DESIGNING A NOVEL CENTRALISED MONITORING AND CONTROL FACILITY

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ABSTRACT

Privatisation has led to many changes throughout the South African economy. This has led to the development of various new approaches in the different market sectors. Businesses have taken new approaches to optimise their business processes. Part of the optimisation has also been introduced into the telecommunications industry. The local service provider (Telkom) has also privatised the facility management sector of their business.

One of the major problems identified in the new company is that although a facility manager is responsible for ensuring the availability of the customer's premises and environmental resources, there is no method to determine the availability of these resources. A system had to be designed to prevent the downtime of the environmental control systems. Downtime of the systems can cause big losses in revenue to the client.

A building automation infrastructure together with a monitoring and control facility will therefore enable the facility manager to correctly understand the reasons for downtime. The goal of such a monitoring and control facility is (a) to be able to pro-actively become aware of potential system failures and (b) to respond to system failures by correctly identifying the system failure mode.

The purpose of this study is to design a system that will increase environmental system availability through the use of reactive and preventative action. A complete analysis and requirement definition was done to fully understand the need for the system. Furthermore, an in-depth analysis was done to determine the current situation of the availability of environmental systems in the telecommunications industry.

After the initial research work has been done, a system model was defined for the building automation system architecture. This architecture defined all of the major components and strategies, which were implemented in the final system design. The design is able to accommodate buildings that are part of a campus environment, stand-alone or in remote locations. The network architecture was also taken into consideration as it can also influence the control model.

Centralised monitoring, control and service activation was thoroughly investigated, as the option to implement this function in a decentralised way can not be ruled out. The motivational factor for a control centre is to minimise system downtime as much as possible. The control centre was designed with the philosophy in mind to not only monitor remote facilities, but also to remotely control certain functions at these remote facilities.

In designing the system architecture, the following criteria were specified as being important:

- using technology which can be re-used in similar applications in the South African industry,
- sustain the South African technology development and manufacturing industry where possible,
- a comprehensive technology transfer should be done for all technologies and products imported from the international market,
- at the successful completion of the project the value-add and benefit of the system should be determined by implementing the system in more application fields.

The building automation solution based on the Niagara framework was chosen, since it is utilised extensively in the building automation environment. This solution is ideally designed to operate in a distributed or centralised networking environment, which makes it suitable for rollout in national projects. From the results obtained it can be seen that it will be a financially viable solution and it also meets the strict technical requirements. It has the necessary features to enable real-time monitoring of different environmental control systems to minimise downtime.

The features incorporated into the product represent an optimised design, which complies with all the requirements that were set by the client. The evaluation and design process also demonstrated that it is possible to accommodate customisation demanded by processes and interface requirements. It will be able to integrate easily into the business information systems used by the facility management company. With its monitoring and reporting features, it will be easy to evaluate the success of this solution.

Downtime can now be actively monitored and managed in order to ensure the maximum availability of telecommunication equipment. With this successful implementation, it has also been shown that the separation of the monitoring equipment and network can be better optimised for each application. In this case, more information can be obtained by using a design that has been optimised for environmental control systems and is capable of interfacing directly with the controllers. This supervisory software solution has therefore been proven to be capable of successful deployment in this application.

SAMEVATTING

Privatisering het verskeie veranderinge in die Suid-Afrikaanse ekonomie veroorsaak. Dit het tot nuwe benaderings in die onderskeie marksektore gelei. Ondernemings het die geleenthede benut om met nuwe benaderings besigheidsprosesse meer effektief te optimaliseer. Optimalisering is ook in die telekommunikasie industrie bekendgestel. Die plaaslike diensverskaffer het die fasiliteitsbestuurafdeling van hulle besigheid geprivatiseer met die doel om meer effektief te funksioneer.

Een van die grootste probleme wat in die nuwe onderneming geïdentifiseer is, is dat alhoewel `n fasiliteitsbestuurder verantwoordelik is om die beskikbaarheid van die kliënt se perseel en omgewingsbeheerstelsels te verseker, daar geen metode is om die beskikbaarheid van hierdie hulpbronne te bepaal nie. `n Stelsel moet dus ontwikkel word om die werklike status van omgewingsbeheerstelsels te meet en toerusting beskikbaarheid te verhoog. Die staantyd van telekommunikasie toerusting word indirek beïnvloed deur die beskikbaarheid van die omgewingsbeheerstelsels.

`n Automatiese gebou monitering- en beheersfasiliteit, is dus nodig om die fasiliteitsbestuurder in staat te stel om staantyd te verminder. Dit is ook nodig vir die fasilitiersbestuurder om te alle tye bewus te wees van die status van omgewings beheerstelsels in die telekommunikasie geboue. Die doel van die moniterings- en beheerfasiliteit is om (a) in staat te wees om proaktief bewus te word van stelsel foute en (b) om te reageer op sodanige stelsel probleme deur die probleem modus korrek te identifiseer.

Die doel van die studie is om `n stelsel te ontwerp wat die omgewing beheerstels se beskikbaarheid sal verhoog deur pro-aktief en reaktief op te tree. Dit word vereis om `n volledige ondersoek en behoeftebepaling te doen om die omvang van die probleem te verstaan. Verder moet `n in-diepte ondersoek gedoen word om die huidige beskikbaarheid van die omgewingsbeheerstelsels te bepaal.

Na die aanvanklike ondersoek voltooi is, is `n model ontwerp wat die raamwerk van die automatiese monitering- en beheerfasiliteit beskryf het. Al die hoof elemente was alreeds op hierdie stadium geïdentifiseer sodat die monitering van kampus en verafgeleë geboue ingesluit kon word. Die strategië wat gebruik was om die beskikbaarheid van die omgewingsbeheerstelsels te bepaal, moes ook gedefinieer word om te verseker dat die model al die moontlike fasette aanspreek.

Die hoofdoel was om `n gesentraliseerde stelsel in werking te stel, alhoewel die moontlikheid van `n gedesentraliseerde moniterings- en beheerfasiliteit nie uitgesluit was nie. Die hoofmotivering vir

die ontwerp van die moniterings- en beheerfasiliteit is om die omgewingsbeheerstelsels se beskikbaarheid vir telekommunikasie toerusting te verhoog. Die eerste prioriteit van die stelsel is om slegs monitering van die stelsels in die beheersentrum te kan verrig, daarna gaan verdere aandag gegee word om die beheer van die stelsels te kan bewerkstellig.

Die volgende vereistes word gestel aan die stelsel ontwerp en projekbestuur:

- Die ontwerp filosofie wat gestel word vereis dat tegnologie en produkte gebruik word wat elders in die industrie in ander toepassingsvelde aangewend kan word.
- Die produkte moet waar moontlike die Suid-Afrikaanse ontwikkeling van tegnologie en vervaardiging stimuleer deur meer geleenthede daarvoor te produseer.
- Alle kennis wat met die voltooiing van die projek geakumuleer word moet ook weer elders toegepas word, deur te verseker dat buitelandse konsultante nie met kritiese kennis die mark verlaat nie.

`n Moderne stelsel wat gebaseer is op die Niagara-raamwerk is gekies as die middelpunt vir die ontwerp plaasgevind het. Die argitektuur word wêreldwyd in die geboue automatiserings industrie aangewend en beskik oor verkseie unieke eienskappe en kenmerke. Die stelsel is oop vir integrasie met verskeie ander hardeware- and sagteware-verskaffers. Dit is ook moontlik om verskeie gebou automatisering netwerk-argitekture direk met die stelsel te kan koppel. Die stelsel gaan in `n sentrale beheersentrum geïmplementeer word vanwaar dit die nasionale netwerk van telekommunikasie geboue moet bedien.

Die resultate wat behaal is toe die evaluering van die stelsel gedoen is in die ontwerps fase is baie gunstig aangesien dit aan die streng tegniese vereistes voldoen het. Dit is ook verder moontlik om met industrie standaard-intervlakke na besigheids inligtingstelsels te kan integreer en `n nuwe dimensie in die plaaslike mark and fasiliteitsbestuur te bring. Aangesien dit ook verder aan die vereistes voldoen van in-tyds monitering van die verskillende omgewingsbeheerstelsels, sal dit suksesvol geïmplementeer kan word in hierdie toepassing. Die stelsel het dus gelei tot die suksesvolle ontwerp van `n sentrale moniterings- en beheerstelsel vir die omgewingsbeheerstelsels in die telekommunikasie mark.

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LIST OF ABBREVIATIONS

API	Application Programming Interface
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
BACnet	Building Automation and Control Network
BAJA	Building Automation Java Architecture
BAS	Building Automation System
BMS	Building Management System
CRC	Cyclic redundancy check
EAM	Enterprise Asset Management
EIA	Electrical International Association
FM	Facility Management
FMS	Facility Management System
GIS	Geographical Information System
GUI	Graphical User Interface
HVAC	Heating Ventilation and Air-conditioning
I/O	Input / Output
LNS	LonWorks Network Services
MAC	Media Access Control
Mbps	Mega-bit per second
MIS	Management Information System
MMI	Man Machine Interface
MRO	Maintenance Repair Operations
NE	Network element
LAN	Local Area Network
LON	Local Operating Network
OEM	Original Equipment Manufacturer
OPC	OLE for Process Control

LIST OF ABBREVIATIONS (continued)

RFQ	Request for Quotation
RFI	Request for information
RTOS	Real Time Operating System
RTU	Remote telemetric units
SAP	Systems, Applications, and Products in Data Processing
SCADA	Supervisory Control and Data Acquisition
SI	System Integrator
TCP/IP	Transmission Control Protocol / Internet Protocol
TTM	Trouble Ticket Manager
URS	User Requirement Specification
VAR	Value Added Reseller
WAN	Wide Area Network
WON	Wide Operating Network
WWW	World Wide Web

DEFINITIONS

1) **Building Automation System:** The complete facility control system comprises of mechanical system automation, security control, lighting control, automatic temperature, etc., as defined in the contract documents.
2) **B2B:** It is short for business-to-business, used here in the context of e-Commerce to differentiate a company's use of the Internet to transact business with other companies as opposed to use of the Internet to sell directly to individual consumers.
3) **Channel:** Physical media serving a number of nodes
4) **Control Bus:** a relatively simple mechanism for interconnecting nodes, dealing more with the physical (for example, electrical or optical) and low-level attributes on the communication medium.
5) **Control network:** a means of intelligently interconnecting nodes, using both low-level and high-level concepts (for example, network management and addressing)
6) **Dead-band:** a temperature range over which no heating or cooling energy is supplied, such as 45-50°C, i.e. as opposed to single point changeover or overlap.
7) **Distributed control:** A system whereby control processing is decentralised and independent of a central computer.
8) **EDI:** The term is an abbreviation for electronic data interchange and represents an early form of e-Commerce built on essentially proprietary technology. Available long before the Internet achieved wide usage EDI attempted but failed to become a computing standard that would allow non-compatible computers to share information. Today, the Internet and XML are replacing it.
9) **Extended-MRO solution:** describes an application that automates an entire information-gathering or transaction process from one end to the other. In the context of procurement, it means an application that integrates all steps in the process, from machine-driven requisitions (i.e., via process-automation integration) or desktop requisitioning through the corporate firewall to suppliers on the outside.
10) **Front end devices / node:** in a control network an autonomous processing entity usually containing a sensor, actuator, or both, plus a transceiver for communication on a common network and a processor that runs the user application.
11) **Firewall:** A network security device, a corporate firewall is designed to prevent unauthorised people from getting into a corporation's information systems. Inside/outside, internal/external are no longer geographic terms, but a new way to define a corporation in an e-world where bricks and mortar no longer create boundaries.
12) **Gateway:** A device that contains an I/O software driver to translate data from a particular format to that conforming to another standard, i.e. BACnet to LonWorks.

DEFINITIONS (continued)

13) **Intelligent devices:** Control products that incorporate solid state components based around a micro-processor to perform a single dedicated control loop or function (i.e. actuators, sensors, switches)
14) **Intellectual Property:** All inventions (whether patentable or not patentable), all improvements thereto, and all patents, patent applications, and patent disclosures, (b) all trademarks, service marks, trade dress, logos, trade names, and corporate names, together with all translations, adaptations, derivations, and combinations thereof and including all goodwill associated therewith, and all applications, registrations, and renewals in connection therewith, (c) all copyright works, all copyrights, and all applications, registrations, and renewals in connection therewith, and (d) all mask works and all applications, registrations, and renewals in connection therewith
15) **Interoperability:** the ability of products from different manufacturers to work together without modifications or the use of a third-party agent.
16) **LonWorks:** The generic technology that incorporates LonMark compliant products and non-LonMark compliant products that communicate using the LonTalk™ communication protocol.
17) **Man Machine Interface (MMI):** A graphical object oriented method by which an operator is capable of communicating with the BAS. MMI allows the operator to manage, command, monitor and program the system.
18) **Network:** A system of distributed control units that are linked together on a communication bus.
19) **OSI reference model:** the International Standards Organisation's (ISO) Open Systems Interconnect (OSI) architecture a seven layer "reference model" for computer networking. The OSI model is concerned with the interconnection of systems.
20) **Peripheral:** Input and output equipment used to communicate to and from the computer and make hard copies of system outputs and magnetic files.
21) **Sensor:** a "non-intelligent" device capable of converting a physical quantity (such as temperature or light level) into electrical signals. The output of a typical sensor generally needs furthers processing for use in a control system.
22) **Object linking and embedding (OLE):** A technology for transferring and sharing information among applications.

CHAPTER 1: INTRODUCTION

1.1	*Introduction*
1.2	*Background and demarcation*
1.3	*Problem statement*
1.4	*Objectives*
1.5	*Research methodology*

1.1 Introduction

During the past decade the national government has placed a lot of emphasis on privatisation as a vehicle to empower previously disadvantaged communities and people. There are various factors driving privatisation including empowerment, aligning the core competencies of businesses and ultimately – cost savings. Some government funded businesses (or parastatals) have been privatised completely. In other cases only government departments have been affected.

This phenomenon has had a huge impact on South Africa, specifically in terms of competitiveness between service providers and their suppliers. South Africa has been transformed into a country with much more opportunities than before. Government has capitalised by introducing these privatisation initiatives to and hence providing previously disadvantaged individuals with vast opportunities in the telecommunication industry. Various departments and business units in the industry have already been privatised. Privatisation has enabled these businesses to introduce new technologies and other telecommunication developments into the industry with less difficulty.

South Africa follows global market trends in respect to these new technologies and other telecommunication developments currently taking place. This is as a result of increasing competitiveness, more technology available, superior supplier solutions and advanced equipment. South Africa is not a market leader of the technologies used in the new electronic era but tend to follow the best practises set out by developed countries, this is a direct result of the globalisation effect. It is a fact that a lot of technological innovation and manufacturing takes place in the first world countries.

Facility management and building automation are some of these technologies currently being exported internationally. Facility management encompasses various different aspects and tasks, which need to be executed on a day to day basis or intervals of up to one year, to ensure a tenant optimal availability of the premises being occupied. To ensure the smooth running of these activities in an organisation various technologies and solutions is applied to run the operations as effectively and efficiently as possible.

Building automation is one of the many sub-components in a facility management solution. Building automation has developed into a solution driven by technological advanced products and solutions. These intelligent electronic systems sustain an optimal working environment and climate for the people and equipment functioning in an organisation. In South Africa, as in many other countries, the working conditions vary. These conditions include (1) environmental, (2) social, (3) economic and (4) political aspects. All of the above-mentioned aspects have a significant impact on the solutions applied to ensure an optimal working environment for people and equipment.

The goal of the facility manager is to have optimal operating conditions for people and equipment occupying the facility. Managing more than one facility in such a manner can become cumbersome, and therefore delegation is required. Facility managers that excel in their goal have a growing business, and soon need to manage an increasing number of facilities. This results in the establishment of centralised centres to cater for customer complaints, relaying of information, coordination, purchasing of consumables and so forth.

These centralised control centres have become increasingly essential to manage the business in a more cost effective and efficient manner from a centralised and coordinated location. As the various systems in buildings become increasingly intelligent, or electronically controlled, information become available to a greater extent. Not utilising this information in the correct manner is the main reason for downtime of the organisation's facilities. Optimising the time available to occupy facility leads to greater client satisfaction and ultimately, higher revenue generation.

This study will focus primarily on the intelligent systems used in managing facilities and how to extract information in a meaningful manner. This information can then be used to take pro-active actions to ensure maximum equipment availability for the customer. The reason for the focus on equipment availability is as follows: telecommunication equipment is stand-alone revenue generating equipment, and even with minimal downtime in critical sections of the telecommunications network, great losses in terms of revenue and client aversion can occur.

Facilities management of telecommunications infrastructure must satisfy the primary requirements of high reliability and fast response times. Cost effective management of such facilities furthermore requires integration between systems developed for different functional areas, as well as ease of use. Systems designed should be universal and interoperable allowing it to be re-applied in similar environments. Technologies and products utilised should be compatible for re-use in more than one environment.

Real-time information regarding the status of environmental systems must always be available. These systems include Heating Ventilation and Air-conditioning (HVAC), Electrical Demand and Security. A centralised control room is of vital importance. This control room makes use of a distributed controller, which is networked to distribute information regarding the various conditions of the system. This study will show that real-time monitoring and control of building automation components is of great value to the end-user.

Gone are the days where networking means the physical rewiring of electrical contacts to central patch panels for the sole purpose of monitoring of inputs and outputs. This information is now being relayed by intelligent protocols such as LonWorks, BACnet, or TCP/IP. Information is currently transmitted from one location to another, with the aid of minimal wiring or even radio frequency technologies.

Software solutions are a very important aspect of building automation systems. Data is transmitted over various transmission media to a central location where it is gathered for processing. This data, either raw or processed, is used to monitor and control inputs and outputs at the front-end device. The data can then be stored for further purposes such as data gathering for historical purposes, process optimisation or saving energy. For the purpose of this study these systems will be judged on their performance and the underlying technology, which is programming languages. However, databases will also be addressed as they have a vital impact on the ability of the end-products.

1.2 Background and demarcation

An investigation has been launched to identify the different role players in the building management sector, which could benefit either immediately or in future, from open interoperable systems. After identification, these potential industry partners were screened according to certain criteria, to assess the viability of a project of this nature. A project in the telecommunications industry sector was then identified with the greatest possibility of a feasible return on investment.

The project has been initiated by a joint venture in the industry, aimed at developing the business of managing facilities in the telecommunications industry to a level at which production downtime is minimised. The possible return on investment in terms of intellectual property must not be under estimated. A technology partner with the necessary insight into conveying information from field level to managerial level was needed. The technology partner needed to have thorough knowledge of the telecommunications industry and the building management environment where the technology will be applied.

A crucial motivation for this project has been the fact that the technologies utilised in this project can be deployed in not only one type of application, but in other fields as well. Technologies include advanced software management and control, networking infrastructures, and mobile and remote platforms. The integration of the above with the user requirement will give the user a competitive advantage and enable them to run their business effectively and efficiently. One of the most critical aspects to be addressed in establishing a facilities management support infrastructure is the design of an appropriate system architecture that optimally exploits new technologies without creating risks in terms of system stability.

During the past decade, the South African government has pressurised government departments and organisations to privatise. The main reason for this was to capitalise on the fact that the government owns and obtains foreign investor capital in South Africa. Privatisation also started in the telecommunications market a few years ago. This process influenced the South African fixed-line telecommunications supplier, Telkom. Telkom, as a national organisation, owned and occupied various facilities. An operational business unit within Telkom was responsible for maintaining these facilities.

As managing facilities is not a core component of supplying telecommunications infrastructure to the public, it was decided to outsource this business unit. The outsourcing of this aspect created opportunities to obtain foreign capital and global knowledge regarding managing facilities. The new business, Telecommunications Facility Management Company (TFMC), was constituted in the year 2000.

TFMC is responsible for several thousand facilities and it has therefore become necessary to manage and control the facilities precisely to ensure maximum availability for its client. The scope of responsibility includes (1) obtaining the facility or premises; (2) design, build and construct the facility; and (3) maintain it on a continuous basis.

Some of the greatest operational requirements from the clients are the availability of electrical power and optimum environmental conditions (temperature & humidity) to ensure performance of equipment in normal conditions. A strategic decision by TFMC was that in order to meet the strict criteria being set out in the Service Level Agreement (SLA) between TFMC and its client, insight into the operational conditions of the facilities is necessary.

It was decided to design a building control centre with the focus on giving the business the insight into the current status that the facilities are responsible for. The correct infrastructure is necessary to ensure that it will be able to handle the load of several hundreds, or even thousands of facilities. This infrastructure includes resources such as human resources, computer networks and equipment, information systems, network infrastructure and field devices to gather the information from sensors and actuators.

During the research period various emerging philosophies were being investigated to understand the changes foreseen in the near future in terms of communication technologies (for industrial and commercial use); information systems and solutions; and business processes for the facility management sector. Key disciplines as defined in facility management will be defined and investigated to ensure that the terminology and its criticality are well understood. Various methods of investigation will be utilised, public and internal, research methodologies, to obtain information from various sources.

After carefully studying the constraints of the environment, investigating solutions available in the market and proposed solutions and technologies in the market, a technological viable and performance capable solution has been proposed and implemented. The solution was based on current technologies used in the market, leading the industry sector in terms of building automation systems and software solutions.

It should be noted that the difference between leading-edge technologies is minimal but the cost to the client can be excessive if differentiation and objectivity is not maintained. A solution based on international standards in the building management environment, (which is internationally competitive in the information solutions industry and interoperable in various other market sectors) has been proposed and was implemented to document the results achieved.

1.3 Problem statement

Downtime in the telecommunications industry as a result of environmental factors is critical as in most cases it could have been prevented by precautionary measures. If identification of the problem resulting in the downtime of equipment is possible, it would allow maintenance personnel to repair the specific system fault in the shortest possible time. It would thus be highly beneficial if one could remotely diagnose system faults in order to be able to apply corrective measures accordingly. The ability to control the functions for process control remotely is also critical. It is therefore of vital importance to design, develop and implement a centralised monitoring and control facility for the building automation systems in the telecommunication industry.

The focus of this study will fall on the design aspect of this scenario. The following issues have been identified that need to be addressed by the study:

- The system should be able to react pro-actively on possible failures to ensure maximum system availability.
- The design of the system should have the characteristics to be easily configured and make use of known industry standard technologies.
- The system should be able to accommodate the transfer and storage of real time data to support decision making in emergency situations.
- The design needs to be fully comprehensive to integrate control systems at the facilities that range over several decades. One of the major problems with these control systems is the technology being utilised in the control units and systems.
- The re-use of the installed systems is questionable and need to be addressed.
- The system should support the measurement of data to ensure that the availability of the environmental systems in the buildings increases.

1.4 Objectives

The primary objective of the study is to design a centralised monitoring and control facility for building automation systems in the telecommunications industry. The criteria are strict as the project influences the future role-out of a system on a national basis to an initial requirement of 300 sites, which could escalate to several thousands. It is therefore essential that design errors must be minimised to limit modifications. This facility must be implemented in a centralised manner in order to accommodate the integration with other business systems.

The secondary objective is that the system must be compatible and interoperable in the telecommunications industry. This is due to the requirements set by the beneficiaries who require capitalisation on the investment being made. The cross integration with the telecommunication systems must be limited to allow the ability of easy integration with other potential clients. The functionality of the system must therefore be compatible with the prerequisites of other commercial building management requirements.

1.5 Research methodology

This study aims to ensure a comprehensive understanding of the status quo of the international community with respect to the design of a centralised monitoring and control facility for building automation systems in the telecommunications industry. The study is by nature descriptive and explorative, and contains quantitative elements, as crucial aspects of the study are based on existing research and secondary data on a centralised monitoring and control facility in the telecommunications industry.

The study is divided into several phases. Firstly, an outline of the research methodology was established by creating a problem statement, setting objectives to reach a solution to the problem statement, and outlining the study. Secondly, a literature study was undertaken to determine possible solutions for the problem at hand that have been reached by other experts in the building automation industry. Research was further undertaken in the industry regarding possible solutions products that can be applied and implemented in the current project. The products were then evaluated against certain technology and value criteria in a matrix.

Thirdly, a system strategy was developed. The researched results were evaluated, and together with the procurement and automation strategies a strategy was formulated around the requirements. Lastly, a functional design was done in order to comply with basic principles of systems engineering that are utilised in the study. The functional system design complied with the system strategy that also included technologies, which would be utilised in the project. From this it will be shown that the results obtained in the field trial proves that the system architecture implemented is beneficial. Benefits such as more availability of buildings will thus be realised.

1.6 Outline of the study

Throughout the study the reader will be guided through the steps of developing a monitoring and control facility for the telecommunications industry. Chapter 1 sets out the overview of the study.

Chapter 2 contains the literature research. Various aspects will be discussed, including building automation systems, automation software solutions, fieldbus technologies, fieldbus controllers in applications and the need for further work and author's contribution.

Chapter 3 encompasses the design strategy. This is done by firstly evaluating the business and how the project was planned and foreseen to be executed in accordance with the project schedule. The sourcing strategy and various elements of sourcing are then defined to establish the baseline for the procurement of the system. Following the sourcing strategy the criteria for evaluation of supplier proposal were set. Different aspects that need to be adhered to in the proposals and also how the decision making process will be managed to be as objective as possible.

Chapter 4 consists of all the detail elements of the system design. For a baseline the system requirements is first defined, which includes items that were previously overseen. The architecture specification then follows together with the fieldbus network and device specifications. To complete the design the operational required procedures and information flow are outlined which must be implemented in the system implementation.

Chapter 5 reviews the results obtained from the enquiry that was made available to the industry. It shows the different scenarios that are available from the industry and also where possible pitfalls are in proposals. The proposals are evaluated against the criteria detailed in Chapter 3 and the results are also reviewed. To summarise the successful architecture is reviewed against the criteria set in Chapter 3 and 4.

Chapter 6 concludes the results obtained and brings the complete process from the requirements phase through the designing and procurement phases into perspective. It furthermore states the final conclusion that have been obtained from the process that have been followed in the designing of a monitoring and control facility for the telecommunications industry.

CHAPTER 2: LITERATURE SURVEY

2.1	*Overview of the current information* system
2.2	*Building Automation*
2.3	*Automation software solutions*
2.4	*Fieldbus technologies*
2.5	*Fieldbus controllers in applications*
2.6	*Need for further work and author's contribution*

2.1 Overview of the current information system

The literature survey should address the following components:

- the background to the situation which has led to the identification of a problem,
- the problem statement that can be broken down into more than one problem for clarification,
- the student must show with confidence that he or she understands the research methodology that must be followed,
- the impact of the problem on the beneficiaries must clearly be outlined which is the motivation for investing in the study.

As explained by Mclennan [8] the stages to obtain a physical resource for a business, institution or government body is:

- The financial stage, which involves both the identification and definition of the problem, will be solved through building a physical resource by one or more of the company's operating groups. An important part of the project is the criteria set out in the business case. The project requirements are then set out by a series of briefing documents that are produced for external use. These are business brief, operational brief, and a design brief.
- The design stage, which involves a team of building professionals, as well as product suppliers, who develop the design brief into a set of contract documents – plans and specification – which detail the specification and arrangement of materials.
- The building stage, which involves the construction of the physical object – building, streetscape or motorway. The built object is then used in the "operate" stage.
- Finally, the operational stage that is concerned with the long-term occupation or use of the physical resource. This stage is the domain of facility management professionals.

Figure 1 gives a schematic process overview of how a resource for a business can be obtained. It gives the basic principles or stages that need to be addressed even in the simplest resource acquiring projects. Although this is a very simplified model, several organisations still use it, as it is very easy to manage.

Figure 1 Stages to obtain a physical resource for a business

Facility Management is a very important part of every organisations business in the new millennium. Employee's requirements from their employers have grown tremendously in the past three decades. To cater for al the different needs of employers corporate institutions have a facility management department to ensure that the buildings are always in an operational condition.

The role of building automation systems is to automate and control systems in buildings that form part of the environmental control systems. Therefore, building automation today implies a computerised system that oversees and controls building component operations and also systems such as energy and life safety systems. In concept it is possible to integrate all the systems, into one big inter-linked control system but practise has shown that the operational control still tend to very separated. One of the reasons therefore is that when a project is specified and various tenders are received the ability to integrate has only in the past few years become an important criterion.

Facility management has a large and key role to play in a national telecommunications operator environment. A facility management company can therefore offer various services to the operator that is cost saving. The facility manager can offer services to a client that entails consulting, facility management (including maintenance), space planning, telecommunications services infrastructure audits, quality management, property services and project and programme management.

One of the critical aspects is however the ability to ensure environmental system availability for the telecommunication equipment to have an environment that is suitable for safe, durable and continuous operation. With a proper maintenance schedule online monitoring of facilities is still required to be able to react to breakdowns promptly.

2.1.1 Operational overview

In the local telecommunications market the problem has been identified of not knowing the current status of the environmental systems. It is important to understand the status of the systems as this has an impact on the safe continuos operation of the telecommunication equipment. To solve the problem, a initial system audit must be done to determine the current status and then a system must be activated to monitor the status of the equipment on a continuo basis.

To determine the status as a baseline an audit must be done by physically determine the status of the equipment. A mechanical and electrical audit must be done and also an operational performance check. Unfortunately the first two components requires the presence of the correct trained personnel, but the operational checks can be automated. It can be automated in such a manner that it can be monitored from a remote location.

Due to the fact that the install base of telecommunication equipment in South Africa exceeds twenty thousand it is preferential that some elements must be automated. These audits also need to be done on a regularly identified interval to ensure that system availability is maximised. Although maintenance is done on regular intervals the record keeping of installed equipment must still be done to ensure that the business information system is kept updated.

To partially address the problem the telecommunications operator is making use of a solution initially specified and developed to monitor telecommunications equipment and power supply equipment for monitoring the environmental control systems. It has proven to be a adequate solution for the telecommunication network equipment monitoring and fault management.

One of the big challenges of such a system is the ability to do a root-cause analysis of a failure. For example, with the failure of a network service, the services may be interrupted to several pieces of equipment. Due to the operational impact of this failure it may seem that every piece of equipment in the affected region's network has failed. The system must therefore have advanced filtering capabilities to correctly identify to origin of a fault.

The Telkom telecommunication network is operated, monitored and serviced from a single premise that is known as the National Network Operations Centre (NNOC). This site is responsible for national fault monitoring, analysis and service or work activation. The telecommunication infrastructure has been designed to be managed and monitored either from the national control centre or from nearby remote sites. This centre is only the operational centre headquarters.

For the network service provider reliability and Quality of Service (QoS) are dominant factors for continual business. In the telecommunications environment it is practise to deploy a network analyser. Some of the several advantages of a network management analyser (NMA) in the telecommunications environment are [22]:

- Proactively enhancement of service quality and customer satisfaction, by anticipation of service disruptions and resolving of network issues before impacting on customers.
- Protection against revenue loss from unacceptable long outages. In disaster situations the powerful alarm analysis engine processes alarms, alerts and messages and then generates a single intuitive trouble report that identifies the root cause of the network event.
- Assistance with the launch of new services to the market due to the system flexibility and support for multiple vendors.
- Avoidance of duplicate costs and efforts where multiple operations centres can be consolidated into one or two strategic centres with multiple users.
- Minimising of training time and the need for specialised expertise due to the generic approach in the network element interaction and web-based release training and various online help systems.

The Telcordia™ NMA®[22] system used provides a total integrated view of the network across switch, transmission, and signalling equipment. The equipment that form part of the telecommunication network is referred to as Network Elements (NE's). The equipment must however be deployed on a fault tolerant platform to ensure maximum resistance to faults. It must also provide real time event correlation capabilities to determine a "root cause" fault analysis.

The NMA systems utilised uses a single, powerful alarm analysis engine to process and analyse alarms, alerts and messages from all aspects of the network, generating a single, intuitive trouble report. A trouble report or a fault analysis report is being used to generate work orders in the system. Work orders are given priorities depending on the criticality of the fault. Depending on the fault level personnel at the central operations centre can resolve the problem, or field service technicians need to be deployed to action the work order.

The NMA system functionality can be described as having the following characteristics:

- The network element communication rules and scripts defined by the system analysts;
- The Graphical User Interface (GUI) maps and icons used in animations;
- Event correlation rules which serves as filters for system faults; and
- Fault report destinations to ensure that the routing is correct.

This system also has the ability to create fault reports internally that can also be prioritised depending on the level of severity. This provides the following capabilities:

- a complete fault management solution for display and control of network troubles,
- NMA internal system trouble reports will be sent for potential dispatch, that can be done automatic or as manually-directed trouble reports,
- Enhanced client customisation capabilities, and
- Trouble Ticket prioritisation and destination routing.

The NMA system is able to integrate with a wide range of vendor interfaces. There are essentially four different types of interfaces where ASCII, SNMP and VT100 are the most commonly used. These interfaces provide full surveillance and fault management capabilities for all network sub-domains. Part of the networking infrastructure also allows for remote telemetric units (RTU).

The following equipment are being monitored via the NMA communication infrastructure and remote telemetric units:

- all relevant telecommunications equipment (detail not to be discussed), and
- environmental control systems, such as 48 Volt Direct current (DC) rectifier equipment for the telecommunications equipment; standby power plant equipment; incoming mains failure to all equipment on site and the main site supply; UPS equipment; cooling plant equipment; intruder detection to the site and perimeter control; fire and smoke detection on the site.

All of the above monitoring points form part of the critical alarm list from the telecommunications provider. The facility manager has the freedom to determine the points to be monitored remotely. It is however to responsibility of the facility manager to select the points as accurately as possible to minimise monitoring costs but obtain as much operational information from the system as possible.

2.1.2 Information system overview

With the enhanced hardware monitoring installed throughout the network it is possible to easily fault find system alarms and faults. The Trouble Ticket Manager (TTM) provides a highly configurable and versatile service assurance controller for the network operator. This includes the opening, routing, analysing, tracking, reporting status and closing of trouble reports. The TTM gives the enhanced customer service by:

- improving overall trouble report tracking and co-ordination,
- improving routing of troubles and internal communications,
- improving time required and accuracy of solution determination, and
- helping to reduce trouble report rate and average trouble duration

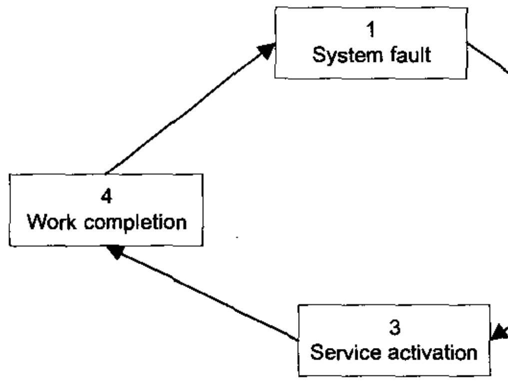

Figure 2 Simplified diagram of service activation

The NMA and TTM both have separate Oracle 8i databases running on Unix main frames to give the applications the necessary computing resources. Data from the databases regarding the trouble tickets are then accessible via a Web-interface for viewing from workstations on the network. This Web-interface, Web-force, enables control room personnel, administrators and network engineers, to active monitor the status of an outstanding fault.

The Trouble Ticket Manager (TTM) Task Management and Fault Management capabilities can include trouble tracking and control for customer and network trouble reports. Task prioritisation and routing may include the following rules-based sequencing control:

- customer modifiable rules as stored in a database,
- automatic generation of databases fields and entries for creation of work lists and job activation,
- automatic entries in the customer care ticket manager for liaison with the client,
- a automated workflow recommendations process,
- history files and event logs for each fault logged,
- automatic fault correlation feature available for common facilities and equipment,
- automatic fault correlation between customer and communication network reports which will reduce the unnecessary despatching with the consolidation of fault reports,
- interface to the NMA system,
- build in ability to accomplish system tests, and
- interface with the internal work force management to despatch technicians.

Operators constantly monitor the system for the creation of new work orders and monitor work orders that are in progress. A work order can only be closed if a full system test can be completed. A work order can only be closed in the case that the system no longer reports an error, as this is the final check in the system. It is also possible for users to query closed work order, dependent on certain input parameters to estimate if problems are repetitive or not.

Access to the system is gained via a web-browser interface and also requires a valid username and password for identification on the system. System faults are monitored on a 24 x 7 base as part of the inevitable race to try clear system faults. This continuous operation of monitoring system faults is divided into two main categories, (a) faults related to telecommunications equipment and (b) faults related to the environmental control systems. As can be seen from Figure 2, even in the most simplified manner, an end-to-end task completion must always be done.

Because of the big role of privatisation in South Africa, the management of facilities for the telecommunications network operator has been privatised. It was therefore necessary for the new facility manager to do an internal investigation to determine the need that it has for a monitoring and control infrastructure. In the context described above an infrastructure must be put in place to monitor the environmental control systems. This will enable the facility manager deliver services of a superior level.

From the existing system background the following task elements can be identified as being essential to be addressed:

- A study must be done to identify the various system components that must be addressed, and furthermore to propose technologies and solution for these systems. The study will form part of a Master Plan that will outline important factors for systems and projects to be technological feasible an applied correctly within the next few years.
- Designing of a central monitoring and control facility. The design must allow for the easy integration of the components with the business information systems of the facility manager. This integration of information will allow for the pro-active management of system components and pro-actively identify system failures.
- The procurement of a suitable system to meet the stringent requirements defined.
- The implementation of a pilot site to test the concepts and identify any oversights in the initial design. This design must then be finalised and implemented in the monitoring of the most critical sites.

2.2 Building Automation

2.2.1 Definitions and key concepts

Building Management and automation has a long history, which dates from the first days that buildings and facilities have been available for humans to occupy. Systems that have previously been automated in controlling the environment of buildings include systems such as escalators systems, air-conditioning systems and access control systems, to name just a few.

Although the terminology "Intelligent Buildings" has been around for almost 20 years, there is not really a generally accepted definition for the term. Too show the diversity of the terminology, a few definitions are quoted:

"a building that is fully leased" – Unknown

"an intelligent building combines innovations, technological or not, with skilful management, to maximise return on investment" – Toronto 1985

"an intelligent building is one that provides a productive and cost-effective environment through optimisation of its four basic elements – structure, systems, services and management – and the interrelationships between them. Intelligent buildings help business owners, property managers and occupants to realise their goals in the areas of cost, comfort, convenience, safety, long-term flexibility and marketability." – Intelligent Building Institute

"to improve building investment performance by applying ASTM E1557-96 'Standard Classification of Building Elements and Related Sitework – UNIFORMAT II' This classification enables seamless link of all phases of a building life cycle – from facilities development through facilities management." www.uniformat.com

"intelligent buildings use electronics extensively and are high-technology related. The electronics is part of the following four groups – energy efficiency, life-safety systems, telecommunications systems and workplace automation." – National Academy of Science in Washington, DC. [4]

According to Citect intelligent buildings have furthermore merged into two broader categories [2]:
- *Facilities Management (Energy and life-safety): relating to the physical structure and how it is operated.*
- *Information Systems (Telecommunications and workplace automation) : how information is handled within the building.*

Intelligent Buildings is defined by Jong-Jin Kim [4] as having the following features:
- *Local area networks for communication between the computers and intelligent devices used in the business,*
- *Raised floors for easy access and maintenance of infra-structure support systems,*
- *Horizontal chases and vertical risers to make the building more energy efficient,*
- *Audio-visual systems and intelligent cards for security systems and communication systems.*

Jong-Jin Kim also addresses occupant's amenity, office automation and energy efficiency. He defines energy efficient buildings as having the following guidelines implemented; (a) floor-mounted air supply ducts; (b) floor supply and ceiling return systems; (c) decentralised environmental control systems, and (d) furniture integrated control systems

An Intelligent building has also been described as one *"that utilises computer technology to autonomously govern the building environment so as to optimise user comfort, energy-consumption, safety and monitoring-functions."*[23]

Intelligent buildings make use of building automation systems as the underlying technology that brings intelligence to buildings. The definitions have outlined the amount of integration needed between different building control elements and the building infrastructure systems.

2.2.2 Intelligent building automation

The focus of this study will be primarily on the designing of an integrated monitoring and control facility that makes use of the various building automation systems. The design needs to accommodate for the integration of the facility into the existing business information systems. The design team therefore need to understand the multiple options and configurations that can be accommodated for in the building automation environment.

When designing a building, there are some guidelines that developers and owners should follow to make the most of intelligent buildings, and some of these guidelines are:

- clearly establish the mission / objective of the building,
- demonstrate how the building's intelligence benefits the occupants / tenants, and
- evaluate as part of the application the technologies that need to be part of the building.

When referring to a system as being intelligent in the building automation environment, one concept stands out as the main feature of intelligence:

> *The system must be able to alert the user / supervisor of changes in the state of the system.*

Although this alert can be obtained with crude techniques only specific standards and regulations can prevent making use of the discrete technologies.

An alert is defined as

> *a notification of a change of state that has the possibility to cause an event or situation that may potentially lead to a system stop if the necessary actions are not taken.*

Although there is a trend towards the use of interoperable technologies with the commissioning of systems it is sometimes required to integrate to legacy systems that still have a considerable life-span. It is not possible to replace these legacy systems due to budget constraints or various other reasons. Requirements also necessitate the implementation of a solution that are best fitted for the solution.

The implementation of a "best-of-breed" approach in the selection of support systems furthermore requires the integration between systems based on different technology standards and platforms. It is not always possible to obtain a best-of-breed solution. The role of the project consultant is essential to address subsystem selection and integration issues in an objective way.

The intelligent building domain poses several interesting challenges to the computer science and artificial intelligence environment. The reason for this challenge arise because of (a) the existence of the many different tasks and interactions involved in intelligent buildings goals, (b) a requirement that actions be taken in real-time and (c) because intelligent buildings comprise large numbers of connected and interacting components.

In a typical agent based intelligent building control goals are split into four related functions [23]:

- Economy for energy consumption.
- Emergency for dealing with unexpected situations.
- Safety to ensure the environmental variables remain at safe levels.
- Comfort which are particular preferences relating to an individual occupant.

Enterprises are moving towards integration of sub-systems into building automation systems (BAS) for user efficiency and effective learning and operation of systems. The five most cited reasons for integration of subsystems are [6]:

- Single seat operation: *a unified system can easily accommodate multiple workstations for alternate modes of operation at different times.*
- Single user interface: *an integrated BAS provides a single look and feel that is intuitive and which facilitates quick action in emergencies.*
- Inter process interaction: *it provides the links between the individual subsystems to make things happen without operator intervention.*
- Data sharing: *improves the effectiveness of the centralised maintenance management systems (CMMS).*
- Media sharing: *single structured cabling system is efficient and cost effective.*

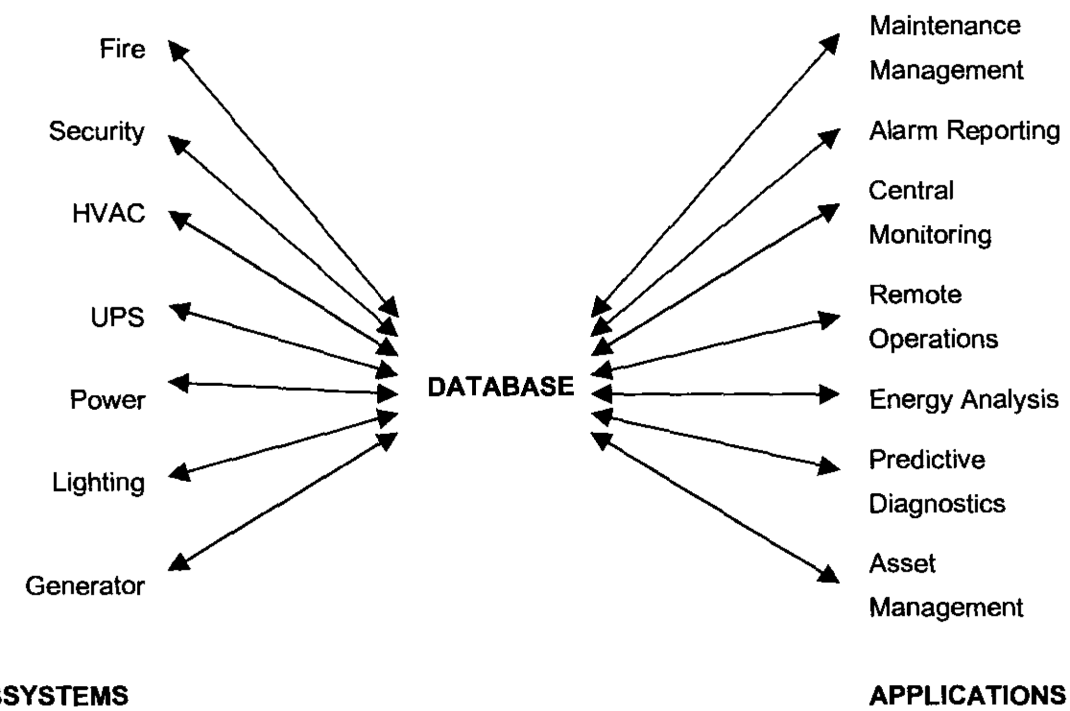

Figure 3 Application diagram derived from building automation systems

From Figure 3 it can be seen that with the different subsystems various applications can be accommodated. All of the information from the subsystems must however be stored in a central database. The database gives the users the ability to do an analysis on the state of systems with the assistance of historical data. Building automation systems have two major components of co-operation namely data and control. Co-operation of systems requires very good integration design and planning from the engineering team.

Intelligent building automation is based upon the availability of information from the control systems to supervisory control system. The data must be available for the control system to automate the processes in such a manner that no human interventions are needed. This requires the availability of information at the decision making centre via a communication network. This network must be able to reliable and in-time transport the data from remote points to the control centre.

In order for buildings to have a safe working environment life safety systems must be installed and operational in buildings. Life safety systems that form part of intelligent buildings are as follows:

- reduced manpower dependency,
- closed circuit television,
- card access control,

- smoke detection,
- intrusion alarms,
- emergency control of elevators, HVAC systems, doors, and
- Uninterruptable power supplies.

2.2.3 Components and advantages of building automation

Automation in the building management environment has followed the same route of evolution as the personal computer industry has followed in the past four decades. With computing systems becoming more affordable it lead to the development of more applications with value-add to the end-user. System automation has proven to be beneficial to businesses and leads to cost savings. Automation also adds value because it makes human resources more available to focus on other problems and areas for development.

Some of the advantages of building automation can be described as follows:

- centralised monitoring of systems to ensure the availability of systems,
- availability of process information for process optimisation,
- ability to share network media infra-structure,
- ability to extract information from remote monitoring points,
- central data storage for system history that will enable users to do a system performance and condition analysis,

In the past there have been a potential opportunity in the market for systems that provides complete integration between building management systems, energy management systems, maintenance management, assets tracking systems, access control and security systems and systems aimed at the high level business aspects of Facility Management. Due to the economic growth and competitiveness in the market suppliers have been forced to supply the industry with integrated systems. The systems must be able to accommodate requirements from the end-user to minimise human intervention, system downtime and ensure optimised control.

Computerised systems as we find it in the market are branded under various names such as [1]:

- Building Automation Systems,
- Energy Management Systems,
- Energy Management and Control Systems,
- Central Control and Monitoring Systems, and
- Facility Management Systems.

The automation industry has internationally experienced an enormous growth. This has led to the development of functionalities that have not previously been part of the solutions offered by the automation industry. Integration via networked control systems together with the integration of the systems with business information systems have added value to the end-user. Several aspects of the feature enhancement have been driven by legislation from industry governing bodies and furthermore to save costs. Due to the big savings that can be realised with the effective management of energy, big development efforts and investments have also been made in this field.

Systems that have conventionally formed part of the automation sector are the following [1]:

- Heating Ventilation and Air-conditioning (HVAC) systems,
- Lighting systems,
- Security (including perimeter) and access control,
- Fire and life safety systems,
- Elevators and escalators,
- Emergency power supplies,
- Uninterruptable power supply systems, and
- Electrical reticulation and power supply systems.

The networking of the important technical building systems are key to the implementation of the demanded scope of safety [5]. Safety can be related to either personal safety, process or asset safety. It is important to define the degree of safety level that the system must be designed for. Control systems must be designed to prioritise personal safety and injury. Because the main requirement of this project is only to implement a monitoring system, the safety aspects are less important than in the case of a control system.

2.2.4 Maintenance Management

Maintenance management furthermore plays a very important role in building management. The automation and integration of maintenance management with the business process have also in the last few years increased in priority. With the integration of maintenance systems with building automation system more value add has been realised to the end-users. Inputs to maintenance systems from building automation systems include information such as:

- equipment failure,
- time of equipment in-use, and
- last maintenance test results.

Outputs that can be generated in an integrated system are automated service orders and maintenance reports. One of the systems that has proven itself as being capable of this level of integration with building automation is Maximo. The product is fully interoperable with supervisory control systems through shared databases and application interfaces. Data stored is an integral part of maintenance management systems. It is being classified as maintenance repair operations (MRO) software for the extended enterprise. It has the ability to manage the full scope of maintenance-related activities and can also be connected to systems outside of the corporate firewall.

Although it sometimes is only referenced to purchasing, it is important to realise that the extended enterprise applies to other aspects of the MRO operation as well. This means that it can either bring information into the organisation or it can assist with conducting business. Both activities have previously been operated manually as part of maintenance operations. The ability of the Internet to facilitate online purchasing transactions (e-Services) and to import information electronically (e-Content) has only recently made the news.

Maximo can also be integrated with to the plant's Supervisory Control and Data Acquisition (SCADA) system. The SCADA gathers information about the plant, such as process temperatures, the amount of material in the plant, and provides the operator interface to monitor and control the entire plant. By downloading the relevant information into Maximo an integrated plant control and planned maintenance system can be achieved.

The links of Maximo to a SCADA system provides plant managers with detailed information on plant functions. For example, when a filter is blocked, the amperage to the upstream pump increases (due to the increased load). By analysing the data captured by the SCADA system and downloading it to Maximo, plant maintenance planners are able to determine the optimum time for maintenance. Companies are therefore able to predict and plan maintenance activities when it is required.

With this insight into the plant regular maintenance inspections can be avoided reducing premature filter replacement and also reactive actions. The same principle can successfully be applied to other applications as well. Maximo is capable of integrating various components and can combine the best-of-breed features with Enterprise Asset Management (EAM) systems, which has the necessary e-Procurement capabilities.

A system like Maximo has several built in tools that can successfully be utilised in a telecommunication environment [30]:

- **Self- service Requisition (SSR):** Easy-to-use interface provides fast, easy searches, real- time availability, on- line creation of requisitions and POs plus on-line order status.

- **Workflow:** Automatically routing of requisitions and approvals based on the company's business rules.
- **Marketplace Adapter:** A single connection for real-time access to an unlimited suppliers and parts. It furthermore has the ability to deliver purchase orders to suppliers in real-time.
- **Intermat Standard Modifier Dictionary (SMD):** Standardise inventory descriptions to find items in your own stores or in on- line catalogues quickly and easily.

It has further benefits to customers to enhance that will enhance the utilisation of resources, such as [30]:

- Providing a best-of-breed EAM functionality,
- Monitoring of the inventory levels prior to purchases are made,
- Ability to connect to international sourcing centre's on the Internet to locate hard to find items,
- Limiting the amount of paperwork to ensure fast placement of orders,
- Reducing maverick and unplanned purchases,
- Providing enterprise-wide procurement which is very important for a national facility manager, and
- Full e-Procurement capabilities with the ability to integrate to a range of handheld devices.

Several of the building automation systems have the capability to integrate into maintenance operations systems. A building automation system in the international and local market namely Metasys has already build-in interfaces to Maximo. An implementation of a Metasys system therefore has the following advantages to a client [5]:

- Running cost-effective buildings which are optimised for energy saving with blinds and light control.
- Maintenance planning and control with computerised maintenance planning and control system (CMMS) for the technical building equipment.
- An interface of the building automation systems through which system data is automatically provided to the CMMS. Data provided include operating times, maintenance and alarm reports to name but a few of the arrays of data that can be shared amongst the two systems.

2.2.5 Energy cost savings

Notwithstanding the fact that customers can be notified of system changes with the control systems cost savings can be realised. Cost savings can be achieved with the activation of any of the following methodologies:

- Energy savings due to process optimisation,
- Process re-engineering and streamlining,

- Pricing re-negotiations with suppliers, and
- Optimisation of maintenance schedules.

Before a user can start with the optimisation of plants for energy savings one must first understand the reliability of energy sources utilised in the plant. Figure 4 shows on a linear scale the reliability that can be expected from various energy sources [9]. Although the topic of energy saving is not part of the scope of this study it is very important to note the impact that energy saving can have on the availability of equipment in a plant.

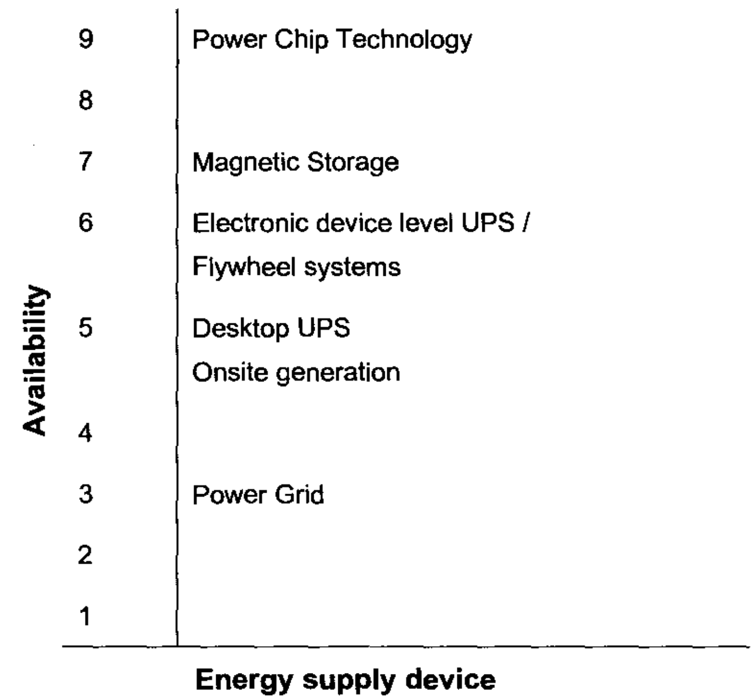

Figure 4 Availability of energy supply devices

Strategies that are used by users to reduce energy consumption of equipment in building automation systems include [7]:

- intelligent programmed start – stop sequences,
- optimal start and stop timing,
- duty cycle optimisation,
- set-point resets,
- electric demand limiting,
- adaptive control,
- chiller optimisation,
- boiler optimisation,
- optimal energy sourcing, and

- usage of environmental energy.

Cost saving can be defined as either an direct saving in terms of money or an indirect saving in longer life-time usage of equipment. Systems can be implemented to enable cost management and to act preventatively. Examples of these systems are (1) power management, (2) remote monitoring, and (3) electric sub metering and (4) plant optimisation. With the various types of process control an initial cost saving can easily be realised.

From analyses that have been done regarding energy usage with buildings occupied by the telecommunications network operators, it has been shown that big cost savings can be materialised. This is due to the fact that energy consumption accounts for at least 20% of the annual operational costs. It can furthermore be estimated that the heating, cooling and lighting in buildings accumulate to approximately 40 % of the energy costs. With the implementation of energy saving solutions, savings can be achieved [1].

The ability to save energy and to quickly reconfigure communications, computer services and workstations are among the most critical issues of contemporary building design and construction. The goals of the intelligent workplace are to develop improvements in four basic areas [8] namely:

- health and well-being of building occupants,
- technological adaptability,
- organisational flexibility, and
- energy and environmental effectiveness

On-site power generation is very important especially in the telecommunications industry and also in the health care industry [6]. Power from the utilities companies is normally approximately 99.9% reliable. However, The specialised industries need approximately 99.9999% availability (30 seconds downtime per year). Companies are willing to pay large premiums to have a high reliability of power availability. This confirms that continuity of services received is a very important aspect.

2.2.6 Monitoring and control facilities

From the discussions it can be seen that it is very important for a facility manager to have the ability of knowing and understanding the status of the systems that is under his control. It is also necessary to have this information available 24 x 7. A monitoring and control facility can assist in addressing this need. Availability of information is important to apprehend the status of the environmental systems in the buildings under the control of the facility manager.

These are all very important aspects that need to be addressed in the RFI in order to comply as a valid document with the limited scope as set out in the above points. The ability of the supplier to stay within the scope of the document will all also be evaluated as part of the supplier evaluation. A very important aspect of the document is to determine the capability of the supplier with the assistance of the of following information:

- A request for a description of facilities.
- A request for information about the targeted infrastructure.
- A request for information about staff and skills that includes education and training.
- A statement about functional capabilities.
- Technological capabilities including growth technologies currently being developed.

The supplier should also be able to show in a suitable manner that he has valid and applicable reference available to add value to the document presented. It should be shown through the ability to provide examples of similar projects that have been completed successfully or are in progress of completion and names of contacts on the projects named above that the procurement team can contact and interview.

With the RFI completed the strategic sourcing team can focus on the RFP which has the following functions and outline:

- To communicate a requirement with the following areas
  - Executive summary
  - Requirements definition
  - Terms and conditions
  - Proposal instructions
  - Evaluation criteria (compliance matrix & contract terms acceptance matrix)
- To solicit responsive proposals

Preparation	Prepare & Release Request for Proposal
	Prepare tailored contract
	Develop Detailed requirements
Alignment	Align top-level objectives
	Define procurement strategy
	Form, Train & charge Procurement team

Table 8 Prepare and release of RFP

With the method as detailed in Table 8 the owner contracts directly for the various work elements (including design) and performs the functions of integrating and controlling that would otherwise be accomplished by a general contractor. When purchase orders and contracts are awarded on a work element basis it is possible for construction to proceed prior to completion of the total design phase.

Table 8 references to the Systematic Technology for procurement (STeP). The conventional method is however the most costly approach to purchase construction as shown in the table. There are specific objectives that should be met when developing a new model with the decision-making strategy and also when making a decision effective and efficiently for global facilities [10].

The objectives are as follows:

- review of previous international business models and identifying their strengths and weaknesses,
- developing of a model that overcomes the weaknesses of previous international business models by combining the concept of strategic management, the management science technique of goal programming, an micro-computer technology to provide a more efficient and effective framework on which to base decisions, and
- applying the model to an example decision involving the selection of a facility site in the international market.

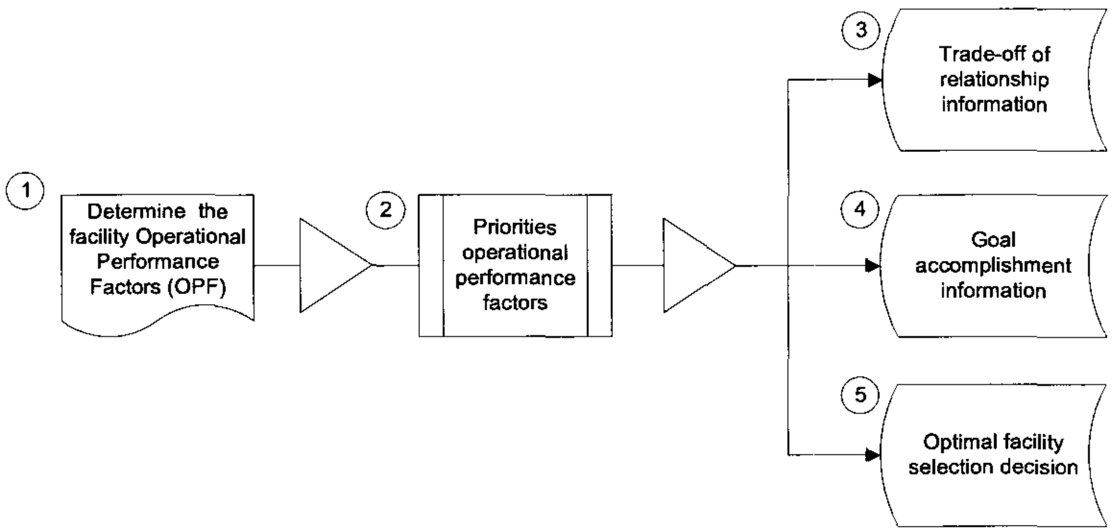

Figure 16 Evaluation of the environment characteristics

With the development of a new monitoring and control facility the above method should be used to evaluate characteristics by which the environment must be evaluated. As Figure 16 indicates it is necessary to first determine the operational performance factors and allocate priorities before the selection of a facility can be finalised.

E-Commerce is a feature that enables the maintenance of your systems with streamlining the maintenance, repair and operations (MRO). The organisation can choose to start slowly with modules that address the most pressing needs and then add features and functionality that are more complementary to the organisation. An immediate implementation of a powerful end-to-end e-Procurement system can also be done to assist in the following tasks:

- automated checking of storerooms,
- access the aggregated supplier catalogues of the MRO,
- link demand planning to purchase for lowest-cost, replenishment and better inventory management, and
- post your RFQ's or RFP's on-line.

With the early implementation cost savings can be achieved by making the organisation more competitive. Although the above advantages can apply more and more to daily activities of supplying systems with consumables the ability to support new systems implemented must also be investigated.

3.3.3 Role of strategic partners

Being involved with a strategic partner is very important because the partner continuously assesses the situation and makes recommendations where needed. As part of the partners for this specific project long term responsibilities for the strategic partner has been set out as follows:

- Detail description of user requirements for different functional areas of Facility Management and support.
- Identification of requirements for short-term systems to remain consistent with the roadmap.
- Identification and evaluation of key technologies of existing systems that can provide the required functionality of Facility Management support.
- Performing economic value added studies regarding functional areas and functionality.
- Identification of opportunities for Intellectual Property development.
- Definition of a total long-term solution for Facility Management support.

South African companies tend to support technologies that have been proven in various installations or applied internationally in the building automation industry. Furthermore consultants and clients support technology that can be supported by more than one local supplier. Reasons why building owners do not prefer to be locked in by one supplier are as follows:

- Companies supplying the relevant services / products in South Africa do not have the local resources, expertise and knowledge of products available.

- The cost of systems from a single supplier that are networked is much higher than sourcing from companies which do not have networkable systems.
- Economic constraints force decision-makers to go for a less expensive and efficient system.
- Geographical separation, cultural and national differences, and variations in business practises all tend to make communication between headquarters and overseas difficult.
- Dealing with the multiple political, economic, legal, social and cultural environments as well as various rates of change within each of them.
- Interactions between the national and foreign environments are complex because of national sovereignty issues and widely differing economic and social conditions.
- Geographical separation, cultural and national differences, and variations in business practises all tend to make communication between headquarters and overseas difficult.
- Analysis of present and future competition may be more difficult to undertake in a number of countries because of difference in industrial structure and business practises.

Performance specification should be written and not a design specification. Contracting for results means not having to tell the supplier how he is to accomplish the job. It is therefore advisable to contract in the services of consultants that specialised in managing this process and writing specifications to manage performance. The consultant will appoint various subcontractors and the system integrators have the responsibility of making everything work according to specification.

System integrators have a very close relationship and technology partnership with the product manufacturer or OEM. System integrators can be involved in various aspects of project contracts. Some of the aspects in which they can be involved are as follows:

- project consultation and project planning,
- drafting of specifications,
- estimation and cost analysis, and
- project management and project implementation.

3.4 System evaluation criteria

Noting that we have all of the above and much more information *available*, which is *correct* and *reliable*, we must now move to the decision making platform. The requirement definition has set out goals in terms of:

- availability,
- response time,
- cost and value of preventative maintenance,

- direct cost of downtime, and
- implied cost in downtime, which results in revenue loss, client dissatisfaction and many other symptoms.

In the next sections the different components that form part requirements will be discussed together with limited requirements for each of the subsystems.

3.4.1 Fieldbusses and automation systems

It is necessary to evaluate the automation systems comprehensively. The criteria used for the evaluation is generalised to accommodate all the different features and configurations available from suppliers. Building automation systems will be evaluated on the following criteria:

- integration with the business information systems,
- ability to integrate via a protocol with intelligent field devices,
- ability to support device interoperability and integration of interoperable devices,
- provision of network management tools,
- ability of supplied hardware to integrate with the business information systems,
- gateways and integrators to support multiple open standards,
- ability support legacy systems,
- it should have the ability to provide real-time internet based control for remote functionality, and
- provides an application server that supports open standards for enterprise connectivity.

As explained earlier fieldbusses are the physical and logical method of connecting controllers. The evaluation of fieldbusses can be done according to the following criteria:

- Practical interoperability between building automation and control systems from multiple vendors.
- Is the fieldbus system based on ANSI and /or a International recognised standard?
- Capability of integration with existing LAN and WAN infrastructures.
- Performance related to the cost and physical size of the units.
- Robust networking that include multiple network media types.
- Unrestricted growth and the ability to add new innovations and new features anytime [17].

3.4.2 Criteria for software interfacing

The supervisory software system should have software drivers to be able to talk to most proprietary controllers. If these are not available then a software driver has to be developed to be able to talk to the controller. To minimise the cost of integration a combination of the three scenarios outlined will be considered. The main consideration will be the cost of integration and the ease of management of the system.

In addition to the main software system communicating to controllers through drivers and gateways consideration will be given to separate supervisory systems monitoring different proprietary controllers and sharing information with software integration methods like OPC interfacing.

Some of the key issues that need to be addressed when designers are busy with the purchasing of a new system are:

- Operating systems that are planned to be used to host the applications.
- Hardware systems required that are needed to host the applications and operating systems.
- Dependency of applications on operating system platforms.
- System requirements that will ensure high performance features (for example multiple user connections, high processing power, support of multiple tasks).
- Customising of the application used and integration with other systems with parameters and scripting tools.
- Need and ability to make adjustments to the product with the availability of source code(not recommended).
- Server-client architecture and ability to run the application over a network architecture.
- Support of networking protocols for distributed applications.
- Licensing schemes and costs associated with the different schemes.
- Ability to support product upgrades that includes aspects such as backward compatibility, regularity of upgrades and support.

3.4.3 Requirements for GIS systems

Operators should have the ability to view the GIS on a normal desktop computer in the control centre. Multiple operators must be able to view different "views" / section of the applications. If more than one operator has access to one "view" the system must support changes being made by both users, and differentiate between times of changes being made. The system must be able to handle multiple views of events simultaneously. Except for the overview of South Africa it must be able to show other views of the country in more detail, for example a province, user defined region, city, town, and suburb. It must make use of thin client-server architecture.

The operator should have the capability to navigate or "drill-down" from an overview (country map) to a property level, from where certain properties can then be selected. The drill down shall cater for level jumps whereby it is not required from the operator to drill down continuously but rather by a single action up to say street level. It should be possible to pass control from this point to another program like a SCADA, which will assist in interrogating the site. Detail information on the screen must be customisable.

3.4.4 Maintenance Management

An unparalleled ability to manage the maintenance process includes streamlining the entire MRO supply chain. A flexible and advanced enterprise asset management solution should be utilised that can easily be tailored to meet specific needs, from integrated safety and compliance features to planning capabilities, to special versions for purchasing personnel, industrial distributors or fleet managers.

The ability to integrate with the maintenance management system is very important and the supervisory system or SCADA-type solution must be capable of supporting data interfaces. The product should be able to exchange data via an ODBC database connection.

When choosing a solution it should be possible to differentiate with following points:

- end-to-end procurement solutions,
- integrate easily with business information systems, and building automation systems,
- have a internet application architecture,
- have the ability to leverage information form historically stored data, and
- demonstrate maintenance and repair operation domain experience.

Although the maintenance management solution is part of the existing architecture that need to be integrated into the critical elements and features must be remembered. It is necessary to understand the level and capabilities that can be achieved with the integration to the maintenance management solution.

3.5 Summary

All of the above information together with other criteria will be put in a matrix to do a comparative evaluation of the suppliers and products available in the market. This value system will help in the decision-making process. The client will have the ability to audit the results being obtained, but will assist in the conclusion of good results. From the evaluation it will be determined which systems will satisfy the user requirements set out, based on the following criteria:

- Which items add value to the system?
- What items in the system can be discarded but still allow system functionality?
- What new system / items need to be implemented?

From a managerial perspective it the following elements are of strategic importance to the successful completion of the project:

- Infrastructure readiness reviews and sign-off's must be conducted prior to start of the enhancement project.
- Business process definitions must be in place prior to the customisation requirements related to the upgraded software. These business process definitions are to be planned and executed by the relevant maintenance and stores personnel.
- Regional champions of excellence, in the business processes and then the Maximo functionality are to be identified and made part of the process.
- User requirement specification to be tabled once the new functionality knowledge transfers have been completed.

When all of the above elements are combined together with the technical criteria detail above and how systems will be evaluated a comprehensive designed system can be achieved.

CHAPTER 4: DETAILED SYSTEM DESIGN

4.1	*Introduction*
4.2	*Definition of system requirements*
4.3	*Systems architecture and specification*
4.4	*Automation software specification*
4.5	*Operational procedures and information flow*

4.1 Introduction

As explained previously, the primary objective of the study is to design a centralised monitoring and control facility for building automation systems in the telecommunications industry. The criteria are strict as they entail the future role-out of a system on a national base to an initial requirement of 300 sites. It is therefore essential that design errors must be minimised to limit modifications. This facility must be designed to accommodate the integration with other business systems.

Downtime in the telecommunications industry due to environmental factors is critical because in most cases it could have been prevented by preventative actions. It should be possible to correctly identify the problem that causes the downtime of equipment. Correct identification of a fault would enable maintenance personnel to repair the system fault in the shortest possible time. It is beneficial to do remote diagnostics of system faults to be able to act accordingly. In designing the centralised monitoring and control facility it is necessary to determine the actions and procedures that need to be followed.

Information must at all levels of the system be available and easily accessible. Management, supervisors and field level technicians should have the correct information available when required. This is one of the goals that are set for the system to be implemented. Information will make it possible to make effective business decisions when a system fault and alarm is received.

In the new digital economy one of the most demanding challenges to business managers is to effectively support the implementation of business strategies by exploiting dynamically changing technologies. This will enable the owner of the newly designed system to apply the concept to telecommunication sites in South Africa and also to apply it to other industry sectors. With the successful design of the system it will enable operators to monitor international sites.

4.2 Definition of system requirements

As part of the systems engineering approach procedures must be followed. The following aspects have been identified that need to be addressed:

- Defining the current situation in an overview.
- Definition of the current integrated monitoring and control systems.
- Definition of required integration between control centre and remote Building automation Systems.
- Definition of required integration needed between control centre information systems and facility management information systems.
- Definition of condition monitoring requirements.
- Definition of requirements for mobile access to IT systems and control centres.

Although some of the above mentioned points have already been addressed detail requirements for system components will now be discussed. A high-level project plan with describes the requirement definition and system design is shown in Table 9. Initial research has been done in Chapter 2 that enables the designer to define all the necessary aspects needed for a requirement definition.

STEP 1	Establish and determine the client requirements.
STEP 2	Technology research to determine the possible solutions available in the market.
STEP 3	Conceptual system design.
STEP 4	Pilot integration of the systems and technologies.
STEP 5	Feasibility study.
STEP 6	Long term roll-out plan.

Table 9 High level activities of the project

4.2.1 Site distribution and requirements

As the goal and aim of this project is to manage the facilities of telecommunications operator the facility managers needs to cater for a wide variety of buildings and sites. The sites will vary from very large to small buildings or structures. It is also necessary to cater both for buildings that will have a high occupancy, as well as those with minimal to no occupants.

Other characteristics of the buildings are the type of equipment that may already be installed. It may vary from high technology equipment to consumer-end products and also low in value. It is therefore necessary to do an audit to determine the type of buildings and the equipment and occupants that utilise the buildings. Figure 17 outlines the distribution of sites throughout the country that need to be monitored [73].

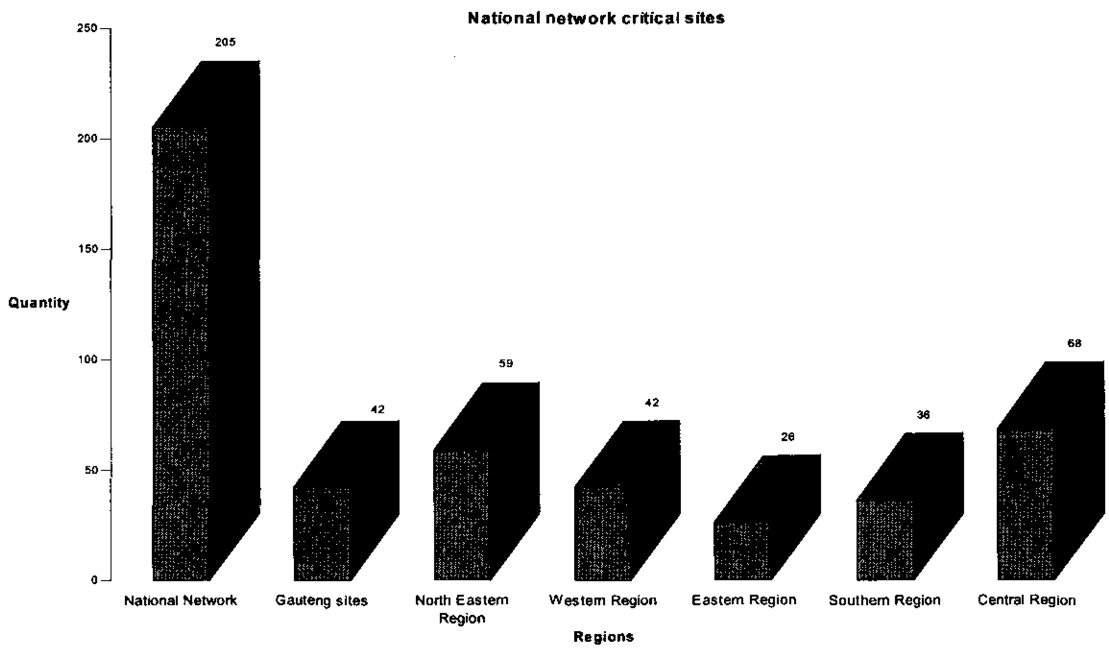

Figure 17 Distribution of critical network sites

Appendix D has more detail regarding each region and the site-type distribution in each region. Sites connected to the national telecommunication network has the highest criticality The sites are not all of the same type, but this will be described in more detail in later.

All buildings have the same equipment infrastructure that can either be telecommunications related or non-telecommunications related. Both of these equipment infrastructures will be managed and controlled from different locations. The telecommunications equipment will not form part of the scope of the study. The environmental control systems do form part of the scope of the work required. In controlling the environmental control systems a certain amount of infrastructure is needed. The infrastructure can be divided into two different sections namely site related and control centre related.

Some of the variables that have to be addressed for each site are as follows:

- cost of equipment that is variable due to no fixed pricing negotations,
- equipment quantities that can vary due to insufficient specifications and incorrect requirement details,
- availability of equipment needed,
- value of equipment to the company,
- redundancy of equipment which includes the availability of equipment in the stores,
- maintenance plan available, including all the necessary activities associated with this,
- life cycle costing of equipment, and
- payback period and return on investment of equipment.

With the above information available, a decision can be made to summarise the state and condition of equipment that are installed on the different sites. An evaluation and audit of this nature has enormous value, to the company at current and for future planning and development.

4.2.2 Centralised monitoring

It is a fact that the different sites will have various types of equipment being controlled by different proprietary controllers and supervisory software. The aim of integrating the equipment is to be able to monitor this equipment on one platform from a single location. This will avoid the need for different computers to monitor the different equipment sets that will are split according to the manufacturer and discipline i.e. standby power, UPS, cooling and fire. One of the advantages of a common system is that it limits the amount of training and knowledge transfer that must be done to operators drastically.

The value add obtained from integration will be balanced against the cost of integration. The following solutions for centralised monitoring will be considered:

- use of SCADA systems with software drivers to talk to PLC and BMS systems,
- use of gateways to a common standardised protocol, and
- exchange of information between different supervisory systems

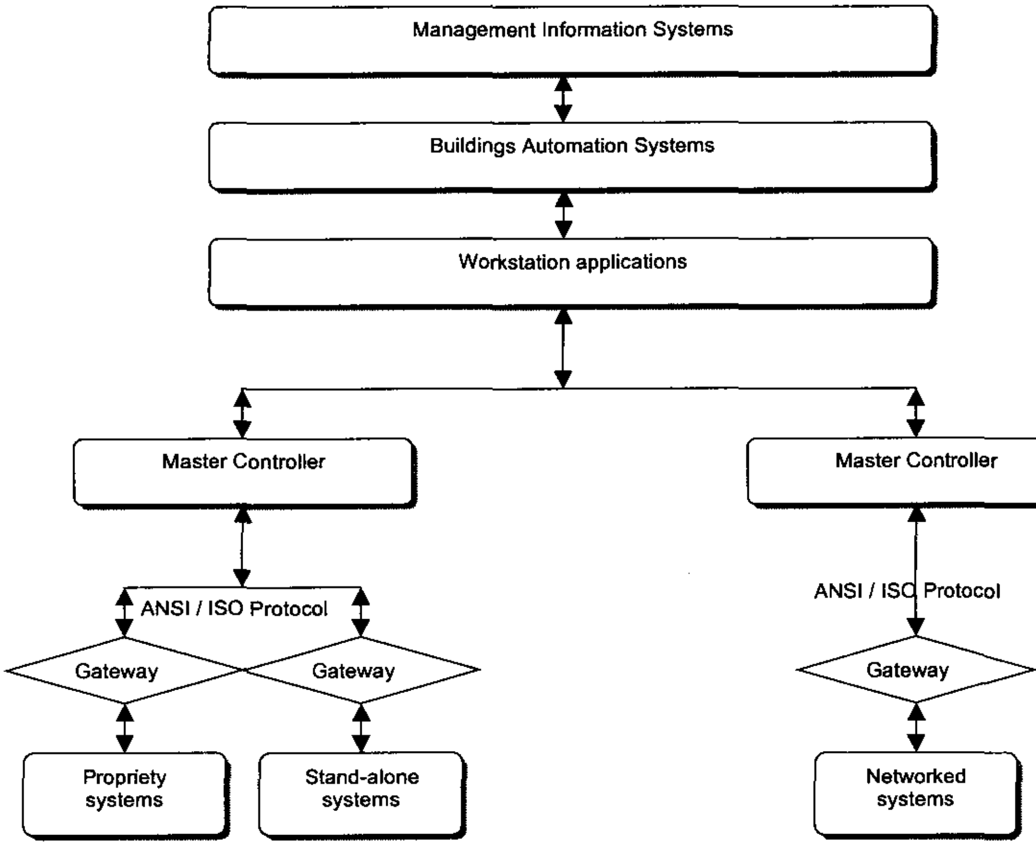

Figure 18 Proposed information flow diagram

Figure 18 shows the hierarchical flow that information will take from the site through the control network to the management information system. The main criteria that the software system tools will be evaluated against are:

- implementation of different protocol drivers,
- ability to support multiple servers and having a distributed network architecture,
- real-time control engine for management and control of network devices,
- integrated network management tool for the building management systems,
- engineering ability from remote sites,
- ability to interface to the Internet for monitoring and control, and
- capability to support the interfacing the databases that allows the storage of large amounts of data and the easy retrieval thereof.

Integrator units, as shown in Figure 19 allow for the connection of two different fieldbus systems and give the controllers or supervisory systems on both ends of the fieldbusses the ability to exchange data. Components are then able to display a full complement of features, including change-of-state (COS) monitoring, alarm notification, scheduling, trending and totality [13]. The amount of information that is shared among the networks is dependant upon the memory size of the gateway / integrator device as well as the processor speed.

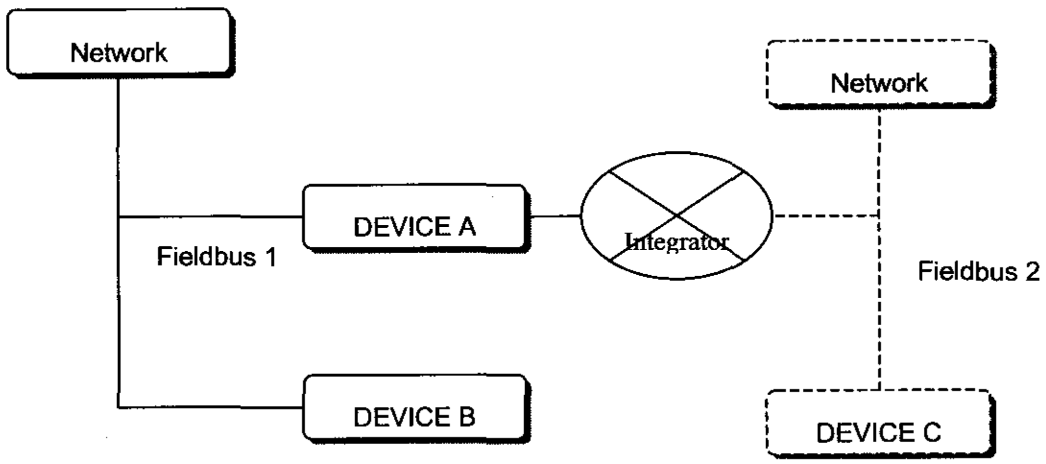

Figure 19 Schematic diagram of networks connected with an integrator

Gateways or integrator units as shown in Figure 19 normally make use of translation tables (for example configuration files) which defines data points that need to be mapped as well as the data types which are being mapped. Gateways can be used to convert data from a proprietary protocol to another protocol that the SCADA software or control network can link to. Some of the aspects that must be considered when evaluating gateways are the following:

- Does it make use of EIA 852 IP Tunnelling Specification compliant for gateway and routers?
- Does the processor support a real-time operating system (RTOS) like the 32-bit ARM 7 TDMI processor?
- Is it an IP Gateway or router that has the capability to do packet monitoring and integrity checking of the control network?
- Is it supporting a point to point or point to multi-point architecture?

4.2.3 Alarming and responsiveness requirements

Due to the fact that an almost similar system exists for the telecommunication equipment, an existing set of alarming requirements exist. Table 10 outlines the different sets of equipment that were initially required to form part of the monitoring set of equipment. The alarm severity level for these alarms will be "prompt" (i.e. highest severity level that must be displayed on the management systems) [32].

Standby plant indicator	
1	Incoming Mains Failure
2	Standby auto mode failure (Any failure on standby unit}
3	Fuel sender 20% (low fuel alarm)
4	Standby running
Rectifier indicators	
5	Input AC fail
6	Output failure/system fault
7	Output voltage low (<47.5V)
8	Module fail
UPS indicators	
9	Incoming Mains Failure
10	Inverter failure
Cooling Indicators	
11	Air plant system pressure failure
12	High temperature
13	Air flow
14	Input AC failure
Security Alarms	
15	System alarm
16	Intruder alarm
Fire alarm	
17	Fire
18	System failure
Solar Systems	
19	Panel removal
20	Regulator fail
Water alarm	
21	Water supply alarm

Table 10 Points monitored in telecommunications sites

The new system alarming requirements must also be defined and expanded to include more equipment sets. The feasibility of the requirement must however be evaluated to determine which are financially viable to be monitored. When the complete system can directly be integrated into the supervisory monitoring system valuable information can be extracted from the site. Bandwidth and the required update rate must also be considered because of the large role-out of the system to many sites.

Monitoring of equipment will be divided into the following categories:

- medium voltage,
- UPS indicators,
- electrical systems,
- emergency power supply,
- rotary indicators,
- energy demand management
- masts and towers,
- antennae,
- cooling indicators,
- cable dehydrators indicators,
- fire detection indicators, and
- technical security indicators.

It is foreseen that more information will be available at the monitoring and control facility. The integration with the different subsystems can be foreseen to be a complicated effort but the benefits will make it viable. System responsiveness is a big criterion for evaluation of products and the design philosophy that must be followed. Responsiveness in the system can be measured whilst several activities are taking place.

The following activities or events must be monitored to ensure performance:

- duration in time that the system takes to report an event,
- duration in time that the system takes to report a failure, if it has higher priority than system events,
- duration in time activate the maintenance response team and availability on site to attend to faults,
- duration in time that it takes to correctly identify the problem, and
- duration in time that it takes to acquire the necessary spares.

4.2.4 Performance requirements

All systems need to be rated according to performance. Performance is a measurable item that can be quantified in terms of units. Two of the most critical measures are reliability and availability of equipment being installed. Most power professionals define "reliability" as a function of the mean time between failures (MTBF). When MTBF is combined with the mean time to repair, we get "availability" [15]. Hence a device that fails once every thousand hours and takes an hour to repair have an availability of about 99.9%.

The operational status of the remote locations being monitored is of high importance. It is therefore necessary to have sufficient systems in-place to manage the monitoring of remote sites. To establish if there is an increase in system availability the current performance must be benchmarked to establish the increase in availability. Productivity is defined as the ratio between OUTPUT and INPUT.

A system analysis will include looking at the expected life cycle with a scientific process or methodology that best describes the problem in terms of related elements. Benchmarking is the continuous process of measuring products, services and practises against the other competitors in terms of:

- planning,
- analysis,
- integration,
- action, and
- maturity.

The building control and monitoring facility will have the capability to function in the more than one mode. A mode is defined as a system state and depends on various activities and inputs. The monitoring and control centre can be in one of the following modes:

- Normal operation: All activities are handled according to standard operating procedures.
- Emergency mode: A disaster has struck the centre or a site being monitored, special procedures need to be followed in the case of such an event.
- Maintenance mode: adjustments or modifications are being made to the system with the goal of either fixing problems that have been identified or to upgrade certain functionality's that already exist in the centre.

4.3 Systems architecture and specification

4.3.1 System overview

This facility model is very much generic and we wish to keep it simple at the beginning. The initial design should be simple but effective in order to limit problems and design errors. In order to accomplish an effective system that enables users to interrogate information regarding the status of devices the design should allow for the availability of the information. Therefore the design for information is an important aspect that must be addressed comprehensively.

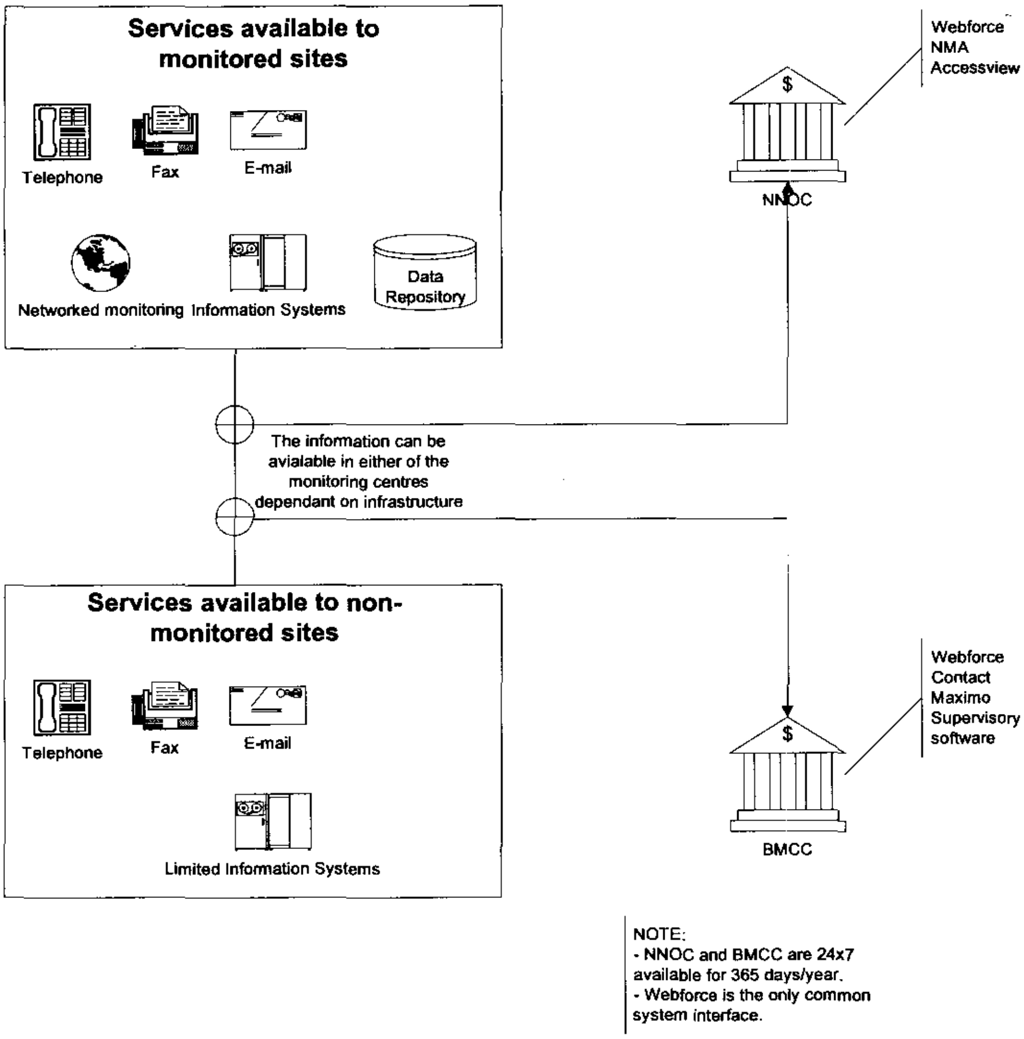

Figure 20 Monitoring centre with support systems

Figure 20 outlines in an overview how the system is foreseen to operate. Two facilities will operate in parallel with one dedicated to telecommunications equipment (not part of this scope) and the other dedicated to the environmental control systems. In both cases there will be instances of sites being monitored and sites not monitored, but as can be seen from the figure some of the services in the control centre are limited to monitored sites.

Figure 21 outlines the flow of information from the respective monitored sites to the control centres. It is very important to note that the data relayed from the sites will have to be audited. The reason for this is to make sure that when an evaluation of the newly designed control centre effectiveness is done, that alarms are registered by both systems. Alarms audited must have measurement points that are common to both systems. Also note the different layers of equipment and software solutions correspond to that of being design for.

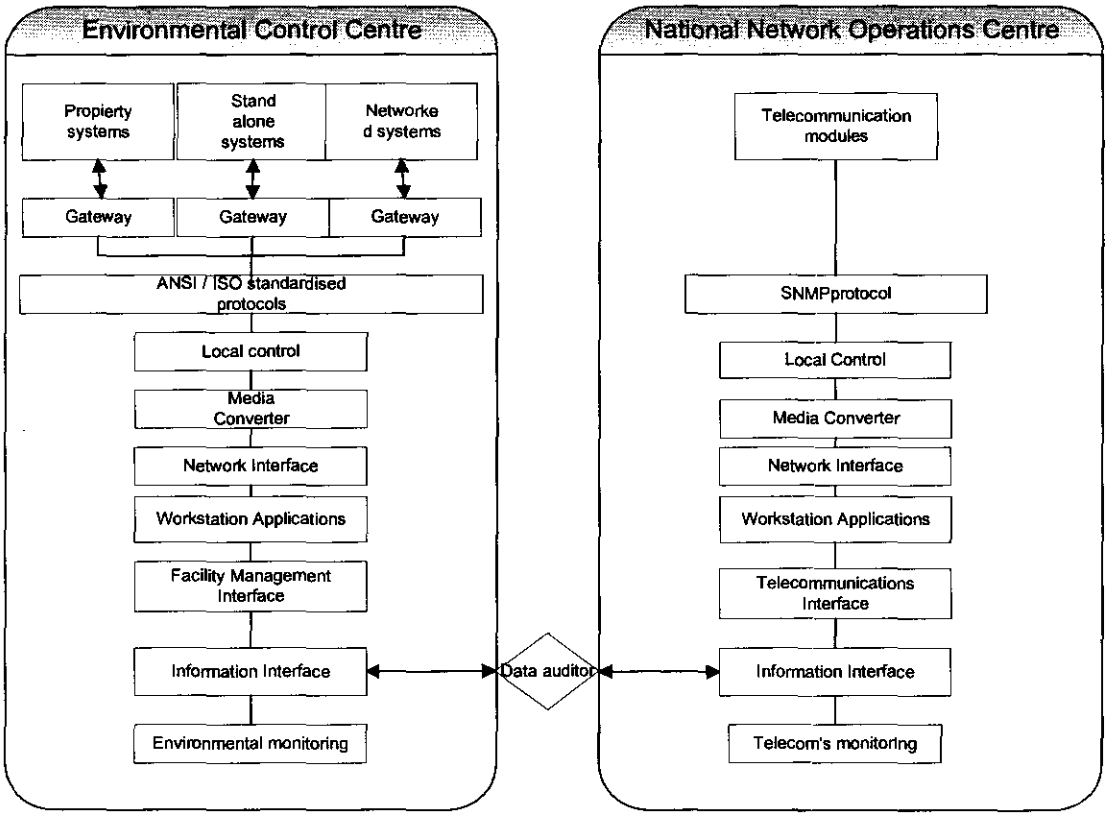

Figure 21 Comparison of data flow for the control centres

4.3.2 Elementary breakdown of sites

Site equipment is very important to ensure that the data gets transported to the necessary end-solution packages as defined in Table 11. It is therefore necessary to understand the type of equipment that will be allowed on site to accomplish this. The most important element to the end-user is when he is utilising the data interpretation and application layer of software. When looking at the network configuration and the important elements then Figure 22 outlines the major components that need to be addressed in the network architecture.

An important aspect of the network implemented is the gateways or integrators used in the network. When utilising a gateway it should comply with the following layers of the OSI network model stack for Ethernet and network applications:

- application layer,
- EIA 852 tunnelling stack,

- IP Services,
- TCP/IP Stack,
- media layer, and
- physical Layer.

Application Program	Business
Data Interpretation	MMI/MES
Remote Actions	IR/EDI
End-to-end reliability	Network Services
Destination addressing	Routing devices
Media access and framing	Field nodes
Pressure sensor	Sensors / Actuators

Table 11 Application interfacing from business to sensor level

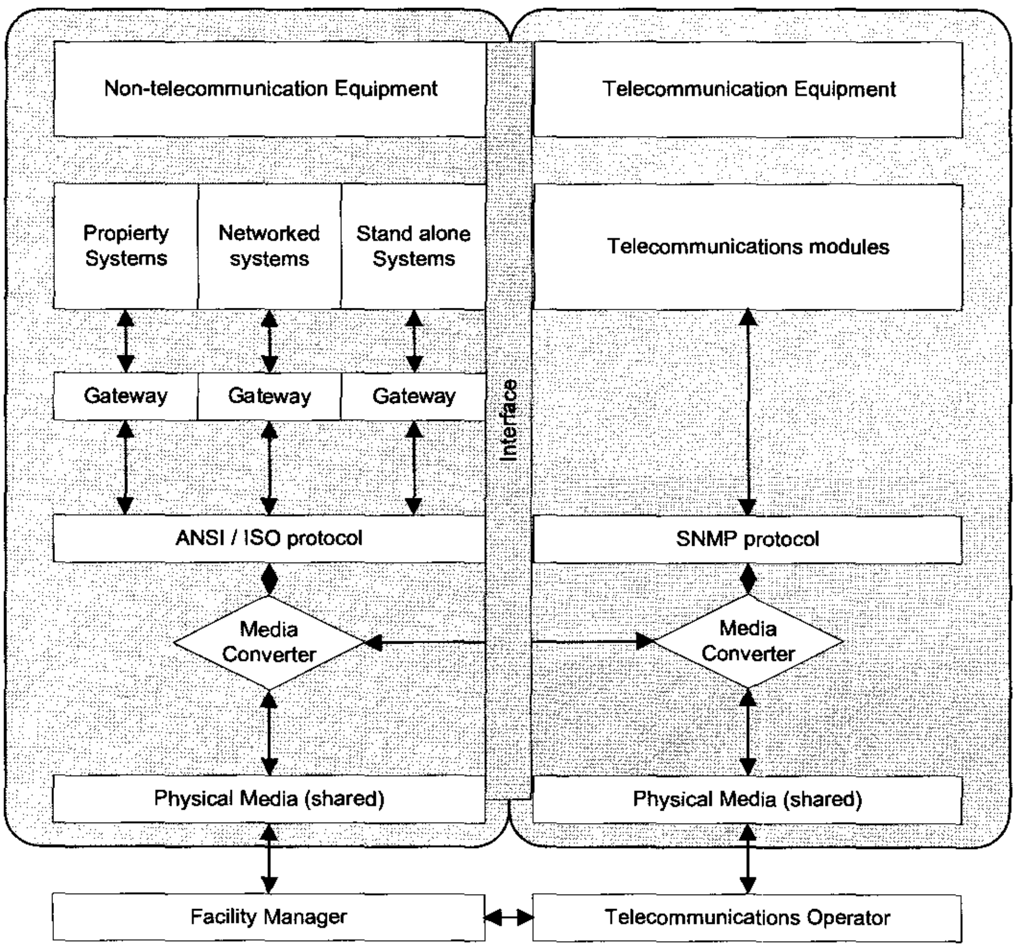

Figure 22 Monitoring infrastructure

Gateways must furthermore be compliant to EIA 852 and ANSI 709.1. The network design and controller selection preference will be given to equipment that is compliant with the LonTalk protocol. This fieldbus has been chosen as the preferred bus system due to the fact that it is one of the preferred bus systems in the European building automation industry.

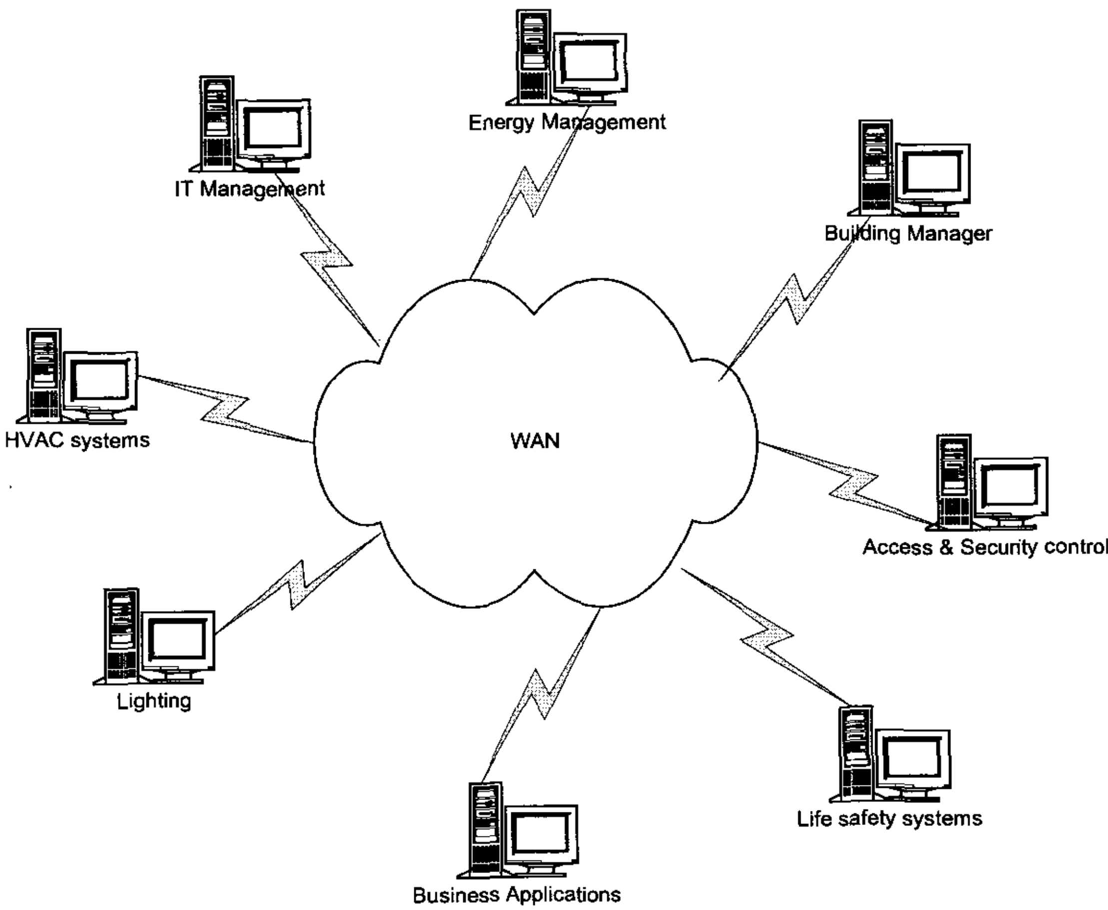

Figure 23 WAN architecture

Major product manufacturers also prefer this bus system as complete solutions are available to suit the requirements set out by the building automation industry. LonWorks is not only limited to this industry, but are also applied widely in the railway and other industry sectors. The fieldbus systems can very easily be integrated into a wide-area network (WAN) architecture as shown in Figure 23. The figure also shows the different components that are part of the environmental management systems and the systems that need to be integrated to for the monitoring and control facility.

4.4 Automation software specification

As part of the solution designed software plays a very important role in enabling operators, technicians and engineers in responding correct to the changes in system conditions. The system must be able to function in an on-line mode with the individual site devices able to function in an off-line mode. Communication failure between the system and the controllers should trigger an alarm. It shall be able to support client server architecture.

4.4.1 Software architecture

The system must be scalable and expandable on hardware without any major modifications. This means that no major changes will be required once the system is expanded beyond the current specified capacity. The system must provide for a multilevel password protection allowing different users different levels of authorisation.

Some of the systems design specifications are as follows:

- It shall have centralised alarm, trend and reporting processing i.e. data shall be available from anywhere in the network.
- It shall be able to support multiple users logged on simultaneously.
- A central database for storing information that are compatible with the ODBC-interface.
- The application shall be web compliant and compatible.
- The system shall support TCP/IP, Net BEUI, IPX/SPX protocols and have PSTN dial-up capabilities.
- It must be compatible with a Microsoft Windows operating system architecture.

Response times for the display of information are critical. It should be possible to perform in the following operating requirements:

- Display of an analogue or digital value acquired from the controller on the operator display – 2 seconds maximum.
- Control request from operator to controller – 1 second for critical and 3 seconds for non critical (Future requirement).
- Acknowledge of alarm on operator screen – 2 second.
- Display of entire new display on operator screen – 2 second.
- Retrieval of historical trend and display on operator screen - 3 seconds.

Figure 24 outlines the route that data will follow logically in software to be displayed in various formats upon the request of system operators. When the data has arrived at the supervisory system, the system configuration must allow any of the other functions to retrieve the data. The database and online cached data are the only sources from where any application or function will be able to retrieve data. Real-time data will also be cached in control room.

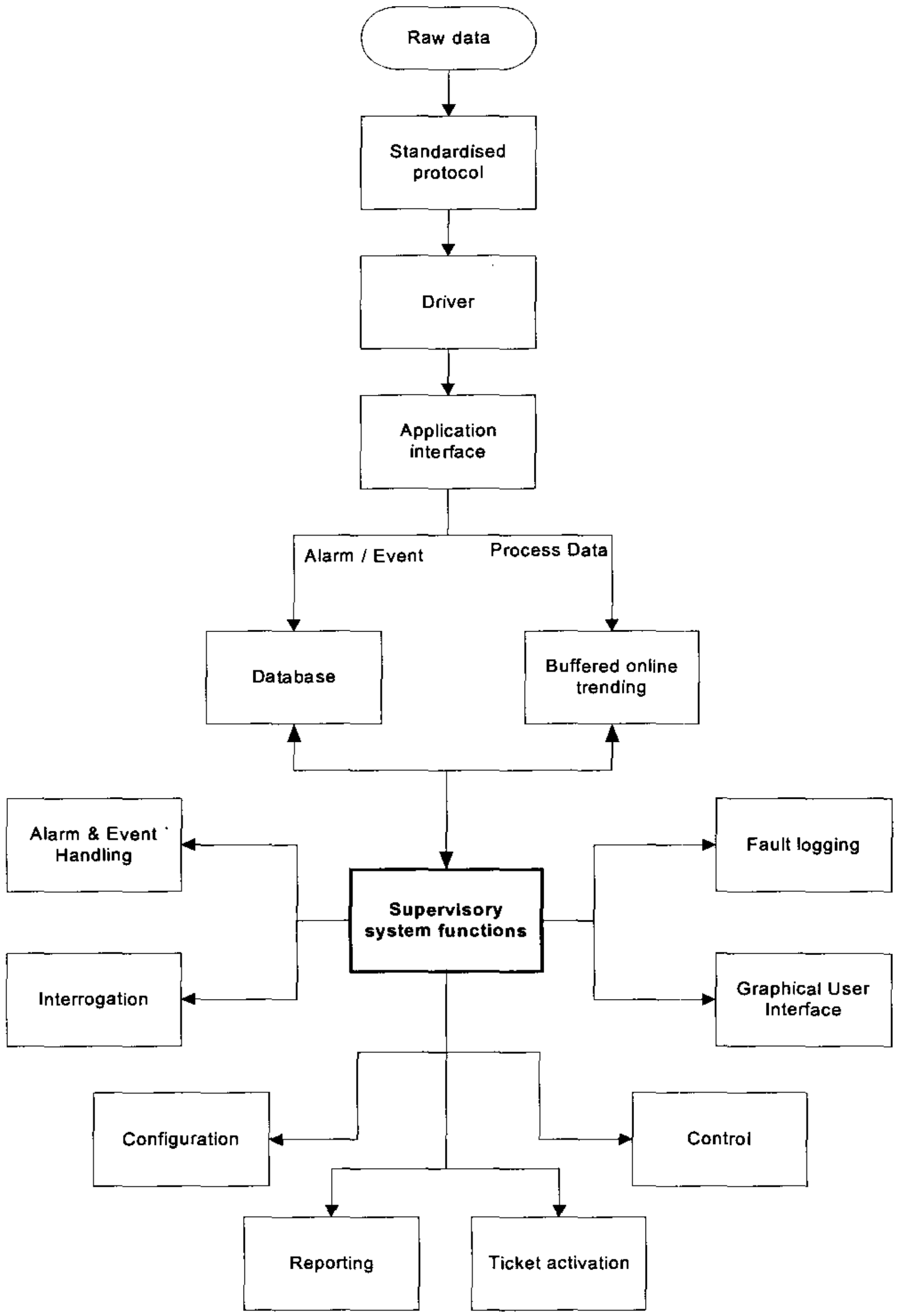

Figure 24 Data system overview

Figure 25 defines in more detail the type of functions that the supervisory software must be capable of fulfilling. It must be able to produce automated reports from the systems for the monitoring of operational actions and change of statuses. Reports must be configurable to be either periodic, event triggered or activated by the operator. Typical reports that can be generated from the system are as follows:

- reports summarising activities or events over a period of time,
- trends over a period of time,
- required maintenance activities, and
- user activities and changes made.

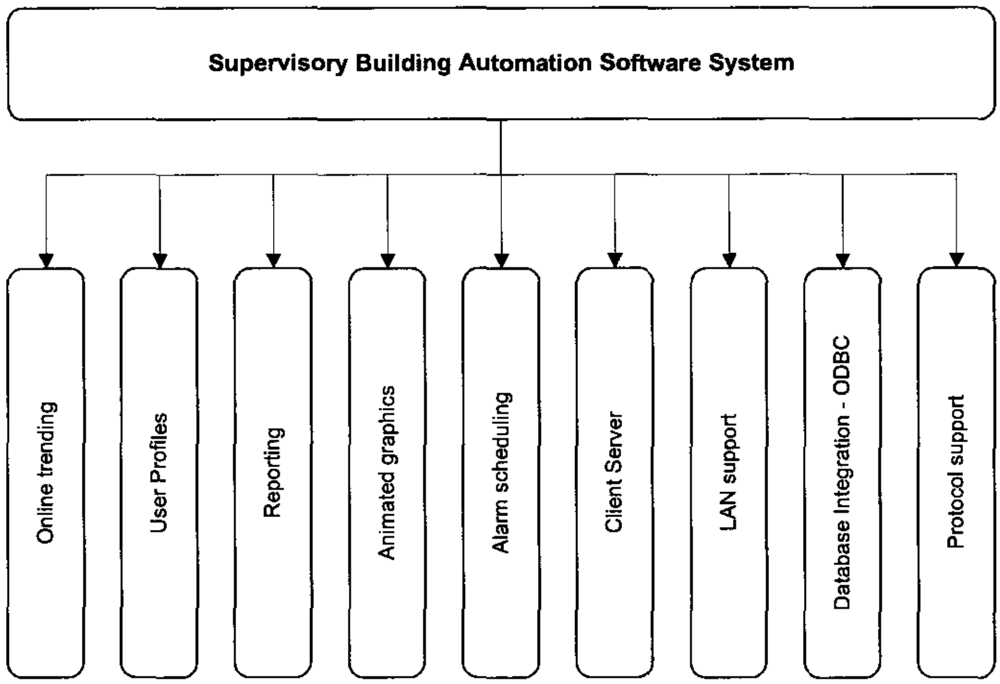

Figure 25 Components in a building automation system

As part of any building automation and supervisory control system, interfacing should be done to various components of the total system. Interfacing to all of the components should be done via industry standard interfaces and protocols. Interfacing to various building controllers is normally done via device drivers. For this application device drivers will not form part of the required interfaces that the automation software should fulfil. The system should be able to get data from devices either direct via its build-in LonWorks or BACnet interface or potentially through an OPC interface.

As outlined in the previous pictures it is evident that a database is crucial to the store of information for later retrieval and also for record keeping purposes. Access to the database for a user through one of the defined data and application interfaces must be real-time. The database must support ODBC-drivers and direct SQL commands and queries. It should be possible to design with the system as outlined in Figure 26.

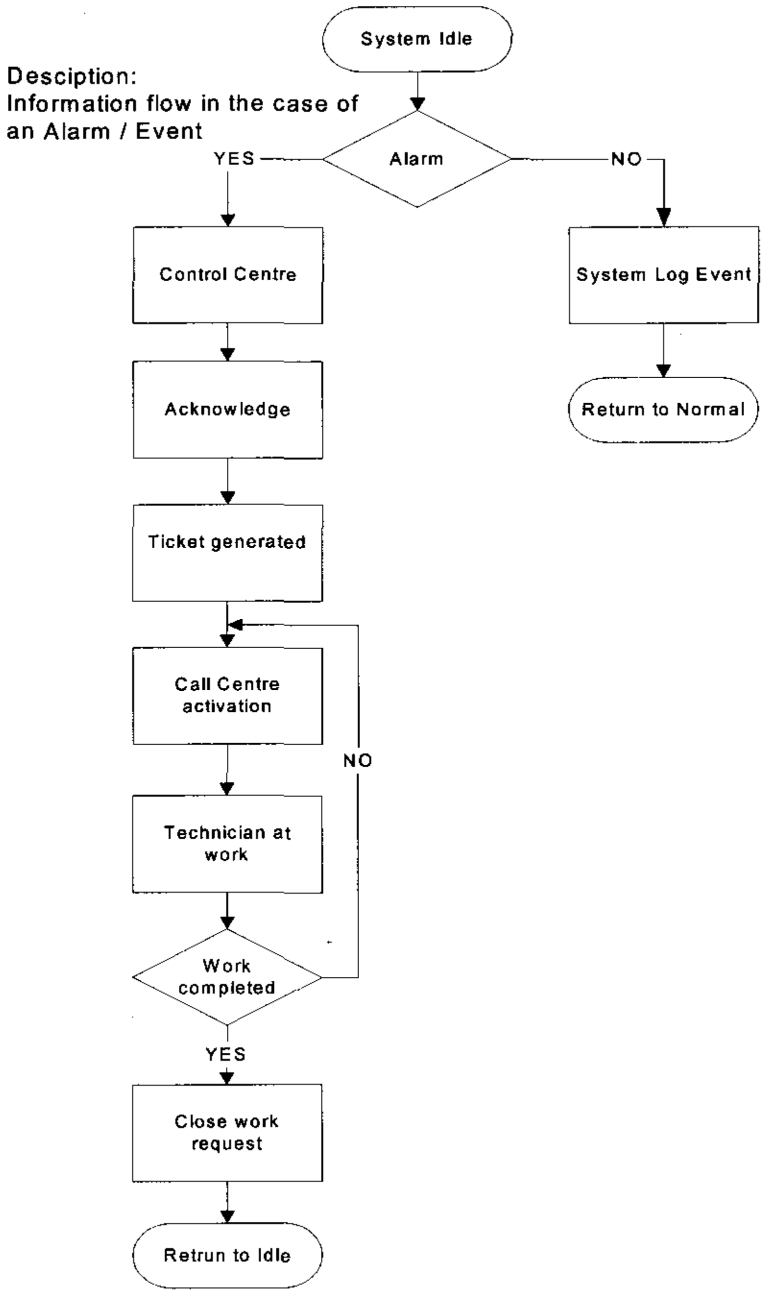

Figure 26 Data flow in event of an alarm

As part of the data architecture and flow of data the database architecture must be designed to store data sufficiently and allow easy retrieval of data. Figure 27 defines the database architecture of the database for the monitoring and control centre – BCC (Building Control Centre). Information regarding the system architecture and actual configuration must be stored in the database.

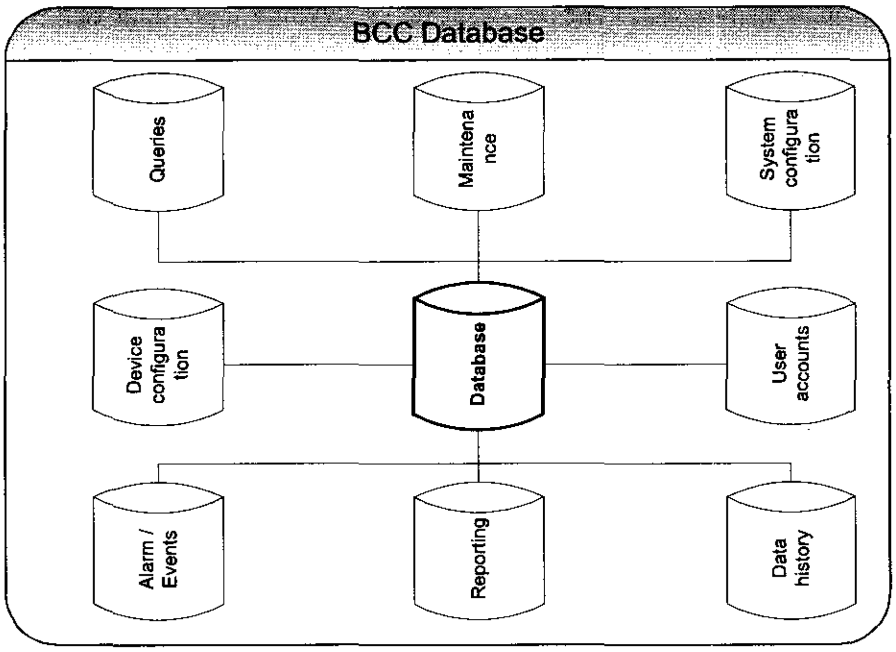

Figure 27 Control centre database

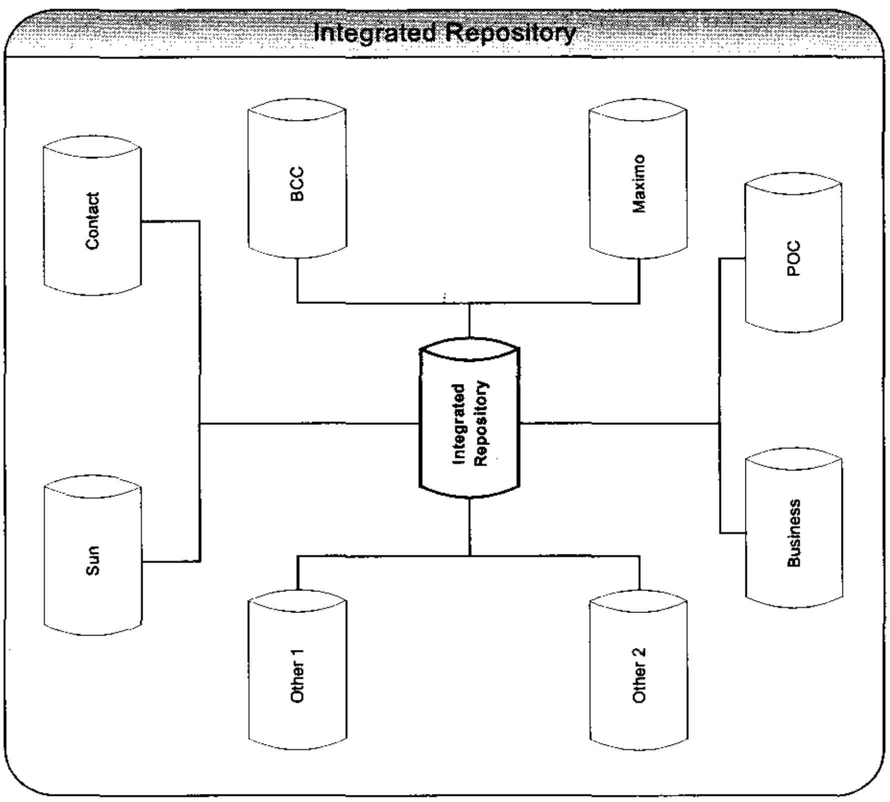

Figure 28 The integrated repository

Real-time information will only be stored before and after system faults have occurred for a limited amount of time after which it will be archived for record keeping purposes. It is necessary to store data pertaining to the configuration of devices and operating parameters. The figure shows component data that need to be stored and not the actual database design.

Figure 28 shows how the database will form part of an integrated repository or a database farm. The integrated repository allows systems that can connect to the repository to retrieve data that is common to more than one system. All other databases that are part of this integrated repository will allow users and applications to query data. One of the most important aspects of architecture is that very limited duplication of data occurs in the business. Whenever two applications need information that is common for their query it can be drawn from the integrated repository.

4.4.2 Display and alarming

The visual aid of the supervisory monitoring and control software is a very important aspect of the tools in the monitoring and control centre. Information must be displayed in a format that allows for the easy access pertaining to event changes and alarm notifications. The graphics display must be of a design that allows a end-user with sufficient training to customise and make modifications as required. It should be possible to configure page navigation and menu structures to easily do fault finding or status reporting on the application.

To enable the system operators sufficient control over the network devices, it should be possible to perform the following actions from the display;

- control of system set-points,
- change of actuator statuses (for example switching breakers on/off),
- acknowledgement of alarms,
- querying the database, and
- querying device controllers.

Alarms are the end-result of sequenced logic that has been configured by the system designer. In order for an alarm to indicate the origin and also the exact nature of the system fault, alarm routing should be designed correctly. Alarms should indicate the type of alarm, alarm tag, description of tag, location of alarm and time of occurrence as the minimum criteria. More information can include the relationship of related alarms (consequential relationship), description of the logic in the generation of the alarm, possible causes of the alarm and action steps to remedy the fault.

Alarms will always have a priority level associated with it for example caution, warning and danger. Priority levels are best displayed in different colours. The following characteristics and rules should be implemented when designing the logic for the events:

- the event list shall be in chronological order,
- the size of the event list and the colour scheme shall be user definable,
- events should be categorised into a predefined list of categories to enable operators to associate events with equipment and criticality easier,
- event logging shall be stored for history purposes,
- routing of alarms should be customisable, and
- it should be possible for the operators to link notes and other information to a specific event.

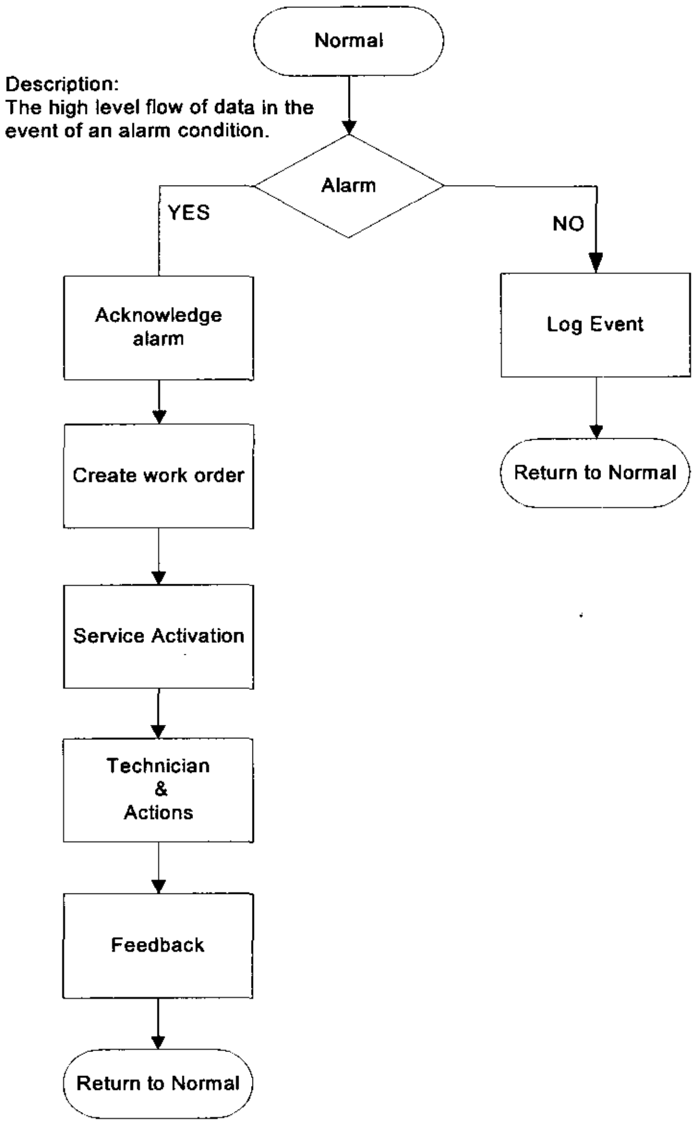

Figure 29 Control centre service activation

Figure 29 outlines the action and the sequence of events that should happen when an alarm is activated. The procedure is adopted from the current system event routing and allows for the sufficient service activation of field personnel. To enable users to build a history of events it is important to store data for a short period of time and also for longer periods, also referred to as archiving of data. Trending plays a very important role in the analysis of real-time data over a short period in time.

Trending assists with the identification of the sequence of events where other methods are difficult to accomplish this. Operators should be able to define tags that must be trended for a defined period of time where after the trend can be deleted or saved for future reference. As part of the system design certain tags or values should always be trended and stored for future reference.

The value add of supervisory software packages are specifically seen with the ability to create graphs and trend data. Some of the characteristics that should form part of the solution are:

- the ability to do trend printing,
- ability to export data to various file formats for easy retrieval,
- multi-dimensional graphing capabilities,
- customisation of trends,
- length of data storage and frequency of monitoring can be specified on a per-point basis, and
- trending of current data over a archived data set.

The characteristics described in the above paragraphs makes the user interface easier to work with. It allows operators to easier identify system failure and leads to the increase of overall environmental system availability.

4.4.3 Geographical Information Systems

As explained in the requirement paragraph of the document a GIS system gives the operator the ability to effectively route calls to the field personnel. It will furthermore enable field personnel with the ability to easier locate equipment that are not always stationary and are part of a mobile station. Field personnel must be deployed with mobile geographical positioning devices because this will allow them to locate the equipment they are looking for.

There are several advantages to a GIS system and the incorporation thereof into a national monitoring and control system. With the integration of the GIS system into the business applications the database must also be part of the integrated repository (IR). This will allow for the sharing of collective information with the other business applications.

The graphical user interface (GUI) must be able to display different symbols for different types of data on a map. If the user selects a symbol, the system must display relevant information pertaining to the data point being represented. The user must also be able to select data records and display them on the map. The resolution on the map must go down to street level in towns in South Africa.

An example of the above is that the user must be able to navigate from a national overview screen to street level of a town. The map should display street level detail as well as be able to identify buildings related to the building automation system. It should also be possible to add user animation and detail at this level. From this level the user can then navigate to the various systems that are integrated in the building automation system. The user must also be able to navigate to this level from only an alarm or fault list.

The implementation of a GIS in the business should provide the following functionality:

- Access location or equipment information.
- Ability to view outstanding work orders and active alarms on the geographical representation map.
- Create thematic maps of work orders by Type, Priority, Date, etc.
- Create grid queries with the collaboration of the maintenance management package.
- View map information in the other business applications.

To fully utilise a GIS implementation it will benefit if the fleet vehicles can be equipped with global positioning systems (GPS) and the real-time positioning information can be relayed for integration with the GIS and supervisory application software. It is increasingly important that the tools necessary to achieve and maintain the specific goals set by the business be placed in the hands of those closest to the problems. Maintenance personnel must have these tools at their immediate disposal if they are required to make decisions based on the information available to them.

Currently field technicians are equipped with a clipboard with the allocated work orders. Business decisions require instantaneous and accurate data. Whether remotely on laptops or hand-held devices, GIS provides the ability to locate and access location and equipment information from a map. If the technician's equipment can be installed with mobile communication equipment he will be able to retrieve and send data related to current work orders real-time. It will also be possible to update work orders automatically.

Interfacing to other applications must be done via a database connection (ODBC). An example of general information to be shared amongst the various applications is the *Property Identification Code* of site. The purpose is to serve as a technology vehicle that can handle needs from every database in the TFMC context through the Information Repository.

4.5 Operational procedures and information flow

Due to the fact that the system in the monitoring and control facility is driven by day to day operational activities, the procedural activities must be streamlined. Several flow diagrams are shown that have been developed for the specific use of the system operators in handling system events and alarms.

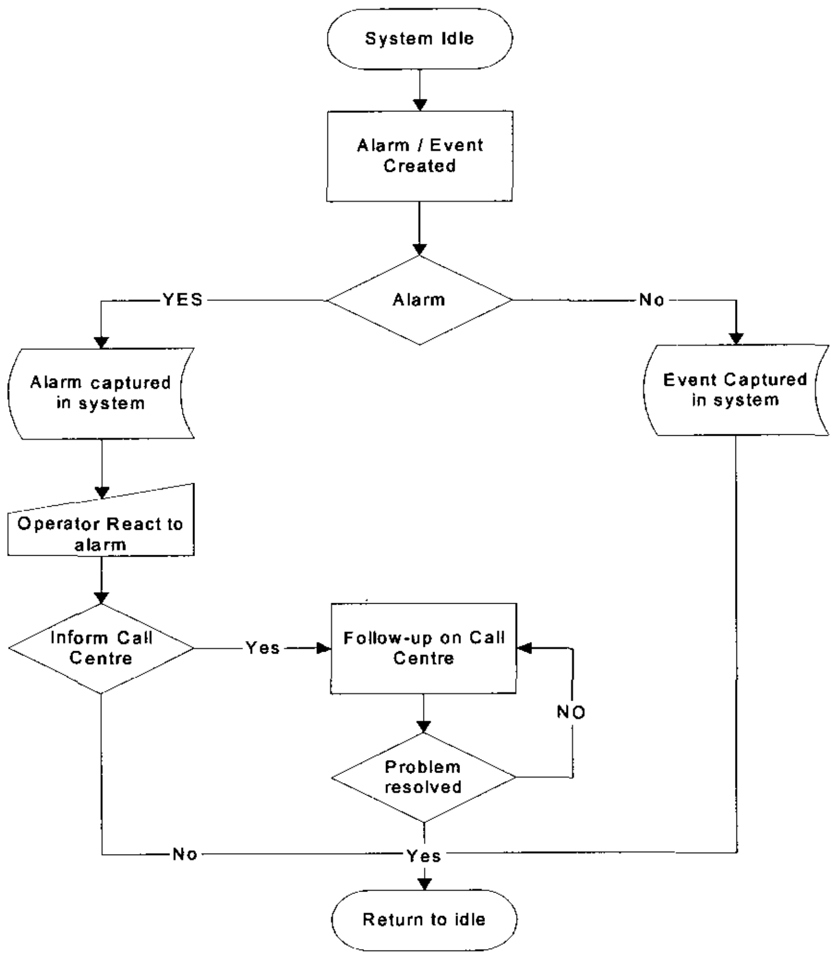

Figure 30 General task activation for an event

In the business the operators must also interact with the call centre that are the interface to the client. It is necessary to keep the call centre informed of the status quo of an alarm or event.

Whenever the tasks has been completed the operator can return to an idle condition or respond to another alarm or event which allows for parallel processes running.

As can be seen from Figure 30, with the initial activation of a system event it must first be evaluated to determine if it is an alarm or just an event notification. The control centre is responsible for the creation of the work order when the response of field personnel is necessary. The control centre then continually tracks the status of the work order until a system test can be done to verify that the problem has been resolved. It is necessary to do a system test to verify that not only the problem is solved, but that the system responds as required.

Whenever it is required for operators to get involved with system tests and configurations, the level of training required by the operators increase drastically. Technical skills are also a requirement because the operator must be able to understand the implications of his actions.

Figure 31 shows the actions that have been followed previously with the previous work order software application. It can be seen that the national control centre authorise the work order creation and then delegates to the regional level supervisor or to the technician directly, depending on the time of the event occurrence. The control centre operator then liases with the field technician according to the information available from the system for rectifying the system problem.

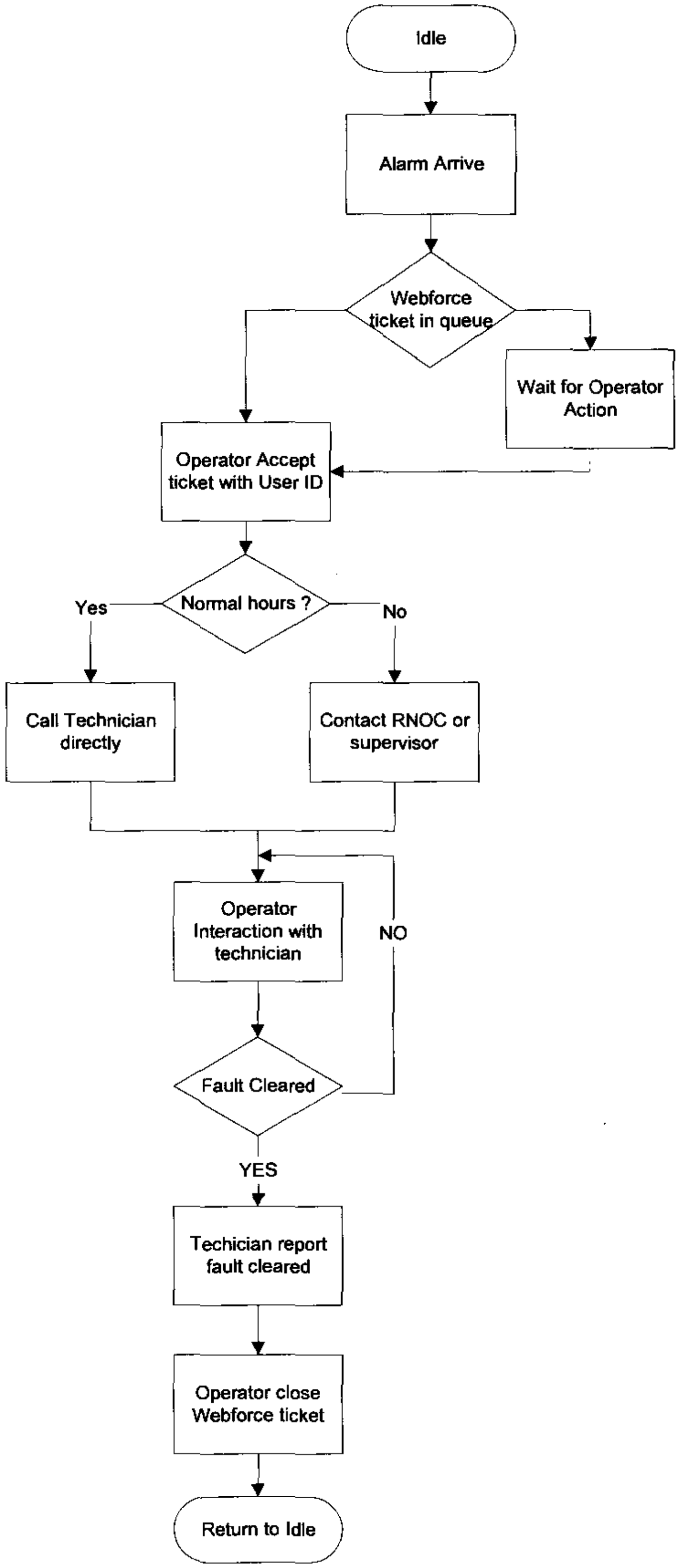

Figure 31 Procedures with a work order created

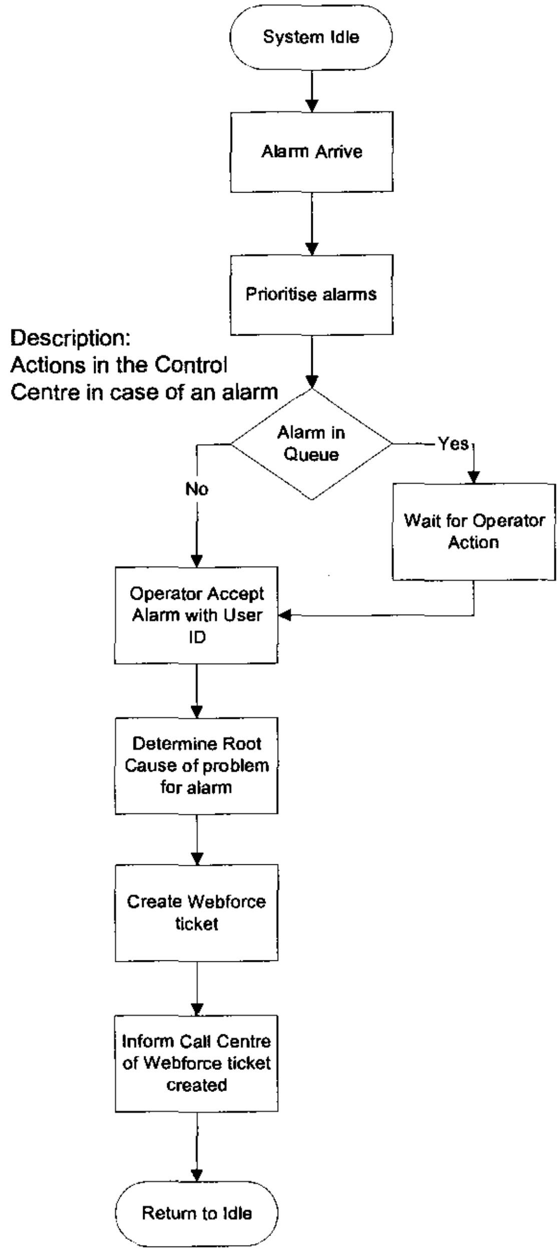

Figure 32 Root cause analysis of an alarm

Figure 32 shows when the root analysis of an alarm must be done. The identification of the root cause too late in the work order creation process will lead to changing the work order. Consequences of incorrect problem analysis are cancellation of orders and despatching of the incorrect personnel which will increase system downtime. Where possible the failure analysis should be automated to prevent human error.

CHAPTER 5: RESULTS

5.1	*Introduction*
5.2	*Results from the RFI*
5.3	*Detailed financial evaluation*
5.4	*Technical and commercial evaluation*
5.5	*Summary*

5.1 Introduction

As defined by Dymza [10] benchmarking is an important and effective method of evaluation. The objective evaluator or consultant must be certain if a functional or generic benchmarking is used in evaluating building automation systems. Functional benchmarking is the evaluation of a system or product in terms of its "best of breed" capabilities. Generic benchmarking is the evaluation of the system or product to determine if it is the "best of the best" product or system available.

One of the critical aspects that have been addressed in the Chapter 3 is the procurement process and criteria of evaluating a product. Results that have been obtained with the procurement process will be shown in the next sections. The possible solutions from industry will be shown and can be evaluated against the criteria defined for evaluating the systems. The products will also be measured against the design specification specified in Chapter 4 to ensure that they do meet the requirements.

5.2 Results from the RFI

The goal of the request for information is to find suitable candidates for the monitoring and control of environmental systems in the telecommunications industry. It is required to find a solution that is fitted for the enterprise market. A request for information data pack was send out to 16 companies of which 12 responded. Six companies responded with comprehensive and complete proposals. Of the other six proposals elements were missing which made them difficult to evaluate. With the RFI the market could be evaluated to determine if the solution needed is available from the local market and furthermore establish an estimated cost to integrate the required amount of sites.

Other companies that are also involved in producing solutions of this nature to the telecommunications industry have also been approached with the conceptual system architecture. Some of them were ruled out in the initial evaluation phase due to critical elements missing or the fact that amount of customisation is too much. These companies do not form part of the 16 companies to which enquiries where distributed.

	Presenting company	**Supporting Technology Partner**	**Market Focus**	**Rating**
1.	Xycom	CiTect & Sixnet	SCADA, process control and automation	2
2.	Emerson	Erricson Energy Systems	Telecommunication environmental monitoring systems	4
3.	Channels	DPAM	Digital Performance analytical monitoring	3
4.	Process Control and Integration	Rockwell Automation	Building and industrial process control	1
5.	Siemens	Computer Associates	Industrial, Telecommunications and building control	3
6.	Alsthom	Alsthom	International Railway Facility Manager	2
7.	Optimal Control System	Metasys – Johnson Control	Building and Process Control	4
8.	AST	Honeywell	Building and Process Control	4
9.	Staefa Control Systems	Staefa Controls, Siemens	HVAC Control Systems	1
10.	Alerton	Alerton	Building and Process Control	3
11.	Tridium	Tridium and Echelon	Building automation and control	4
12.	Adroit	Adroit & Spectrum	SCADA and Telemetry systems	1

Index: 4 – Adequacy 3 – Conformity 2 – Minor nonconformity 1 – Major nonconformity

Table 12 Request for information evaluation

From the evaluation in Table 12 it could be seen that each proposal had its own unique advantage. This is because of the fact that the proposals received are from various industry sectors. Although some of the companies are rated low on a score, it should be noted that they have solutions that are very suitable for smaller applications and process control applications. Stand-alone solutions can therefore easily be implemented on single installations or in cases were cost must be minimised.

Companies that have provided adequate proposals (4) are well established in the building automation market, can competitively compete in the enterprise market, can easily integrate into the business application layers of the client and have a sound financial proposals.

Companies with a medium (2-3) score have solutions have products and solutions that are not technically strong, have a lack of resources, are not competent enough to compete in the enterprise market or have products that are not completely interoperable with other systems in terms of the criteria set out.

Companies receiving a low score (1) have products and not solutions that are suited for smaller stand-alone applications, have a limited range of products, with limited functionality and are not interoperable with the criteria set out.

It can be seen from Table 12 that proposals from a few industry sectors have been received. This detailed analysis was necessary to ensure that the proposals were thorough and complete. An estimate for the cost of the control centre construction was also requested if this would form part of the proposal submitted by the company. A further estimate was also requested for companies that foresee that additional development work had to be done to fulfil certain of the criteria requested by the proposal.

5.3 Detailed financial evaluation

As part of the request for information a request for price was also issued. This request was based on the information supplied by the RFI but it was not a comprehensive set of information supplied. It was necessary at this stage to calculate the expected costs because the necessary motivation still had to be done for capital funding.

The financial proposals received played a very important aspect in the evaluation of the proposals. Proposals were requested for sites of vary size, which included 50 I/O points, 300 I/O points, 1000 I/O points, stand-alone masts, container sites, brick and mortar sites and large buildings.

The proposal by Channels suggested an additional cost of R 1 million for required development work, and Process Control and Instrumentation an additional R 200 000. No estimated time required was supplied in the proposals received but from experience a period of between 6 and 15 months were calculated to be sufficient

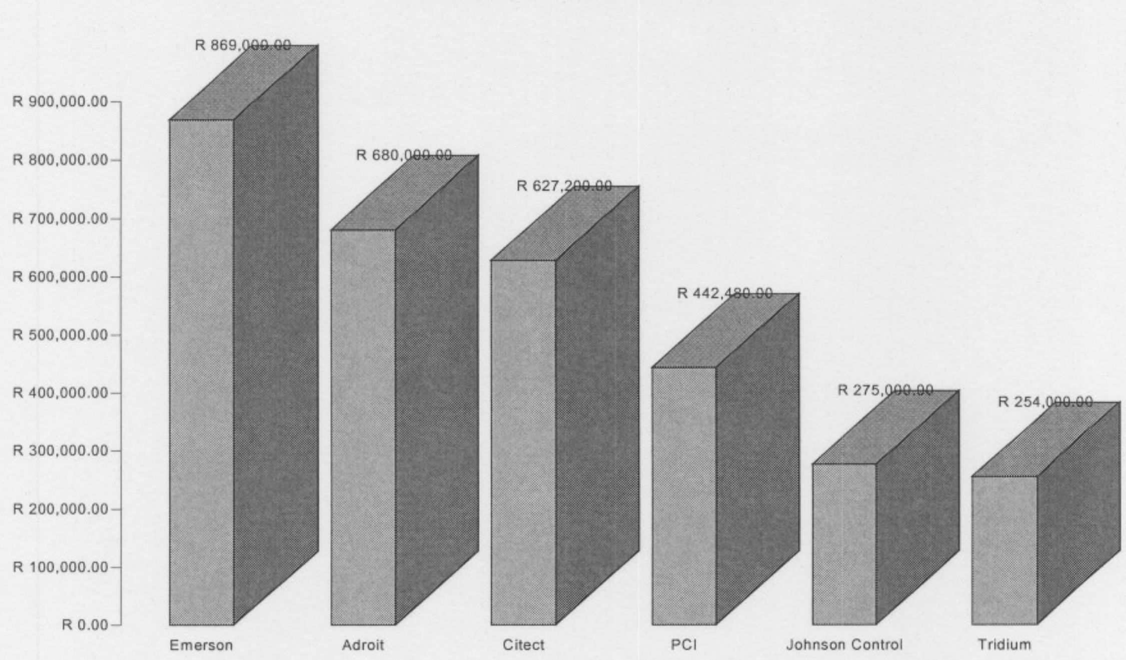

Figure 33 Software cost for the monitoring and control centre

Figure 33 shows the estimated licensing cost and minimal configuration costs needed to install the supervisory monitoring and control software at the national centre needed to monitor an estimated 300 sites with 10 operators using a single server.

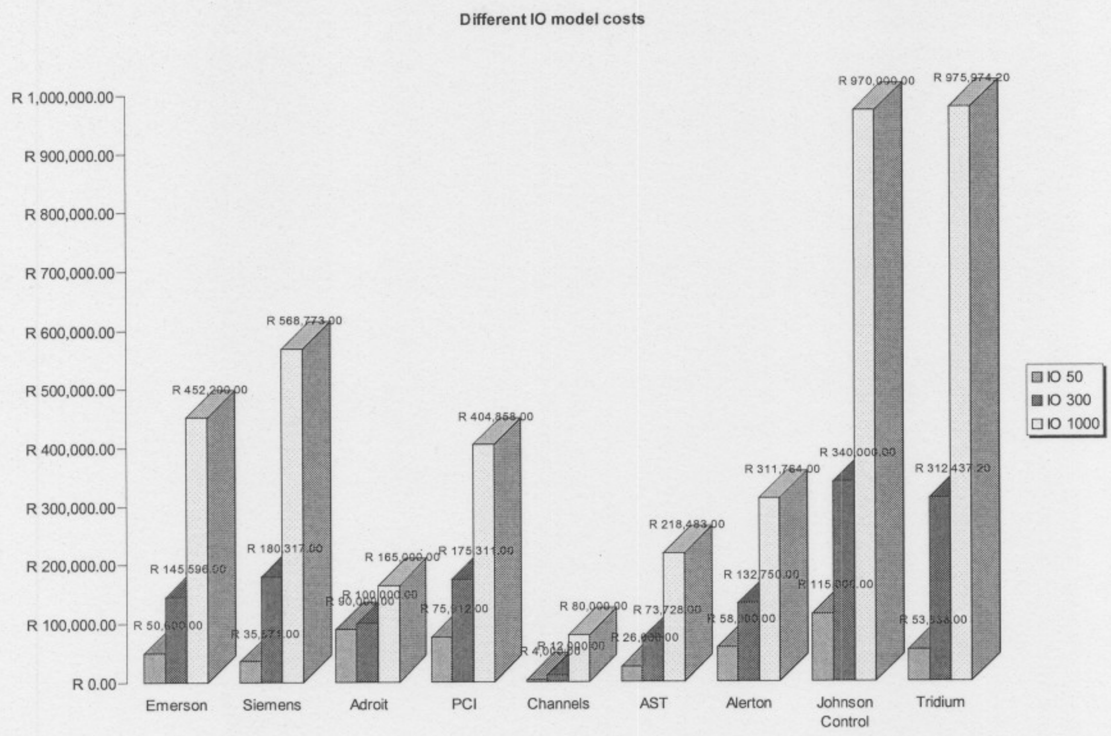

Figure 34 Comparing different IO cost models

Figure 34 illustrates how some of the proposals compare in prices when the same amount of IO has been given for the companies to use in their estimations. A distribution ratio of 40:60 has been used for digital and analogue monitoring points. The costs shown estimate how much it will cost for the hardware and software necessary on site to do the monitoring if no infrastructure is needed. In the cases where already existing infrastructure do exist some of the proposals have shown to be able to cut costs by 90%. Tridium and Johnson controls have shown that they are able to implement such cost savings.

Figure 35 compares the competency of companies with past experience in the telecommunication with that of companies that have little or minimal experience in the telecommunication market. Financial proposals specific to the telecommunication sites size were requested. Although not as important in the final evaluation it shows which proposals are not suitable for the application. Due to the cost savings of some of the proposals in the control centre and definite savings when integrating to already existing monitoring and control infrastructure it is clear which are financially viable solutions.

The ability to furthermore integrate to other business technologies and business application shows the advantage of making use of a specialised system in the industry. It is also very important to understand the technical difficulties that form part of the information technology industry and integrating into maintenance management and work order creation packages.

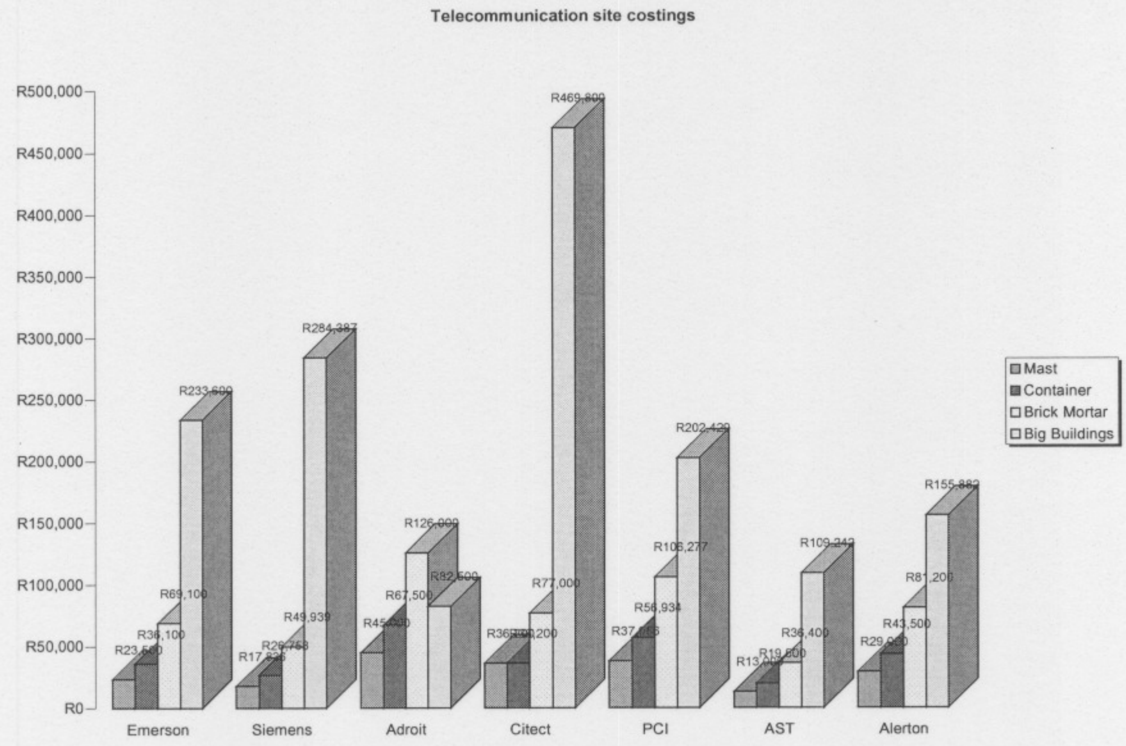

Figure 35 Costing models for telecommunication sites

5.4 Technical and commercial evaluation

Although the financial proposals are an important aspect, evaluation was also done on other criteria. Summaries of all of the characteristics that the proposals were evaluated against are listed in Table 13.

The criteria were sub-divided into a Company Profile, General quality and responsiveness of the proposal, Organisation personnel and facilities, Technical Approach and General evaluation. All of the aspects addressed in Chapter 3 for supplier evaluation are addressed in either sections 1-5 in Table 13 or in the more in-depth technical evaluation not described below.

1	**COMPANY PROFILE**
1.1	Company submitting to RFI
1.2	Supporting hardware company
1.3	Supporting software company
1.4	Supporting installation company
1.5	International company and support
1.6	National support
1.7	Previous exposure to telecommunication environment
1.8	Market focus
1.9	Black empowerment
1.10	ISO accreditation
1.11	Financial profile
2	**GENERAL QUALITY AND RESPONSIVENESS OF PROPOSAL**
2.1	Completeness and thoroughness
2.2	Understanding of problem
2.3	Responsiveness to terms, conditions and time of performance
3	**ORGANISATION, PERSONNEL AND FACILITIES**
3.1	Evidence of organisation and management practices
3.2	Qualification of personnel
3.3	Adequacy of facilities
3.4	Record of past performance
3.5	Geographical locations
4	**TECHNICAL APPROACH**
4.1	Reliability
4.2	Maintainability
4.3	Producability and economy
4.4	Technical data and communication
4.5	Existing solution
4.6	Development
5	**GENERAL EVALUATION**
5.1	General quality
5.2	Organisation, personnel and facilities
5.3	Technical approach

Table 13 Non-technical evaluation criteria used

APPENDIX B: DISTRIBUTION OF SITES OVER THE NATIONAL NETWORK

In the following section the four different types of sites that exists will be graphed to show the quantities of each type in every region. The regions are not according to the provincial borders of South Africa. The abbreviations are defined as follows:

d) RNOC – Regional network operation centre
e) NNOC – National network operation centre

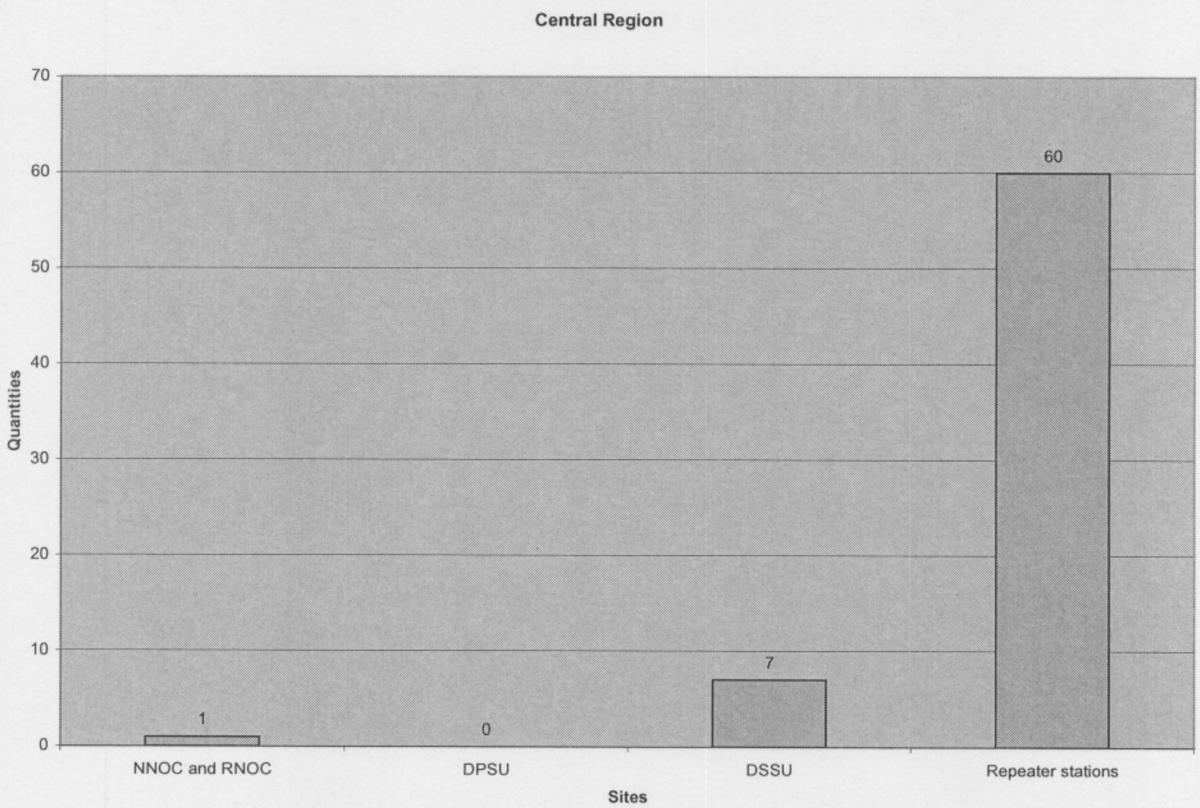

Figure 1 Site types and quantities in the Central region

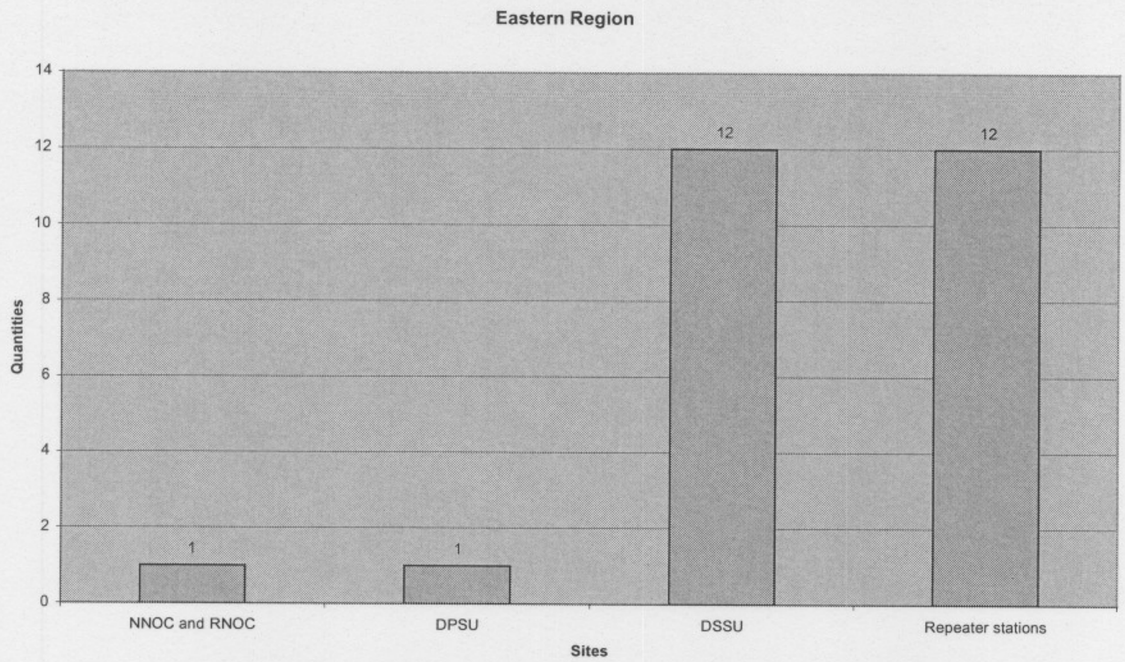

Figure 2 Site types and quantities in the Eastern region

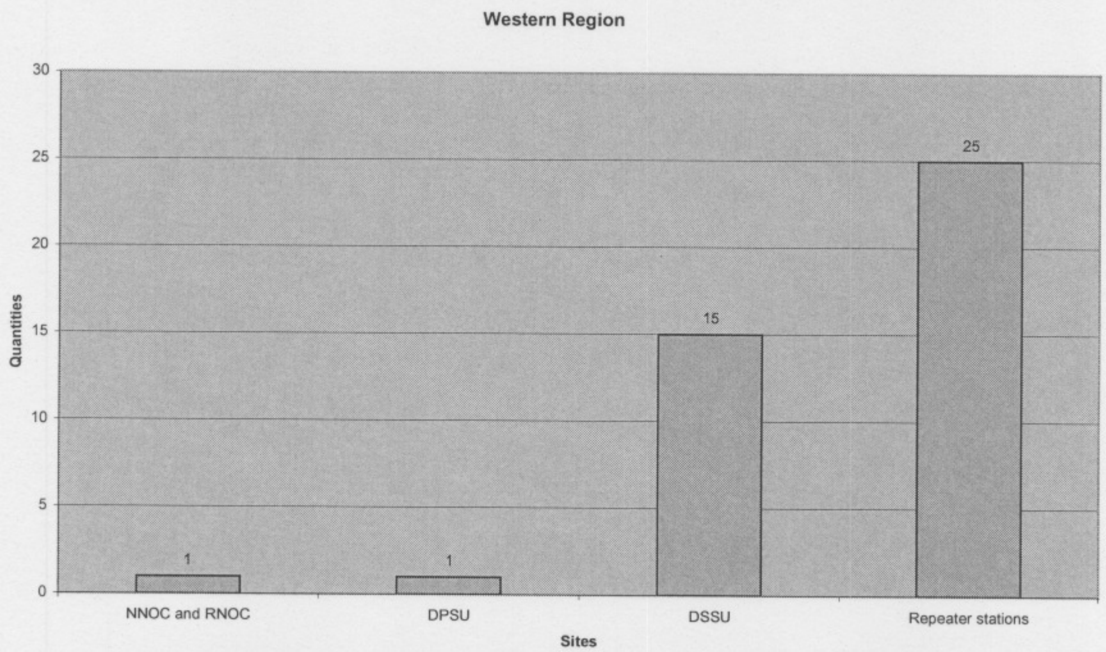

Figure 3 Site types and quantities in the Western region

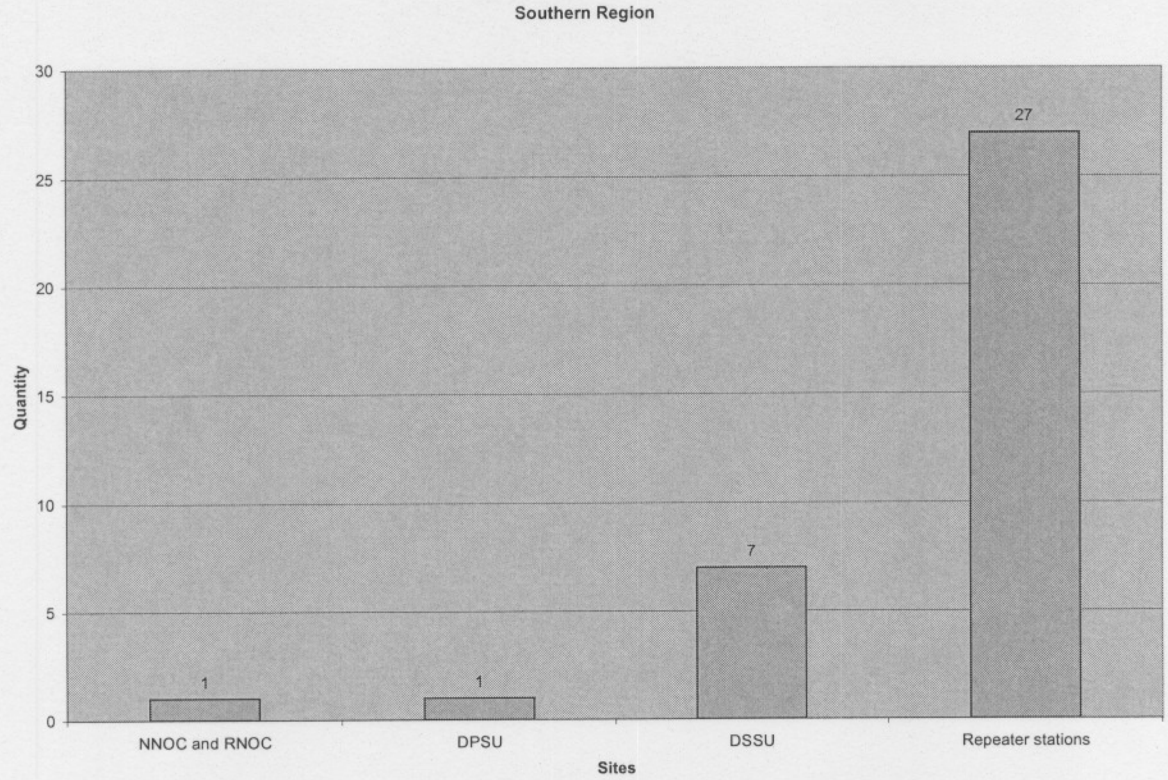

Figure 4 Site types and quantities in the Southern region

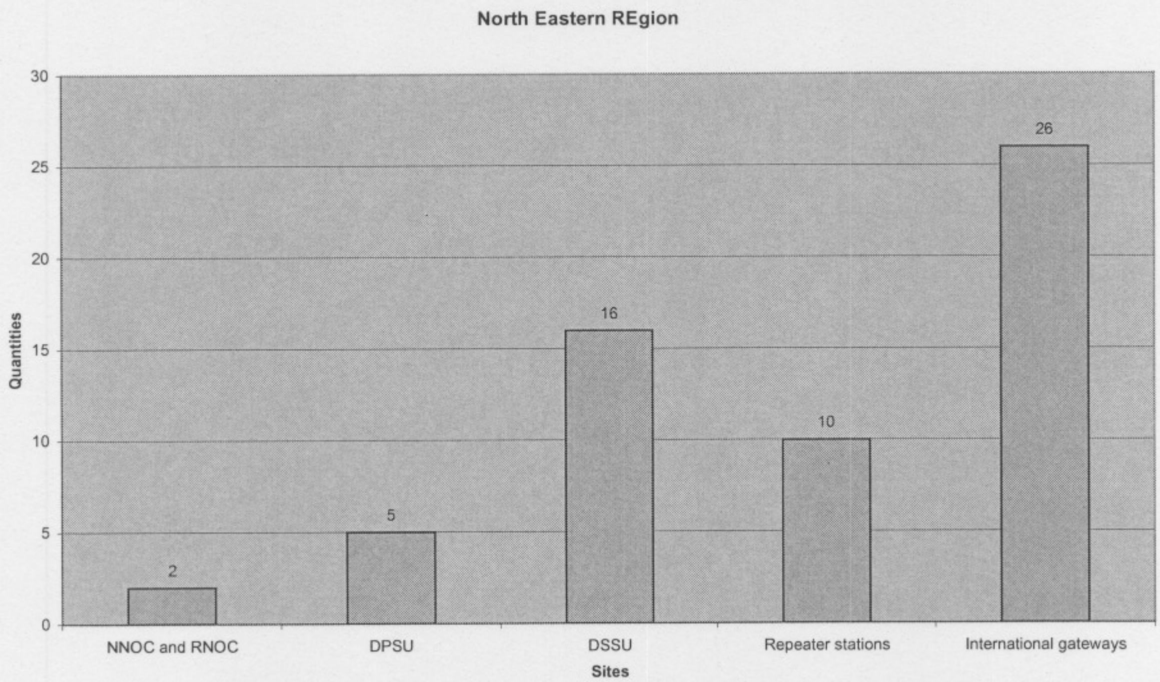

Figure 5 Site types and quantities in the North Eastern Region

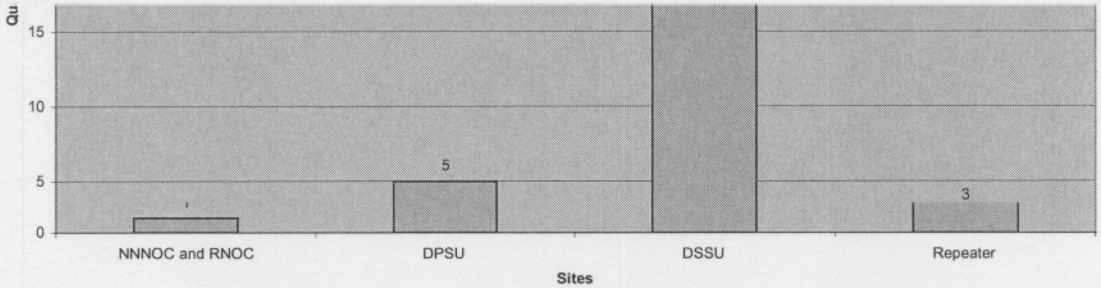

Figure 6 Site types and quantities in the Gauteng region

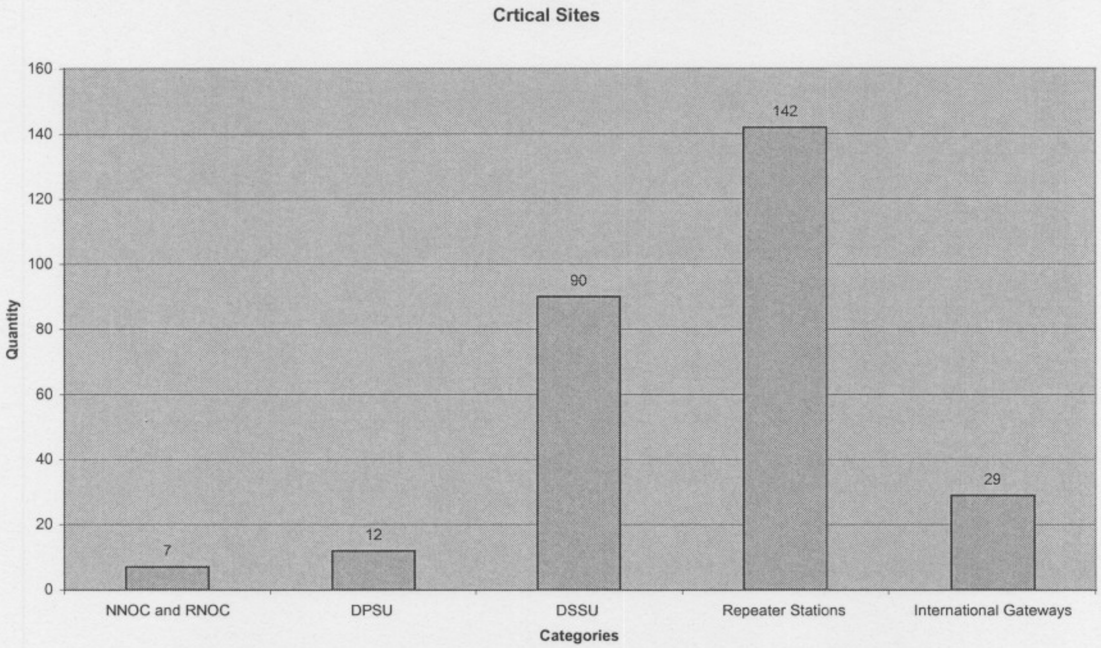

Figure 7 Site critical types and quantities

1	**COMPANY PROFILE**
1.1	Company submitting to RFI
1.2	Supporting hardware company
1.3	Supporting software company
1.4	Supporting installation company
1.5	International company and support
1.6	National support
1.7	Previous exposure to telecommunication environment
1.8	Market focus
1.9	Black empowerment
1.10	ISO accreditation
1.11	Financial profile
2	**GENERAL QUALITY AND RESPONSIVENESS OF PROPOSAL**
2.1	Completeness and thoroughness
2.2	Understanding of problem
2.3	Responsiveness to terms, conditions and time of performance
3	**ORGANISATION, PERSONNEL AND FACILITIES**
3.1	Evidence of organisation and management practices
3.2	Qualification of personnel
3.3	Adequacy of facilities
3.4	Record of past performance
3.5	Geographical locations
4	**TECHNICAL APPROACH**
4.1	Reliability
4.2	Maintainability
4.3	Producability and economy
4.4	Technical data and communication
4.5	Existing solution
4.6	Development
5	**GENERAL EVALUATION**
5.1	General quality
5.2	Organisation, personnel and facilities
5.3	Technical approach

Table 13 Non-technical evaluation criteria used

1	**SOFTWARE ARCHITECTURE**
1.1	Technology partner
1.2	Control room architecture
1.3	Site architecture
1.4	Maintenance management integration
1.5	ODBC integration
1.6	Operating system
1.7	Software interfacing architectures
1.8	Client / Server architecture
1.9	Database type
1.10	Networking architecture
1.11	Fieldbus protocol integration
2	**FUNCTIONAL ABILITIES**
2.1	Interfacing via fieldbus protocols
2.2	Digital input modules
2.3	Digital output modules
2.4	Analogue modules
2.5	Expandability of IO modules
2.6	Integrator units
2.7	Scalability of system
3	**HARDWARE**
3.1	Hardware architecture
3.2	Native fieldbus architecture
3.3	Interfacing method to IO modules
3.4	Expandability of modules
3.5	Support for protocols
3.6	Support for existing modules

Table 14 Technical evaluation criteria

Table 14 illustrates the different criteria that were used to evaluate the technical soundness of the proposals received. All the necessary aspects that are necessary to evaluate an enterprise system for this type of application are being addressed in the table. Not all of the evaluation criteria are shown below because the table is merely a summary of the key aspects that are necessary for the evaluation of a complicated architecture for a national monitoring and control centre.

Some of the critical aspects are that the system must be able to be expandable and integratable with existing systems. The capabilities of the system that have been selected lies in the superior software architecture utilised and the capability to easily integrate into various building automation systems.

5.5 Summary

From the research done in Chapter 2, and the design strategy followed in Chapter 3, the solution proposed by Tridium can be seen to be sufficiently capable of satisfying the needs for the requirements that have been set. One of the critical elements is the software architecture that is based on a JAVA development platform. This has several advantages for networking applications and the integration capabilities thereof with other current business applications.

The system has a strong background in the building automation industry and specifically in system integration applications. It has been deployed in similar applications, although not in the telecommunications industry. The product has successfully adhered to all of the criteria set out by the sourcing strategy. It seems to be a financially very expensive solution but the benefit of the investment will be shown in the application thereof.

Tridium has the ability to integrate direct to a LonWorks control network through its gateway or integrator devices. Although the company did not supply a solution for the site device and controllers some of the other proposals did include solutions that are easily integratable with the Tridium framework. An advantage of this integration work is that resources will be free to continue with several sites while the commissioning of the national monitoring and control centre can continue. Due to the large scope of the project it is necessary to get many resources involved to limit the critical path.

Tridium has very strong energy saving elements. This is clearly a field that needs further investigation as the infrastructure has been designed and only needs the implementation of the energy strategy. Energy saving strategies are high in demand because the electricity supplier company of South Africa has not foreseen that the industry requirement for energy would develop so much. Due to the lead-time to construct new power stations it is possible to run short of energy in the near future.

CHAPTER 6: CONCLUSION

6.1 Introduction

6.2 The monitoring and control facility

6.3 Need for further work

6.1 Introduction

The purpose of the study was to design a system that will increase environmental system availability through the use of reactive and preventative action. A complete analysis and requirement definition has been done to fully understand the need in the business sector for such a system. Furthermore, an in depth analysis was done to determine the availability of environmental monitoring systems in the telecommunications industry.

After the initial research was done a system model was defined for the building automation system architecture. Centralised monitoring, control and service activation was thoroughly investigated. The motivational factor for such a control centre is to minimise system downtime as much as possible. The control centre was designed with the philosophy in mind to not only monitor remote facilities but also remotely control certain functions at these remote facilities.

In designing the system architecture the following criteria must be fulfilled at the completion of the project:

- using technology which can be re-used in similar applications in the South African industry,
- sustain the South African technology development and manufacturing industry where possible,
- a comprehensive technology transfer should be done for all technologies and products imported from the international market, and
- at the successful completion of the project the value-add and benefit of the system should be determined by implementing the system in more application fields.

These aspects have been addressed in the design and process followed, and will be shown further in this chapter. It must also be noted that the difference between leading-edge technologies is minimal but the cost to the client can be excessive if differentiation and objectivity is not maintained. A solution based on international standards in the building management environment, (which is internationally competitive in the information solutions industry and interoperable in various other market sectors) has been proposed. Results documented in the previous chapters shows the success of the proposed solution.

6.2 The monitoring and control facility

As a result of the requirements of the client a certain process has been followed in which the project has been managed. Due to requirements certain items in the project has been re-scheduled to meet the requirements. This has, however, not affected the successful completion of the design of the system for the national monitoring and control facility of environmental control systems. A solution has been found that can be implemented in the facility.

The most important criterion to maintain is to ensure that the availability of the facilities do not deteriorate during production time. The criterion is driven by the operational requirements of the telecommunications market. It must be able to minimise the downtime of telecommunication equipment due to the failure of environmental control systems to a maximum of thirty seconds per annum. Due to the combination of several factors, which include equipment failure and acts of God, it is very difficult to achieve this kind of performance.

A totally redundant set of equipment, installed on a separate location and linked with a redundant network, could potentially lead to such stringent system availability requirements. It has been shown that it is financially not viable to do installations of this nature. Even in these extreme redundant scenarios it is still very difficult to achieve such high margins. It is therefore necessary to install monitoring systems to try to minimise the system downtime.

Early despatch of field personnel and correct problem identification can decrease system downtime drastically. Maintaining good customer relationships and client satisfaction is the essence of having a healthy and sustainable market. Customer relationship management is very important in a market where the requirements are so strict. Call centres play a very important role in managing good relationships with customers. It is therefore essential that the control centre operators have defined procedures that must be followed in order to maintain control and good customer relationships through the call centres.

In this design several aspects have been addressed which were additional to those that were initially required in order to ensure the optimal availability of the environmental monitoring and control systems. An in-depth study has been done to ensure that a complete study of available systems and solutions are covered. The selections have been done on a system that has successfully demonstrated itself to be operationally capable of handling the alarm routing algorithms described and allow for the interaction with other business applications.

Although the application is unique in the telecommunication market, no problems are foreseen with its implementation. The building automation solution based on the Niagara (Tridium) framework is utilised extensively in the building automation environment. This solution is ideally designed to operate in a distributed networking environment. It is capable of being directly integrated into a LonWorks and BACnet control network. These are some of the aspects that have shown that an implementation in the telecommunication industry, to monitor and control environmental control systems, is within its scope.

In Chapter 4 the system requirements have been outlined extensively and in detail. This has led to a detailed system specification and criteria to evaluate systems. Due to the extent of the involvement in the operational activities of the monitoring and control centre, a lot of design time has been used to integrate the operational procedures with the requirements of the system. This has proven to be beneficial to system operators and also to the system architect because of the close interaction between the requirement and conceptual ideas.

Central to the system is the database where operational data and network architecture data is stored. This will be important when the system has been successfully running for several months and more than a year. At that stage sufficient data would have been stored to do trending on the availability of monitored sites. This information must then be audited against the information available from the telecommunications operator to determine the improvement over the period of time that the system has been installed.

As can be seen from the results obtained in Chapter 5 qualitative measures have been taken to evaluate results obtained from the request from information. Results have been found to be objective when evaluated by other members of the industry. It has furthermore proven to inspire new development to mobilise the solutions even more advanced than initially anticipated.

Due to the effort that was invested in the detail evaluation of the proposals received some of the important aspects of the design has been outlined in the proposals. The nature of the building automation industry is very competitive because new developments and contracts of this potential size are very limited. Interviews with certain companies have therefore been arranged to ensure that information received is legitimate and correct.

6.3 Need for further work

As part of the privatisation initiative cost savings will also be introduced in an effort to minimise operating costs and increase of shareholders profit. Optimisation of the environmental systems with the goal of energy savings in the telecommunications industry can have major cost saving implications. Before cost saving initiatives can be introduced effective uptime management of the systems must first be accomplished.

The potential savings still need to be quantified in further work, as it has not been foreseen to have such a big impact on the investment of this system. With initial investigations done it has been shown that cost and savings both follow an exponential curve, which are directly related to the utilisation of the telecommunication equipment.

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APPENDIX A: QUESTIONNAIRE

Questionnaire that can be utilised in the evaluation of suppliers

	GENERAL
1.	How many years of background does the company have in the Building Management and Automation industry?
2.	Are the company registered as a professional system integrator with any OEM?
3.	List the projects that the company has been involved with in the Building Management and Automation industry in the last five years.
4.	List the relevant qualifications of team members that have been identified to work on the project.
5.	Does the company have an official licensing agreement with the OEM of the products that are proposed in the proposal?
6.	What role describes the function of your company best in the industry. a) Integrator b) Installation c) Consultant d) End User e) System developer
7.	When implementing an upgrading of a system what is the preference with regards to: a) The original supplier that supplied the first installation can only supply the new system? b) The upgraded system should only be compatible / integratable with the existing system? c) The new system need not be compatible with the existing system, as they can both run in parallel?
8.	What is the preference of your company with regards to: a) A system with the capability to be integrated over a network. b) A system that can be integrated over an network, and share the same network as your business network does. c) A stand-alone system that can not be networked.
9.	When implementing or recommending a system from a specific OEM, would you prefer:

	a) The system must be compliant to general industry standards and design methodologies. b) The system must conform to Building Automation standards and profiles. c) The system must conform to both (a) and (b).
10.	Which fieldbus technology in the building automation market does your company have the most experience with? List the projects that have been completed by utilising this technology.
11.	Is the company involved in any local or international standardisation committee that drives standards or policies in the building automation industry?
12.	When implementing the Building Automation SCADA system, would the preference for the system be a) A system from the process control industry? b) A system from the Building Management environment? c) A system that is universal enough to be utilised in both industry sectors?
13.	When designing a new system architecture for the environmental control system in a building complex, would the preferences be for a) A system for each discipline that is sourced from independent OEM's each with it own supervisory system? b) A system that can accommodate all the disciplines in the specified system architecture, with one integrated supervisory system? c) A system for each discipline sourced from the various OEM's, but with one common supervisory system?
14.	Please state the operating system that the supervisory system software or SCADA package requires. If there is option for more than one, please state the preferred operating system.

APPENDIX B: DISTRIBUTION OF SITES OVER THE NATIONAL NETWORK

In the following section the four different types of sites that exists will be graphed to show the quantities of each type in every region. The regions are not according to the provincial borders of South Africa. The abbreviations are defined as follows:

d) RNOC – Regional network operation centre

e) NNOC – National network operation centre

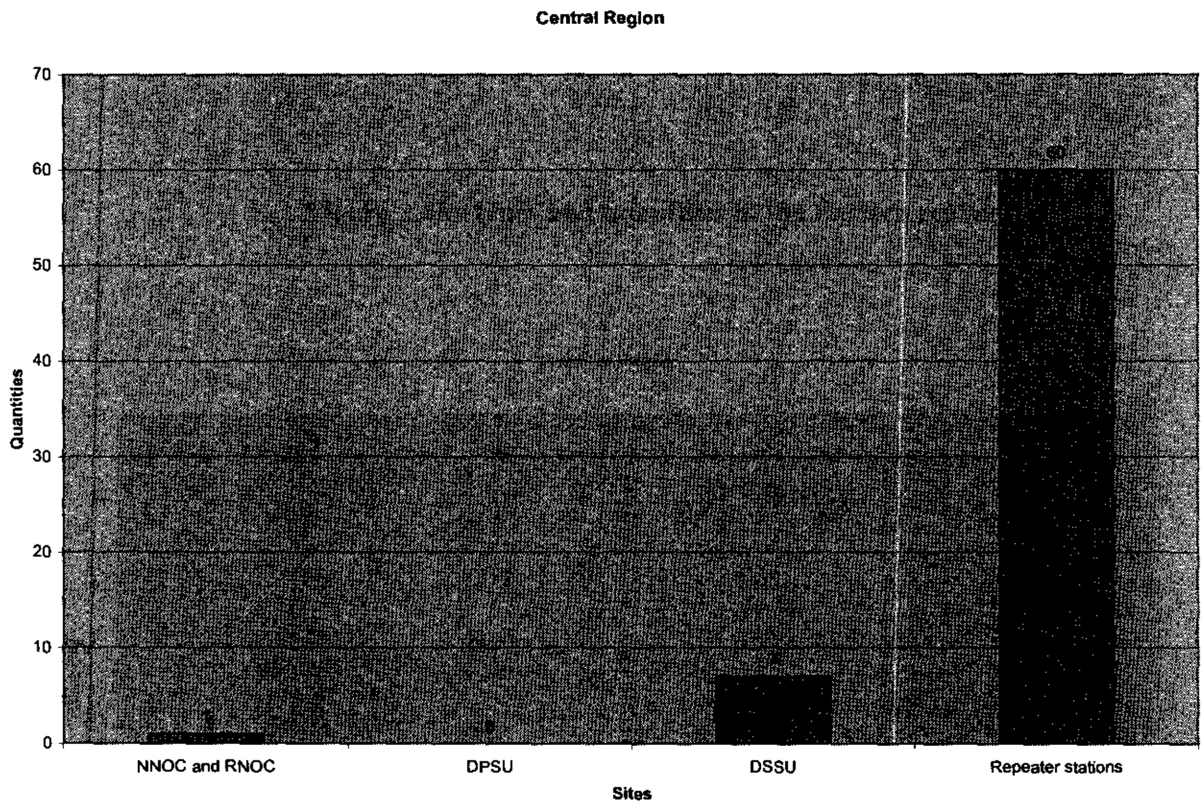

Figure 1 Site types and quantities in the Central region