coherent, consistent and consolidated data collection, collation, fusion and distribution systems – i.e. systems' intelligence, and
3. The application of the platform for the multi-mode, multidisciplinary characterisation of transport and peripheral systems' performance for purposes of mobility (including social aspects) optimisation, impact assessment, traffic engineering science, analysis and informed decision making – i.e. context sensitive mobility.

3. RATIONALE FOR THE 'SET' FOCUS

The road transport environment is synonymous with many pertinent problems that relate to lawlessness, crime (specifically associated with vehicles as object and instrument of crime), facility operations, operations management to service current demands for transport, and to plan and implement upgraded and new facilities, including concomitant budgets and finance schemes to provide for the future. In this context the importance of having the relevant accurate, appropriately formatted and timely data and information to effectively and efficiently manage the road transport environment is obvious.

The collection of transport and traffic data, however, requires a significant and dedicated effort from all tiers of transport infrastructure managers to deliver the value proportionate to the cost of the monitoring and data collation exercises. For various reasons, this is currently not done coherently, if at all, or not at intensity, accuracy and coverage levels to produce consistent, persistent, reliable and relevant information to be of value for operational, tactical or strategic transport applications, purposes, and policy and decision-making. Other limitations of current efforts to collect transport and traffic data is that the focus is on covering the main road networks and obviously the lower order roads and other public accessible areas and amenities are seldom monitored if not only for specific project purposes.

Arguably, great potential benefit could be derived by improved integration and accessibility to transport-relevant data. The proposition for NyendaWeb lies in, apart from data collected in traditional ways, capturing and integrating systemically generated transport data, specifically including data which are not reliant on the specific efforts or budgets of transport infrastructure managers, through a neutral and integrative platform with appropriate public access and exposure to value-addition. There are numerous conventional sources of systemic transport data and also some emerging ones associated with technological advancements. Conventional sources are the traffic data loggers and a variety of other routine and non-routine traffic counts, including those that are typically done manually, by local and provincial authorities, toll transactions, weigh bridge transactions and logs, vehicle tracking information, goods tracking, train/bus ticketing transactions, the current accident databases, etc. Emerging sources are camera surveillance, electronic vehicle identification or automated number plate recognition, cell phones, transport transactions, GPS-based loggers, etc. By integrating all these sources with the suitable data collation, merging, verification and validation mechanisms and technologies, virtually ubiquitous sensing of transport users and vehicles in near real time over the transport networks can be created and which will generate information for operations and planning on both ends of the demand and supply chain. The premise is that this can be achieved with minimal capital commitment.

4. VALUE FOR PROSPECTIVE STAKEHOLDERS

4.1 Introduction

There is obvious value in integrated transport and traffic data, but NyendaWeb is not just another transport database or yet another effort to consolidate transport databases into one big super-duper database. NyendaWeb resorts under the realm of Intelligent Transportation Systems that use information and communications technology to integrate transport functions and other technologies. It is a computer accessible network of many, spatially distributed devices using sensors (that can be a database or electronic library of some sort) to monitor or measure conditions at different locations, such as temperature, sound, vibration, pressure, motion, visibility or pollutants. In this respect, the word “sensor” carries a broad definition and in the context of NyendaWeb, it means that anybody and anything that can provide geo-spatially referenced features-of-interest content would be able to contribute to the NyendaWeb Sensor Observation Service (SOS) database.

4.2 The NyendaWeb value for the transport management fraternity

NyendaWeb is a nerve centre that is capable of selectively collecting and archiving only specific bits of transport/traffic sensor data and it makes use of mostly open source software. The intent is to create a public accessible layer of data that will allow anybody to collate or analyse the data or to develop applications to add value to the content and provide specialised services. Most importantly, NyendaWeb is configured for near real time and continuous monitoring which means that once it is fully configured, monitoring will happen automatically as long as the sensors are maintained at a level of sufficiency. Part of NyendaWeb will also be the functionality of visualisation of specific content in formats suitable for specific purposes and for specific users. NyendaWeb will also protect data that is proprietary or not intended for the public domain.

Below are some of NyendaWeb’s offerings:

1. NyendaWeb provides a common structure for the collection and archiving of data for community safety-related and other data collection projects independent of the CSIR. Once the input interfaces are developed, any consultant or service provider can collect the data and utilise the NyendaWeb functionality. NyendaWeb will ultimately also have necessary correlation, verification and validation functionality to also facilitate reliability and quality certification;
2. NyendaWeb could ultimately automate general monitoring services and aggregate near real-time continuous streams of data in an efficient way. For example, before and after studies may in future not be done on a project by project basis. Instead it will be possible to create baseline (or ground truth) measurements through NyendaWeb applications at any selected point in time;
3. All transport communities will ultimately be able to provide direct input to NyendaWeb either through the Internet or through GPS-enabled cell phones, PDAs or similar devices. A person carrying such a GPS-enabled device becomes a sensor when a phenomenon/observation is coded with a time stamp and a geo-spatial reference. So is a person recording a phenomenon/observation, the time and the location through a Graphical User Interface at a Community Centre (e.g. Digital Doorway - <http://www.digitaldoorway.org.za>). During the initial phases of NyendaWeb roll-out, conventional methods to collect data, including possible manual interventions, will have to be used to populate the NyendaWeb SOS database. But by distributing appropriate sensors in a community or region (e.g. a ward in a municipal area), community members are empowered by them being actively involved in a current project, but also in future by continuing to contribute towards providing data that will enable community status reporting on any relevant

issue depending, of course, on the active sensors in the community. Community members will also be able to, in near real time, see the impact or results of their involvement. This could be through the Internet but a connection through other community ICT empowerment projects, like Digital Doorway, is possible and will provide broad-based ICT exposure and empowerment to communities;

4. NyendaWeb will be able to provide a tool for community representatives and community service institutions with up to date information on any specific community or area at any specified point in time. This will involve ICT capacity building of community representatives, particularly on municipal levels, and others involved. NyendaWeb will have flexible functionality to facilitate presentation and reporting in formats as required. NyendaWeb will also facilitate uniformity in ward status reporting which should contribute towards more efficient prioritisation and budgeting processes. NyendaWeb will thus deliver an invaluable tool for benchmarking and other developmental decision-making;
5. Since NyendaWeb will provide ongoing monitoring functionality, it will be feasible to also provide objective assessments of the achievements and impacts that result from actions and projects that the Council implements. NyendaWeb could thus also be configured to provide the information necessary for performance measuring and appraisals. More importantly, communities could get access to information about service delivery. Through these processes, communities are empowered by having knowledge of the service delivery processes regarding needs prioritisation and budget allocation as well as by providing inputs and comments on these;
6. NyendaWeb is a platform for the future and over time will become a more significant tool for research, performance measurement, status and impact assessments, etc. as the number and variety of sensors increase. All stakeholders that participate in the project (providing access to data through the use of the NyendaWeb Sensor Web Enablement technology is one way of participating) will be allowed to get access to the public domain and other data on the basis of user agreements that will be put in place in future to ensure the sustainability of the platform over an extended period of time. Therefore the value of NyendaWeb to a wide spectrum of communities will grow in time. NyendaWeb will effectively capture all learning through its sensing, analysis, evaluation and intelligence creation functionalities and applications, into a dynamic platform. It will thus grow in terms of the value it will add towards efficient community empowerment, problem identification, prioritisation, problem solving, solution implementation and service delivery. The concomitant improved intelligence will enhance efficient policy making, policy implementation and monitoring cycles, and
7. An important element of the NyendaWeb development is the ontology development of transport and traffic concepts, phenomena, etc. According to Wikipedia (see http://en.wikipedia.org/wiki/Ontology_%28computer_science%29), ontologies are used in artificial intelligence, the Semantic Web, software engineering, biomedical informatics and information architecture as a form of knowledge representation about the world or some part of it. Ontologies generally describe:
 - Individuals: the basic or "ground level" objects;
 - Classes: sets, collections, or types of objects;
 - Attributes: properties, features, characteristics, or parameters that objects can have and share;
 - Relations: ways that objects can be related to one another;
 - Events: the changing of attributes or relations.

In transport/traffic terms the ontology thinking means that improved qualification of the collected data and information and that are ultimately collated are endeavoured. The data fusion science builds on more precise descriptions of what a specific data element represents typically in the format of the ontology outline above. In practical terms, e.g. observing a vehicle means recording where, when, what, with what, when calibrated, what units of measure, what level of accuracy and so on. Ontologies thus enable data fusion processes that result in qualified knowledge presentation. Most importantly, it enables data-enrichment that can make even poor data useful when data fusion techniques are appropriately applied. Although this is one of the longer term objectives of the NyendaWeb development, participants and collaborators on the project during the development phases become part of the process of ontology development that aims towards universally exchangeable transport and traffic data and information.

5. NYENDAWEB OUTCOMES AND IMPLEMENTATION

5.1 Research and development focus

The NyendaWeb project is a cutting-edge development that will take 2 to 3 years to achieve demonstrable functionality with current levels of expertise and capacity. But NyendaWeb is also part of the ITS Lab intended to serve as an international platform for collaborative research and development as well as capacity building in ITS and Traffic Management – of which such skills are in dire shortage. The platform is intended to ultimately provide the means to give exposure to aspiring students (starting at the Grade 10 level) to science, engineering and technology in the fields of transport/traffic engineering, traffic management, electronic engineering and ITS. Undergraduates and graduates are already being recruited to engage in the research and development work to expand the NyendaWeb sensor network or to develop the science and technology aspects of the ITS Lab. Through this, it is believed, the CSIR can make an important contribution to local skills development and the grooming of high level researchers, scientists, engineers and technologists.

5.2 The CSIR ITS Lab Collaboratory

The NyendaWeb infrastructure development commensurate with the delivery of the short term transport and traffic project outcomes will contribute significantly to the achievement of these interim results and to the building of the ITS Lab. NyendaWeb is also a part of a broader Nyenda Programme conceptualised to ultimately deliver a world-class tool to support advanced transport R&D internationally.

The Nyenda Programme of the ITS Lab platform is envisioned to be composed of the following three main areas of development, which are also depicted in Figure1 below:

1. NyendaWeb is the transport data capturing and storage system for real time and post processed data. It discovers transport and other relevant sensors and instructs such sensors on the required data delivery and transport data processing.
2. NyendaView is the demonstrator system with the capability of mapping and visualisation of the NyendaWeb data and could include the linking the NyendaBEe (Nyenda Built Environment Emulator) virtual infrastructure, which is the third pillar below, for demonstration emulations, projections, impacts, emergent behaviours, etc. NyendaView as the visualiser / virtualiser / demonstrator will map transport objects from NyendaBEe and thus providing unique tools to combine near-real time data (e.g. with data fusion techniques) with emulated data for various transport/traffic- and other built environment studies (e.g. intervention and

scenario testing). NyendaView will also link to a GIS that will allow for geographic environmental interaction.

3. NyendaBEe is the emulator which is a powerful built environment virtualisation system utilising the mass data of the NyendaWeb and, based on amongst other swarm theory where many independent agents, emulate built environment objects operating on a virtual built environment infrastructure. The essence of NyendaBEe is that it consists of a generic framework creating the virtual built environment and running on multiple servers with a whole complexity of agents doing the real work on independent networked computers, called a computer farm. This computer farm can be highly distributed allowing near real-time collaboration between various collaborating institutes.

Figure 1 below provides a graphical presentation of Nyenda Programme architecture.

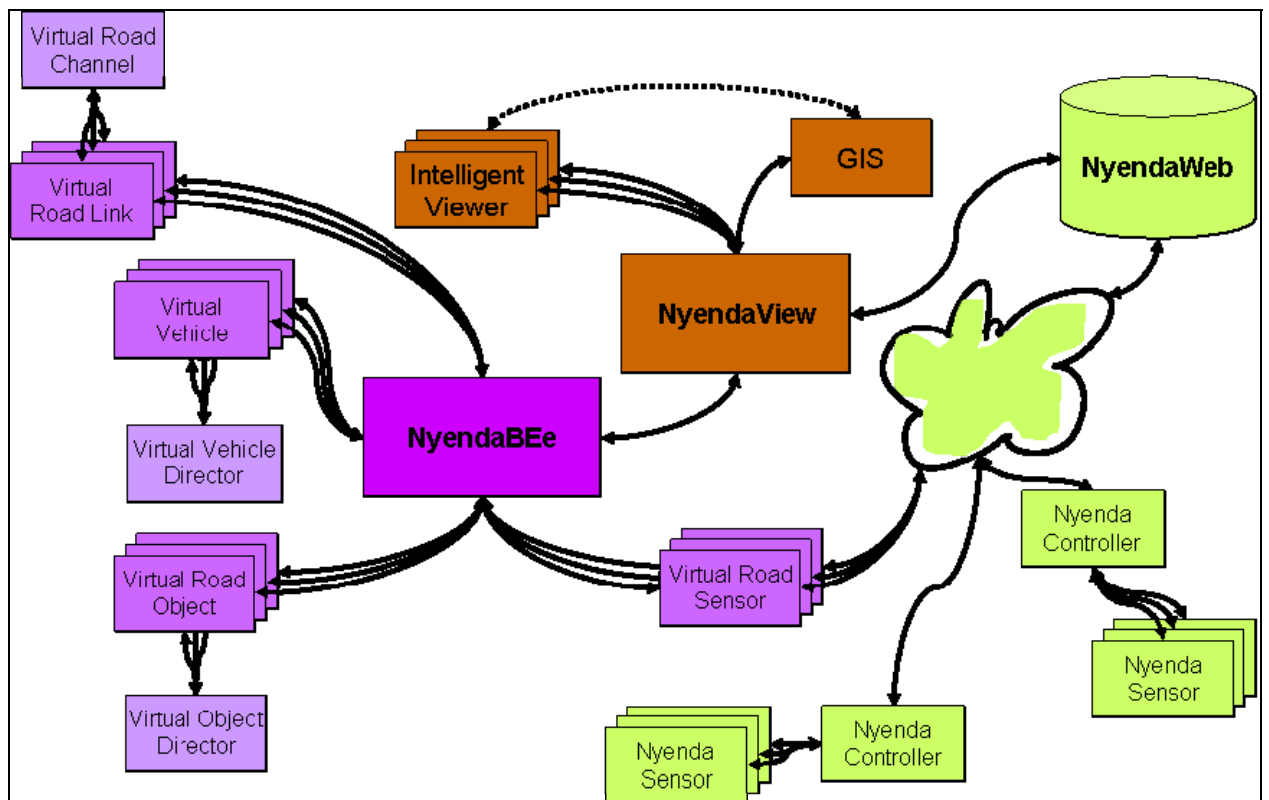


Figure 1 The Nyenda Architecture

5.3 Nyenda developmental methodology

NyendaWeb (www.nyendaweb.co.za) is an open platform that will ultimately allow all owners of transport- and traffic-relevant data, to voluntarily plug-in their sensors and/or databases to create a synergistic environment that will improve the quality of information to all levels of potential users, road authorities, businesses, transport operators, etc. NyendaWeb will also be configured to protect users from unauthorised access to their proprietary information. The following are some of the important aspects of the development approach:

- Sensor networks with a large number of diverse sensors interconnected via a low data-rate communication network have the potential to make a huge impact on many areas. The area of sensing technologies and sensor networks is now considered by international funding agencies such as the European Commission, DARPA and NSF to be one of the top five emerging technologies that will shape the future of human kind.
- The NyendaWeb research network will harness the great strengths of its highly qualified multi-disciplinary participants in a national co-operative effort which will:
 - Provide an urgently needed national focus and identity for research in the rapidly emerging and highly significant area of sensor networks;
 - Provide researchers with strong linkages and exchange opportunities with the major international sensor networks research efforts in the USA and Europe;
 - Link industry with world class research programs covering all the critical facets of the highly multi-disciplinary sensor network science and technology base;
 - Significantly enhance the relevance and quality of postgraduate training in the broad area of sensor networks;
 - Provide a framework for guiding and supporting young researchers in the area of sensor networks;
 - Build a national collaborative framework to grow and support the essential industry/research co-operation needed to fully exploit advances in sensor network science and technology to address major national social challenges in the areas of mobility, health, environment and security. The scientific challenges which must be overcome in order to realise the enormous potential of sensor networks are substantial and multidisciplinary in nature. The NyendaWeb research network will provide an exciting environment for effective collaboration amongst a multi-disciplinary team of world class researchers with outstandingly successful existing research programs covering all the core disciplines required for the successful development and exploitation of sensor networks. These disciplines include bio- and nano-sensor science and manufacture, large scale system optimisation, data and information processing, wireless networks and computer communications, electronics and mechatronics.
 - NyendaWeb participants will be linked with many of the very best overseas researchers in these core disciplines and to the world's best sensor networks research groups. NyendaWeb participants will generate collaborative multi-disciplinary proposals under the ITS Lab® as a centre of excellence, and will facilitate linkage and discovery of funding opportunities and grants in an envisaged major national collaborative effort to solve the key underlying scientific problems facing sensor networks and provide industry with the opportunity to exploit and apply sensor network technology in the socially and commercially important areas of transport, security, health care and the environment. NyendaWeb provides an unprecedented opportunity for CSIR to become a global player of significance in sensor networks by supporting and assisting co-operation and collaboration amongst existing world class research activities in relevant disciplines.

- NyendaWeb strategies are driven by a vision to create the collaborative research foundations which support a world leading sensor networks industry. The NyendaWeb vision will be realised through six strategic priorities:
 1. National collaboration and identity - to build a fertile and effective national collaborative environment for undertaking innovative multi-disciplinary research in sensor networks and to create a strong sensor networks research identity with a focus on the interrelationships of transport, mobility and urban dynamics and deriving value-adding intelligence from the sensing infrastructure.
 2. Industry linkage - to work with international sensor network researchers and relevant industry sectors to explore opportunities for the application of sensor network technology and transport, mobility and urban dynamics intelligence.
 3. International linkages - to create opportunities and an environment for linking sensor network researchers with the premier mobility sensor networks research groups around the world.
 4. Education and capacity building - to actively pursue the expansion of sensor networks related postgraduate student research opportunities in Universities and raise the public awareness of the emerging sensor networks science and explore undergraduate and secondary school educational opportunities.
 5. Sustainable research funding - to build co-operative multi-disciplinary research teams and industry linkages that will generate a future stream of collaborative multidisciplinary research activities including new multi-disciplinary proposals for research funding.
 6. Early practical applications - to pursue early applications of the NyendaWeb platform serving as demonstrators of the sensor web functionality and the NyendaWeb mobility intelligence.

Through these 6 strategic priorities NyendaWeb intends to lay the foundations for a major national collaborative effort to solve the key underlying scientific problems facing sensor networks and provide industry with significant opportunities to exploit and apply sensor network technology in the socially and commercially important areas of mobility, security, health care, the environment and other technological and social issues.

5.4 Current interest

The ITS Lab concept has already mobilise significant local and international support from Tertiary Education Institutes, the ITS industry, road authorities and international research institutions like the TNO and INRETS. Collaboration with the University of Muenster (Germany) and TU Delft (Netherlands) have already been established and will be broadened over the next year of the NyendaWeb Project. The CSIR already supports two PhD studentships in this field – one in collaboration with the University of Pretoria, and the other with the University of Stellenbosch. Both these respective theses are aligned with the ITS Lab objectives and serve to solidify the collaboration of the CSIR with the respective universities.

6. NYENDAWEB DEVELOPMENT PROGRAMME

The NyendaWeb Project is a flagship project of the CSIR meaning that it is to receive support funding, as a defined Department of Science and Technology funding instrument, over a period of 3 years which started on 01 April 2007. The basic components of NyendaWeb, i.e. the Sensor Observation Service database, the Web interface to extract the data from the SOS database and the presentation tool had already been developed to a functional level. The development of the NyendaWeb under the “flagship” banner concentrates on the technological infrastructure to link-up various sensors with the aim to

support current real world applications as soon as possible. It is a pragmatic approach to focus development on the NyendaWeb sensor network where its functionality can be of direct benefit to specific communities on a project-by-project basis.

Currently there are already three such projects that will benefit from the NyendaWeb programme. The NyendaWeb infrastructure will be developed as a continuum over a period of 3 to 5 years and various demonstrators will emphasise the progressive technological development milestones. In parallel research projects are to be defined to support the NyendaWeb technological development but also to research transport issues for which the research methodology can already be supported by the NyendaWeb infrastructure. These research activities will produce the results to assist the NyendaWeb technology development, the expansion of the transport science horizons with the aid of NyendaWeb and then also start producing knowledge to inform contemporary transport operational and management issues and processes.

7. CONCLUSIONS

The NyendaWeb, as a key tool of the ITS Lab, has as objective the development of traffic management systems, including hardware, sensors, software systems and data management systems. The research will focus on sensor networks that provide significant potential to acquire data, link numerous varying transport and other contextual data sources, and to provide broad-based open access for researchers and transport users to such data. As another important objective, NyendaWeb will be configured to sufficiently perform as an extensive monitoring and sensing system that provides timely, comprehensive and continuous real-time data.

The ITS Lab research approach can be summarised in four tenets:

- developing a NyendaWeb as an Open Source platform for connecting transport and related sensors. There is a specific need for the use of efficient data-streaming technologies, real-time data acquisition systems, wireless and mobile communication technologies, data warehousing and advanced data analysis including statistical analysis;
- developing innovative sensors to support the expansion of the NyendaWeb. This research will build capacity in understanding and developing the interface requirements to provide connectivity to a wide spectrum of sensors;
- utilising the real-time empirical data streams of NyendaWeb for research on the improvement of transport infrastructure management and design and operation practices, as well as to provide credible real-time traffic information to transport users.
- promoting human capital development in the ITS and associated engineering and management fields through well structured and institutionalised mentoring and training programmes in collaboration with internationally acclaimed tutors and mentors.