Assessment of information utilisation: A maintenance and operational view, SASOL Infragas as case study

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It all starts here ™

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Abstract

Sasol Infragas uses various maintenance information systems that support operational and maintenance personnel in their everyday environment. These systems have been in operation for more than two years. Currently, there are four maintenance information systems in use at Infragas, these are; alarm management, deviation management, overall efficiency management, and rotating equipment management. The information from these systems is stored on intranet portals which are accessible to all Infragas employees.

This paper aimed to analyse the extent to which these portals are being utilised by Infragas employees, if at all. This paper also investigated the employees' mind-set towards the maintenance information systems. This will assist in understanding which systems enhancements can be made to further improve employee engagement.

These objectives were achieved by means of two methods. The first method was an actual usage measurement. This identified which employees were using the portals, as well as the usage frequency. This investigation method gave a real indication of the system usage and highlighted any shortfalls in employees' interaction with the portals.

The second method was a questionnaire, given to Infragas employees. The first section analysed whether the Infragas maintenance information systems are an accepted technology by investigating whether systems are being used by portal users. This was done by means of a technology acceptance model.

The questionnaire also aimed to gather information on portal quality characteristics. This would indicate which quality characteristics are important to Infragas employees. Maintenance information system quality needs will differ from employee to employee. This information could improve the quality of interaction between the employees and the portals.

The questionnaire also aimed to examine employees' attitudes towards maintenance information systems. This section investigated whether employees felt that maintenance information systems improved plant performance and were beneficial to the Infragas environment.

These investigations revealed valuable information for the improvement of these systems. The connection between the results of the two methods also indicated if both methods were valid.

The information gathered from this study was communicated back to the Sasol Infragas management team. Recommendations for possible system improvements, which would increase employee system interaction, were also made.

Keywords

availability

frequency

improvement

industry

information

maintenance

operations

petrochemical

personnel

plant

portal

production

reliability

system

utilisation

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Abbreviations

ATR – auto thermal reformer

IEEM – intranet efficiency and effectiveness model

IO – input output

ISO – international organisation of standardisation

IT – information technology

MIS – maintenance information systems

MTBF – mean time between failures

MTBR – mean time between repairs

OEE – overall equipment effectiveness

OCLC - online computer library centre

SSBP – Sasol slurry bed process

TAM – technology acceptance model

WSE – web search engine

QUNIT – quality in information technology

CHAPTER ONE

INTRODUCTION

1.1 Introduction

As industrial plants are under pressure to be more reliable with longer production periods, plant maintenance in the Sasol Infragas environment has transformed from reactive to preventative and predictive. Predictability improves reliability. It is an indication of management's ability to control production while unpredictability causes unnecessary downtime which decreases the reliability of a plant. Predictive maintenance in a plant environment can only be effective if information about the equipment is available. This information should be organised in a manner which assists with maintenance decisions that enhance the reliability of the plant (Matusheski, 1999).

Maintenance information can be presented to maintenance personnel visually through the use of maintenance information systems (MIS). The objective of a MIS is to provide the type of information that will improve the coordination of maintenance teams and provide management with access to information relating to the activities undertaken by these maintenance teams. This is accomplished through the use of information technology (IT). IT is the channel, through which instructions concerning production and maintenance may be accurately encoded, transmitted, received, stored, processed and used (Mishra, 2006).

Maintenance teams focus on maximising the mean time between failures (MTBF) and minimising the mean time to repair (MTFR). This can only be done if comprehensive maintenance strategies are in place. The availability of information is a fundamental part of a comprehensive maintenance strategy (Mishra, 2006).

Sasol Infragas, which forms part of Sasol Infrachem in Sasolburg, South Africa, was the case study for this research project. Sasol Infrachem forms part of the chemical cluster of the Sasol group. The chemical cluster is integrated into the Fischer-Tropsch value chain of Sasol (Sasol Ltd., 2012). This case study focussed on two plants in the Sasol Infragas environment; the first was the auto thermal reformer (ATR) plant and the second was the Rectisol plant in Sasolburg.

These plants have various MIS. These systems have been in operation for more than two years, and are utilised by the maintenance and operational personnel. This study aimed to determine whether MIS in the Sasol Infragas environment are correctly utilised by these personnel.

1.2 Problem statement

The maintenance function in the Sasol Infragas plants is going through a transformation phase. The traditional approach to skills development in this area has been that of job mentoring and classroom training led by experts in the relevant field. The average age of an artisan in South Africa is 56 (SRI, 2010). The current skills and knowledge-based artisans will retire within 10 years. This will leave a void in the knowledge availability in the maintenance environment. These skills ensure reliability and efficiency and are critical to any gas and chemical environment.

Sasol Infragas has moved to an asset management-focussed strategy. Various systems have been incorporated to shift the focus from a reactive approach to a preventative and predictive approach. Maintenance information systems do not replace the work required by artisans; instead these systems will guide them through the maintenance function. Sasol Infragas has various maintenance systems in place for optimising, measuring, and assessing efficiency measurement:

- Plant asset management systems provide continuous information about an asset's health and provide predictive information for maintenance purposes.
- Alarm management systems assist operational personnel with the prevention of alarm flooding in emergency scenarios. Alarm management systems are also used by maintenance personnel to identify equipment that is operating in abnormal conditions. Emergency maintenance can then be scheduled on this equipment.
- Condition monitoring systems are used on rotating equipment to inform maintenance personnel of deviations.
- Inspection systems supply maintenance personnel with feedback regarding any deviations found in the plant.

The information from these tools is displayed on web portals. These web portals present an overview of various events, changes, and operational and maintenance actions that have taken place over a specific time. Understanding these can prevent a process or safety incident. If the systems are not utilised to their full potential, there is the possibility that critical plant deviations will be missed which could cause unnecessary production loss (Sonnemans & Korvers, 2006).

There is a need to optimise the current work methods of maintenance and operational personnel. This can be done using maintenance information systems as these systems make the relevant maintenance information and operational data available to personnel. These work methods need to be addressed in terms of personnel interaction, interpretation, and utilisation of the systems to support decisions that will ensure positive production and safety results.

1.3 Research aims and objectives

Various maintenance tools and systems are used in the petrochemical environment. The ATR and Rectisol plants within the Sasol Infragas environment have implemented centralised web portals that produce daily reports on plant performance. These centralised portals provide information on the current status of the various plant assets for maintenance, operational, and managerial personnel. This data demonstrates the availability, reliability and current quality of the plants. An overview of the daily alarms is also given.

This dissertation had two research aims. The first was to gain a clear understanding of the usage of the maintenance information systems in the Sasol Infragas environment. The second was to investigate the mind-set of the Infragas maintenance and operational personnel towards these systems.

The research objectives are summarised as follows:

- to measure the efficiency and quality of the maintenance information systems in the Sasol Infragas environment by means of interaction, focussing on the Sasol ATR and Rectisol plants in Sasolburg.
- to measure the utilisation of the maintenance information systems by determining how frequently the different systems are utilised as well as which of the systems are utilised the most and least.
- to investigate the general view of maintenance and operational personnel towards the maintenance information systems.
- to investigate whether the various maintenance information systems are beneficial to the Sasol Infragas environment.
- to investigate whether the maintenance information systems improve plant availability and reliability from the perspective of the maintenance, operational, and managerial personnel.
- to investigate whether maintenance and operational personnel see the maintenance information systems as being utilised to their full potential.
- to investigate whether the maintenance information systems are accepted as a maintenance and operational support technology.

The research objectives will provide a clear indication of the Infragas personnel’s views towards the maintenance information systems, as well as demonstrate the utilisation rate of these systems.

1.4 Chapter overview

This dissertation consists of six chapters. The following chapters follow chapter one:

Chapter two: Literature review

This chapter contains literature on information availability and web-based information portals. It begins with an overview of the case study plants. This is followed by a brief history of web-based information portals which demonstrates how the industry has changed over the years with the availability of these tools.

Chapter three: Empirical design

This chapter is separated into two sections. The first contains information which includes design parameters and time samples for portal monitoring. Here portal monitoring is discussed in detail. The second section is a questionnaire. The design of the questionnaire, sample design, sample size, and processing, analysis, and evaluation of the data will be outlined.

Chapter four: Findings

This section contains the results from the monitored portal interaction and questionnaire.

Chapter five: Discussion and interpretation

This chapter discusses and interprets the findings of the empirical investigation undertaken in chapter four.

Chapter six: Conclusion and recommendations

Chapter six examines the results of the discussion and interpretation in chapter five and provides recommendations based on these results.

Chapter two establishes the background for this study. A detailed overview of the case study is provided. Literature on web-based portals and quality characteristics is also discussed and reviewed.

CHAPTER TWO

LITERATURE REVIEW

This chapter contains the necessary background information to support the research done for this dissertation. The first section covers the background and overview of information for the case study. An overview is given of the different plants and the systems that have been implemented. The second section provides further background on web portals, portal quality, web portal measurement and log analysis.

2.1 Sasol Infragas environment

The Sasol Infragas environment forms part of Sasol Infrachem in Sasolburg, which is part of Sasol chemical industries of Sasol. Sasol Infragas consists of three sections: auto thermal reformer (ATR), Rectisol, and process coordination. This case study was done on the ATR and Rectisol plants (Botha, 2012).

The ATR and Rectisol plants form part of the Sasol Sasolburg gas loop. The gas loop consists of six plants. The ATR plant is at the beginning of this gas loop process. The gas products from ATR are fed to three client plants; these are Sasol Wax, Sasol Slurry bed process (SSBP) and Sasol Solvents. The tail gasses of these three plants are fed to the Rectisol plant. Rectisol converts the tail gasses and feeds it to the ammonia plant. The loop is completed when the ammonia plant feeds its tail gas to ATR where the tail gas is used for heating purposes. Any failure in the system can cause either financial or production lost or both (Botha, 2012).

The Sasol Infrachem loop is represented in Figure 1.

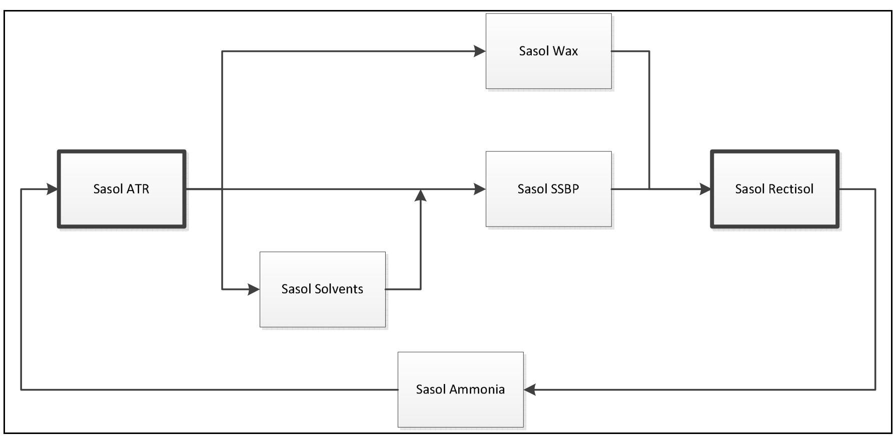


Figure 1: Sasol Infrachem gas loop

The ATR plant is at the heart of the Sasol Sasolburg gas loop. If the ATR plant is out of commission for any reason, the whole gas loop is unable to function. The ATR plant receives natural gas from Mozambique and converts it into reformed gas, syn gas and membrane hydrogen. ATR consists of three sections. The first section is the common section which contains all the utility supports and compression units. The second and third sections are the identical, A-Train and B-Train. These two sections are responsible for reforming the natural gas (Botha, 2012).

The Rectisol plant receives all the tail gasses from Sasol Solvents, Sasol Wax and Sasol SSBP. Rectisol is a dew point correction plant. The purpose of the plant is to remove all water particles from the gas and to reduce the CO_2 content in the gas. This is achieved through cooling and absorption. The Rectisol plant is made up of eight sections. These sections are the pre-wash system, the cooling system, the main wash system, the ammonia system, the fine wash system, pre-wash regeneration, main wash regeneration and gas compressing. The product gas from Rectisol is sent to the ammonia plant (Botha, 2012).

Infragas implemented various maintenance portals because of the criticality of the ATR plant. The maintenance portals are used to improve the maintainability, operability and the availability of ATR. Infragas has implemented the same portals at both ATR and Rectisol.

The maintenance information systems were implemented in order for ATR and Rectisol operational and maintenance personnel to have access to the following maintenance tools at the ATR and Rectisol plants:

- Alarm management portal which provides an overview of the last seven days' process alarms. Maintenance teams use the information to schedule maintenance on devices that are deviating from design conditions. The process alarms are grouped by plant section and by asset.
- DMSI MAINTelligence (DMSI, 2012)is an inspection-based system that is used by production and maintenance personnel. The system is a deviation management system: deviations are logged and displayed on the web portal. These deviations are then scheduled for maintenance.
- System 1 (GE, 2012) is a condition monitoring and diagnostics package which is used on rotating equipment. The package analyses various conditions on rotating equipment, like motors and compressors, and supplies feedback on the overall health of the equipment. Any deviations are displayed on the web portal.
- Overall equipment effectiveness (OEE) portal gives information about the current OEE, energy efficiency, cost efficiency, and flare losses taking place. This portal provides a general overview of the plant performance.

Examples of these portals are displayed in Appendix A. These portals are used on a daily basis. The information from the portals is reviewed by the operational and various other maintenance teams each morning. Specific tasks can be scheduled from the information revealed in these portals.

2.2 Portals

2.2.1 Introduction

The definition of a portal is a "doorway, gate, or other entrance, especially a large and imposing one." (Oxford Dictionaries, 2013). The term portal comes from the Latin word 'porta'. The Latin word 'porta' refers to a gate or gateway (Sulaiman *et al.*, 2012). In the information technology (IT) environment portals are used to collect information from different sources and create a single point of access to information, functions, and services that are relevant to a person's work or personal interest. The aim of a portal is to bring information to a user in a consistent manner (Beringer *et al.*, 2001).

An example of an IT portal is an intranet portal. An intranet portal can be described as a dynamic and personalised gateway to a network accessible resource that belongs exclusively to an organisation (Pickett & Hamre, 2002). According to Benbya, "portals can be viewed as a way to access disseminated information within a company" and a "portal is usually tailored according to the users' needs". A portal is a centralised viewpoint for specific information that is required by the user. Intranet portals can also be referred to as employee portals, enterprise intranet portals, corporate portals, business-to-employee portals and business-to-employees systems (Benbya, 2004).

According to Eckerson, there are four generations of intranet or business portals (Eckerson, 1999). His 1999 study revealed three generations of business portals however, Eckerson argued that there will be a fourth generation of business portals. This fourth generation will be a specialised business portal that focusses on a specific need within the business. Eckerson concluded that the following generations of business portals would be in use during his study.

- The first generation of portals assembles business references in a central place. This portal contains a business index which guides the user to the correct department or information required.
- The second generation personalises the business portal for each user. Each user has a username and password which is used to log in and generate a personalised view. This personalised view is configured for the user and contains only the information required by the user.
- The third generation is the interactive portal. This portal improves the employee's productivity using integration tools such as e-mails and project management tools. Interactive portals centralise all the tools required by a user which causes improved employee efficiency.
- The final generation of portals proposed by Eckerson is the specialised portal. A specialised portal is the same as an interactive portal except that it is business role specific. Each department within a business, for instance the human resources department, maintenance department or managerial department has their own interactive portal focussing only on the tools they require as a department.

The intranet portals in this case study are all specialised portals. They are used for operational and maintenance purposes. The portals can be viewed by any user within the business but are mainly utilised by the Infragas operations and maintenance personnel.

According to Siriginidi Rao, a portal has four core functions. These functions are connection, content, commerce, and community. Connection refers to the link between the user and information. Content refers to the information that is available to the user. Commerce includes the services that are rendered to users through the portal. Finally, community refers to the common interest of the people who access a portal (Rao, 2001).

Arthur Tatnall differentiates between the following types of portals (Tatnall, 2005):

- **General or mega portals** – these portals aim to provide the user with links to as many sites as they may require. These portals were developed from search engines. The success of a general portal is measured by the return of users. General portals are funded by advertising.
- **Vertical industrial portals** – these portals are focussed on a specific industry. The aim is to aggregate information for a group that is closely related to a certain industrial community. Vertical industrial portals specialise in business commodities or a common interest.
- **Horizontal industrial portals** – a portal can be described as horizontal when there is a large user base utilising the portal. These portals are also focussed on industrial communities. The industrial community is more localised and specific to the need of the company.
- **Community portals** – a community portal is set up and maintained by a certain community. The community can share a common location. The portal will have different aims and objectives depending on the community needs.
- **Enterprise information portals** – enterprise or corporate information portals are used by various businesses as the starting point for their intranet. An enterprise information portal is designed for business to employee interaction and to enable employees to access and share information within the company. According to Tatnall, enterprise information portals may include the following facilities: "categorisation of information available on the intranet, a search engine covering the entire intranet, organisational news, access to e-mail, access to common software applications, document management, links to internal sites and popular external web sites, and the ability to personalise the page." (Tatnall, 2005).
- **E-marketplace portals** – this portal extends the enterprise portal by expanding the company's services outside of the company. This could include services such as ordering, tendering and supplying of goods.
- **Personal/mobile portals** – these portals are available on mobile platforms. Information on mobile portals is in a compact form and provides users with a summary.
- **Information portals** – information portals can easily fall into any of the other categories, but the main aim of an information portal is to provide information on a specific subject.
- **Specialised/niche portals** – these portals focus on a specific target group, for example they can focus on a specific age group or gender.

An overview of quality and monitoring overview of portals follow.

2.2.2 Portal quality

Wang and Strong conducted a study to develop an information quality framework from a consumer's viewpoint. This study compiled the elements of information quality into four categories. These categories are accuracy, objectivity, believability, and reputation. Fifteen elements were categorised into these four categories (Wang & Strong, 1996). The information quality groupings are shown below:

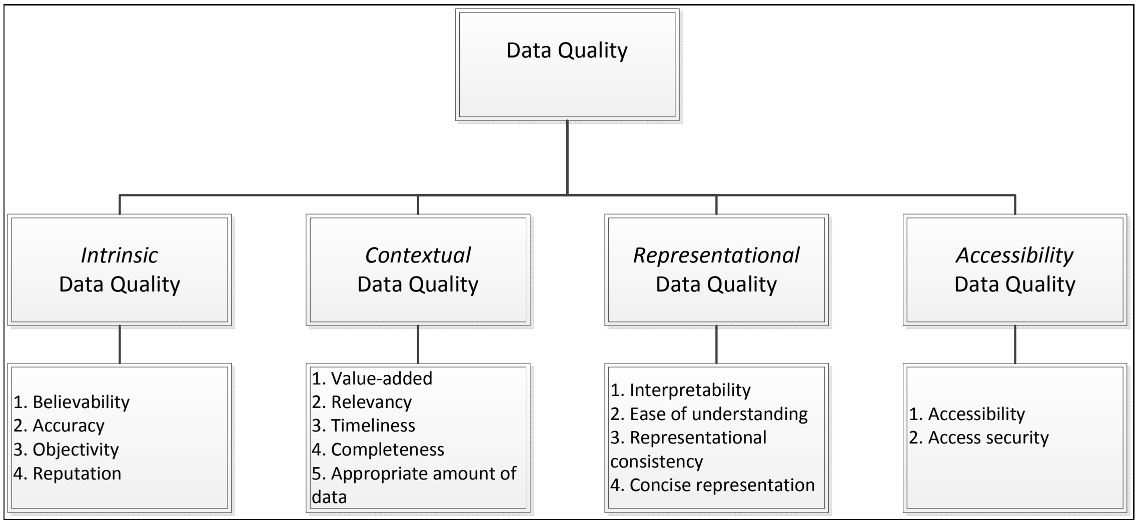


Figure 2: Data quality (Wang & Strong, 1996)

Wang and Strong's study concluded that intrinsic data quality is not only focussed on accuracy and objectivity, which was a focus for portal developers, but also believability and reputation. Contextual data quality is not a primary focus for developers. Their study concluded that the data which is represented must suit the needs of the consumer (Wang & Strong, 1996).

Representational data is split into two parts. The first is the format of the data which includes concise and consistent representation. The second is the meaning of the data which includes the interpretability and ease of understanding. Wang and Strong found that the representation for a consumer focussed on the conciseness and consistency of the representation. The data represented must be reliable and in the format that the user requires. Representation also focusses on the interpretability and ease of understanding of the information (Wang & Strong, 1996).

Klein executed a study focussed on five of Wang and Strong's elements (Klein, 2002). These elements were accuracy, completeness, relevance, timeliness, and amount of data. Klein's study revealed the factors that made up each of these elements. The elements with their factors follow in Figure 3:

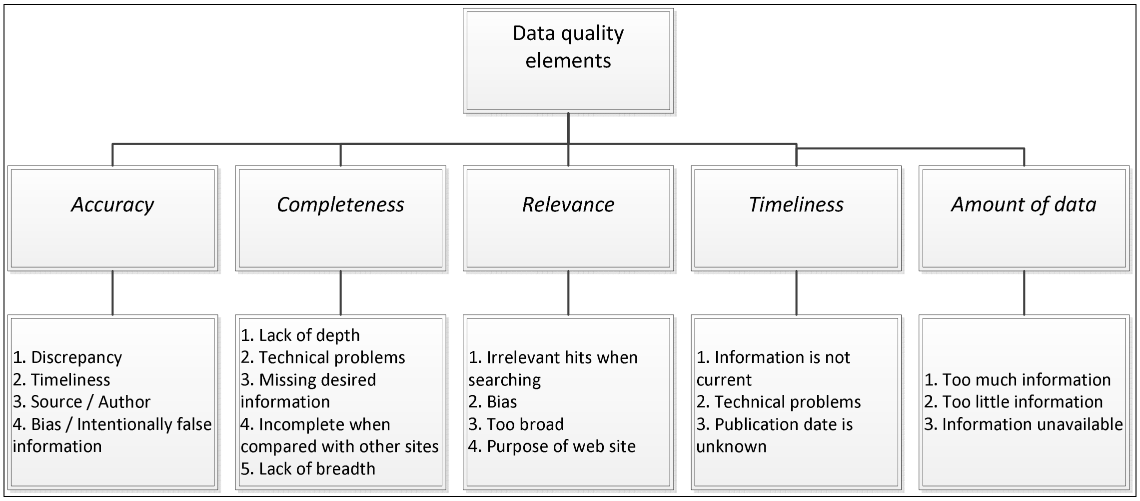


Figure 3: Factors of data quality elements (Klein, 2002)

These factors were found to influence a consumer's view towards information. Klein only looked at five elements of Wang and Strong's fifteen. These were considered during the design of the experimental investigation.

Van Zeist and Hendriks specified a quality framework for software quality (Van Zeist & Hendriks, 1996). This was part of the quality in information technology (QUNIT) project which started in 1991. They created the framework from the results of the first QUINT project results. The framework was an extension from ISO 9126, the model of software quality.

The model proposed by Van Zeist and Hendriks consisted of six quality characteristics. These characteristics were functionality, reliability, efficiency, usability, maintainability, and portability. Each of the characteristics has sub-characteristics which are shown below (Van Zeist & Hendriks, 1996):

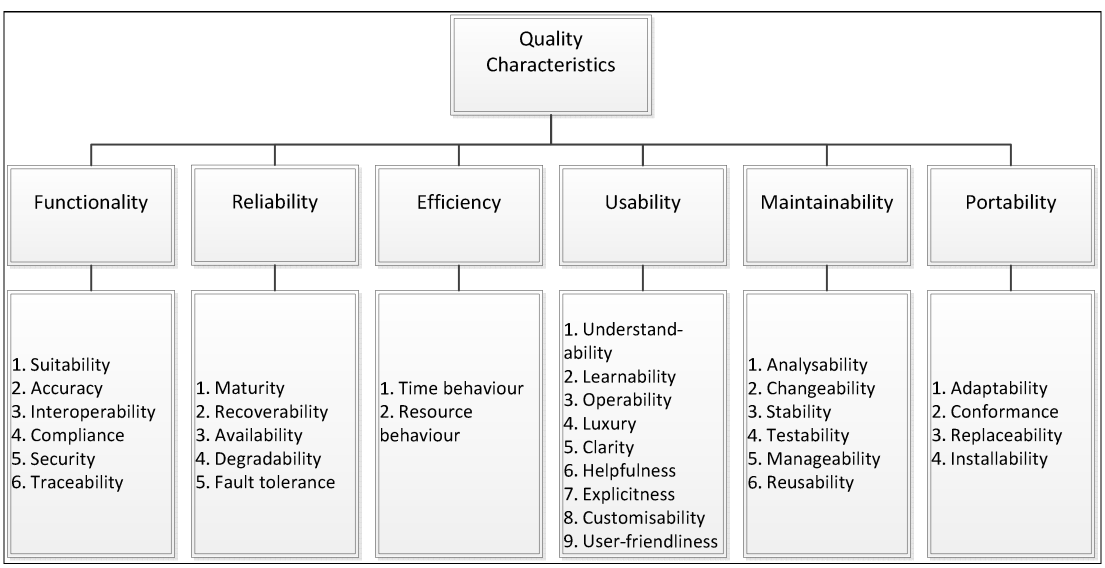


Figure 4: Van Zeist and Hendriks' quality framework (Van Zeist & Hendriks, 1996)

Leung applied Van Ziest and Hendriks' extended ISO model to intranets in a study that verified which factors are important in intranet portals. The study revealed the importance ranking of the quality characteristics of the extended ISO model. The study was compiled on intranet users' feedback (Leung, 2001). The importance ranking of the quality characteristics are as follows:

Quality Characteristic	Ranking
Reliability	1
Functionality	2
Efficiency	3
Usability	4
Maintainability	5
Portability	6

Table 1: Leung's importance ranking of quality characteristics (Leung, 2001)

Leung's study also revealed the importance rankings of the sub-characteristics. The intranet users rated the quality sub-characteristics as follow (Leung, 2001):

Quality sub-characteristics	Ranking
Availability	1
Accuracy	2
Security	3
Suitability	4
Time behaviour	5
Luxury	6
Clarity	7
User-friendliness	8
Fault tolerance	9
Recoverability	10
Operability	11
Compliance	12
Learnability	13
Analysability	14
Understandability	15
Manageability	16

Quality sub-characteristics	Ranking
Maturity	17
Adaptability	18
Explicitness	19
Stability	20
Resource behaviour	21
Reusability	22
Customisability	23
Helpfulness	24
Interoperability	25
Replaceability	26
Changeability	27
Installability	28
Conformance	29
Traceability	30
Degradability	31
Testability	32

Table 2: Leung's sub-characteristics' importance ranking (Leung, 2001)

The quality characteristics from Leung's study will be measured against the results found in the experimental investigation. Knight and Burn compared twelve information quality frameworks in order to identify common characteristics. The twelve information quality frameworks are listed below (Knight & Burn, 2005):

- Wang & Strong, 1996 – a conceptual framework for data quality
- Van Ziest & Hendriks, 1996 – an extended ISO model
- Alexander & Tate, 1999 – applying a quality framework to web environment
- Katerattanakul & Siau, 1999 – information quality of an individual web site
- Shanks & Corbit, 1999 – semiotic-based framework for data quality
- Dedeke, 2000 – conceptual framework for measuring information system quality
- Naumann & Rolker, 2000 – classification of information quality metadata criteria
- Zgu & Gauch, 2000 – quality metrics for information retrieval on the World Wide Web
- Leung, 2001 – adapted extended ISO model for intranets
- Kahn, Stong & Wang, 2002 – mapping IO dimensions into the PSP/information quality model.
- Eppler & Muenzenmayer, 2002 – conceptual framework for information quality in the web site context
- Klein, 2002 – 5 Information quality dimensions

Knight and Burn compared the information quality frameworks. The top five dimensions from all the frameworks were accuracy, consistency, security, timeliness, and completeness (Knight & Burn, 2005). These dimensions will be measured against the results of the experimental investigation.

2.2.3 Portal measurement

Intranet efficiency and effectiveness model (IEEM)

Jacoby developed the intranet efficiency and effectiveness model (IEEM) for efficiency effectiveness measurement of intranet portals. This model is a theoretical approach and provides a framework which groups information by family types. These family types consist of three domains; these are the front end, the back end, and the people, process and technology domain (Jacoby, 2003).

The front end domain addresses user factors such as accessibility and site navigation. The back end domain focusses on site-based factors such as information search and infrastructure. The people, processes and technology domain deals with knowledge worker-based factors. Information regarding how well the portal supports the business model forms part of the knowledge worker-based factors. Each domain is divided further into three different types of metrics. These are hard, soft, and derived metrics (Jacoby, 2003)

Hard metrics consist of factors which can be directly interpreted: this includes server log files or the number of visitors on a portal. Soft metrics are subjective and qualitative factors: surveys and questionnaires are examples of soft metrics. Derived metrics include both hard and soft metrics. This information, such as speed of the market and loyalty to the company, can be gathered from a businesses' history. An example of the model is displayed in figure 5. Here all the domains, factors and metrics come together and demonstrate which factors are difficult to measure (Jacoby, 2003):

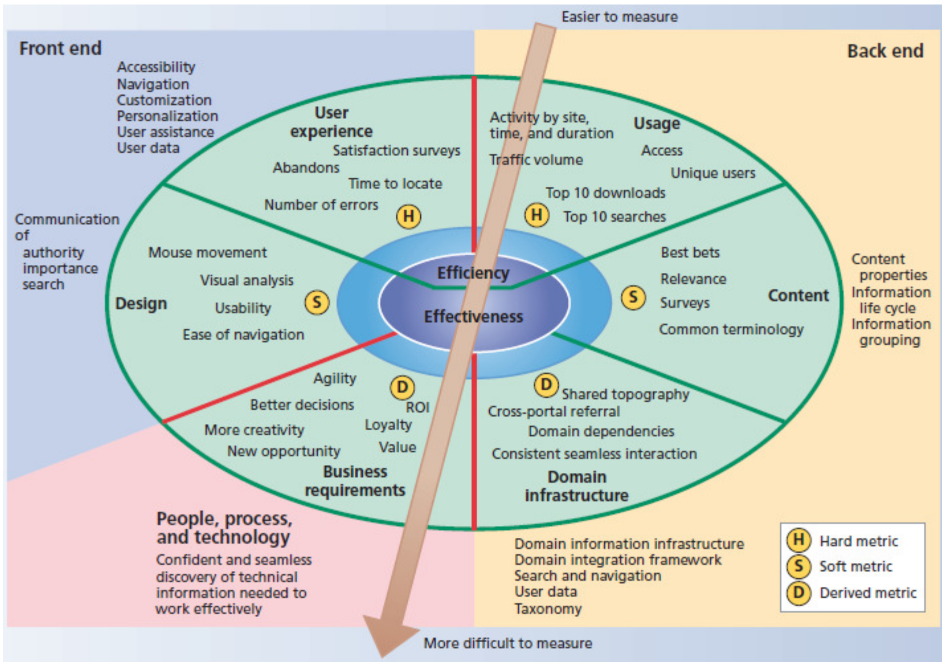


Figure 5: The IEEM example (Jacoby, 2003)

Technical acceptance model (TAM)

Davis developed the technology acceptance model (TAM) to determine the user behaviour of end users in computer technologies (Davis *et al.*, 1989). Davis developed his model using the Fishbein model as its foundation. The Fishbein model is a theoretical psychology model of human behaviour (Davis, 1985). The primary identification areas of TAM are perceived usefulness and perceived ease of use. David defines these two areas as follows:

- "Perceived usefulness is defined as the prospective user's subjective probability that using a specific application system will increase his or her job performance within an organizational context." (Davis *et al.*, 1989).
- "Perceived ease of use refers to the degree to which the prospective user expects the target system to be free of effort." (Davis *et al.*, 1989).

Davis' technology acceptance model also consists of external variables, which includes attitude toward using, behavioural intention to use, and system usage. An overview of the technology acceptance model is displayed in figure 6:

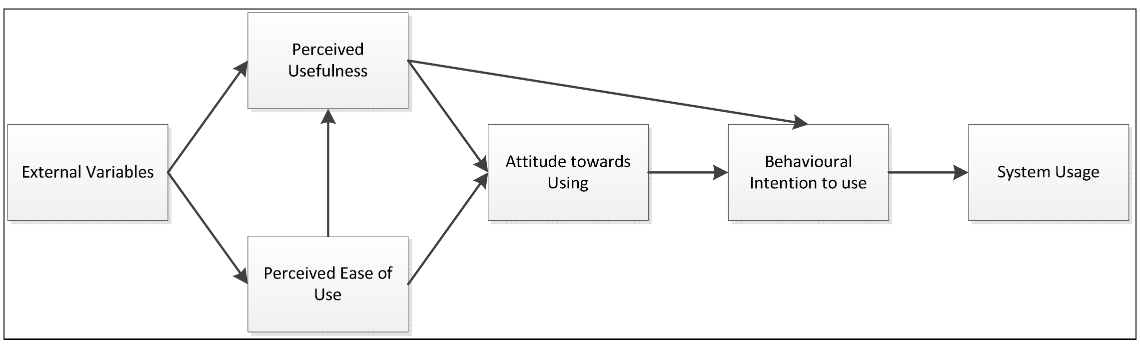


Figure 6: Davis' technology acceptance model (Davis, 1985)

Using Davis' TAM as a foundation, Money and Turner developed a revised TAM (Money & Turner, 2004) that was more focussed on knowledge management systems. The development of this revised TAM eliminated attitudinal and external variables. Attitude towards using was found to be linked with both perceived usefulness and behavioural intention to use (Davis *et al.*, 1989). Money and Turner removed external variables as their model did not investigate any inputs into perceived usefulness and perceived ease of use. The revised Money and Turner TAM focusses only on four sections as seen in figure 7.

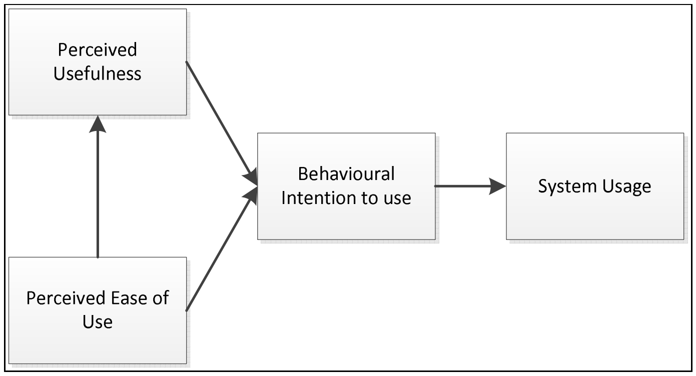


Figure 7: Money and Turner's technology acceptance model (Money & Turner, 2004)

The Money and Turner study revealed relationships between these four sections. Money and Turner's TAM model states the following (Money & Turner, 2004):

- H1: Perceived usefulness will exhibit a significant positive relationship with behavioural intention to use.
- H2: The effects of perceived ease of use on behavioural intention will be significant and positive but slightly mediated by perceived usefulness.
- H3: Perceived ease of use will have a smaller but significant positive direct relationship with behavioural intention to use when perceived usefulness is controlled for.
- H4: Behavioural intention will have a significant positive relationship with system usage.
- H5: Perceived usefulness and perceived ease of use will have a significant combined positive relationship with behavioural intention.
- H6: Perceived usefulness and perceived ease of use will have a significant combined positive relationship with system usage.

These six relationships will be measured against the results found in the experimental investigation.

2.3 Log analysis

A log analysis is defined as a program that collects log data from a web site or search engine and provides an overview of the usage or browsing history (Agosti *et al.*, 2012).

One of the first log analyses was done in 1981 by Tolle. The online computer library centre (OCLC) conducted a study which analysed the usage of online catalogues using transaction log analyses and group interviews. The study was performed to ascertain which functions or sections were being used most. The study revealed that the design of a system must be checked against actual usage recorded in a log analysis. This is still valid today and helps to improve and increase systems' productivity (Tolle, 1983).

The maintenance information portals used in the Infragas environment are classified as web search engines (WSE). A WSE is a web page or portal that deals with the representation, storage, organisation, and access of information (Agosti *et al.*, 2012). At Infragas this information entails maintenance and process information such as that related to alarms, deviation and plant performance. A user's experience with information can be divided into three parts.

The first is the way in which a user requests information on a web site or portal. Is there a direct link or is the user made to go through various steps to gain access to the information? The second aspect is how a user interacts with the information. Is the information displayed in the correct format? The final part is the manner in which the information is organised by the portal. Together these provide a general understanding of the user's interaction with the information in a web portal. The details gathered from these three features can be used to improve the web site or portal in terms of the presentation and organisation of the information (Agosti *et al.*, 2012).

Sen created a web forensic framework for web site or portal logging. The model consists of five levels (Figure 8) of structure measurement in order to evaluate web sites and portals. Each of the levels measures a different aspect of the web site or model (Sen *et al.*, 2006). The model was adapted from the Sterne measuring model (Sterne, 2002).

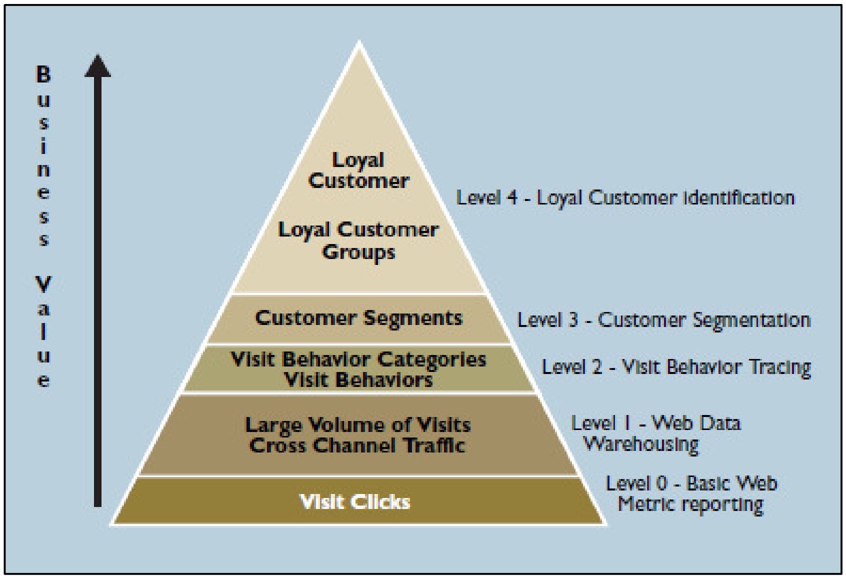


Figure 8: Sen's Web forensic pyramid (Sen *et al.*, 2006)

The lowest level is basic web metric reporting. This basic level of reporting measures information such as page dwell time or which pages users are viewing. These metrics also include usernames, IP addresses and access information. Various methods can be used to trace these metrics; these include null logging servers, server-based log files, server-based plug-ins, and server-based network sniffers. Basic web metrics were measured in this study on the Sasol Infragas portals.

The first level is web data warehousing. Some web sites may store large amounts of access information. This level measures how well information is organised and stored. The Infragas portals' client base is small and therefore this level of the framework will not be included in the study.

The second level of the forensic framework model is visit behaviour tracing. The purpose of this level is to measure the visitors' or users' behaviour in the different sections of a web site or portal. One method of tracing behaviour is foot printing. The users' IP address, date, time, dwell time, referred page, and page-ID will be traced while the user is on the page or portal. This will determine the user's route while utilising the web page or portal. This method will be used in the Sasol Infragas case study. This information will reveal which pages on the portal are utilised the most and which pages are utilised the least.

The third level is customer segmentation. At this level information is collected regarding what information certain users choose to utilise. The purpose of this level is to group customers into same interest groups. In large organisations, this can improve web page and portal structure by displaying only the information required by the users in the same interest group.

The highest level is loyal customer identification. This identification is used in commercial web sites or portals for registered users. This tool is used in marketing and gives certain users specials privileges. This tool was not used in this study.

Basic metric reporting and visit behaviour tracing were the two measurements examined in this study. Portal utilisation and behaviour form the two primary sections of this study.

Agosti identified a few problems in web analysis (Agosti *et al.*, 2012). These problems were addressed in the design of the portal usage tracking for this study. The problems are the following:

- disorganised system logs. Logs were not stored in a proper manner and were not structured.
- complexity of analysis. The analysis was not properly set up and therefore gathering information is difficult.
- incomplete data. Not all the parameters were initially set out, thus causing information loss.
- incompatible systems. Not all systems use the same method of access tracking and create different log formats. These formats need to be revised frequently in order for the data to be analysed correctly.

An overview of the case study plant was obtained and contained information regarding intranet portals, portal quality characteristics, and portal measuring. This information assisted with the research objective of investigating the interaction between Infragas personnel and maintenance information systems and the general attitude of personnel towards these systems. The investigation process is designed in the next chapter. A detailed layout of the measuring methods used in the experimental design follows.

CHAPTER THREE

EXPERIMENTAL DESIGN

3.1 Introduction

The experiment was designed according to the objectives of this study. The aims of the study were to measure the interaction between Infragas employees and the maintenance information systems and to understand the mind-set of Infragas employees towards these systems. The experiment design was divided into two sections.

The first section is to investigate the interaction of Infragas personnel with maintenance information systems. Web log analysis was the measuring tool selected for this task. Web log analysis was implemented on the maintenance information systems to achieve the following objectives:

- Measuring the efficiency of maintenance information systems in the Sasol Infragas environment by means of interaction, focussing on the Sasol ATR and Rectisol plants in Sasolburg.
- Measure the utilisation of maintenance information systems, including the frequency the different maintenance information systems at which they are utilised and which systems are most or least utilised.

The second section of the experiment was designed to determine the general view of personnel towards the maintenance information systems. This was accomplished with the use of a questionnaire. The questionnaire assisted to achieve the following objectives:

- Investigate the general view of maintenance and operational personnel towards maintenance information systems in the Sasol Infragas environment.
- Investigate whether the various maintenance information systems add value to the Sasol Infragas business environment.
- Investigate whether the maintenance and managerial personnel see the maintenance information systems as having improved plant availability and reliability.

The target groups for this questionnaire was the maintenance and operational personnel of ATR and Rectisol who uses the various intranet portals on a daily basis as maintenance information systems. It is medium-sized group consisting of 80 employees. Maintenance information systems have been implemented at these facilities for more than two years. All employees have access to the maintenance information systems. An overview of the design of the portal usage measurement and questionnaire follows.

3.2 Actual portal usage measurements

The intranet portals are commissioned on two Sasol IM servers which are managed by an external service provider. The Sasol IM servers are the alarm management and deviation management portal server and the overall equipment efficiency portal server. The servers are managed by a third party for security and maintenance reasons. Information is gathered from various data collectors and is compiled and displayed on the intranet portal. The data collection architecture (Figure 9) consists of four data collection servers which push information to the various intranet portal servers.

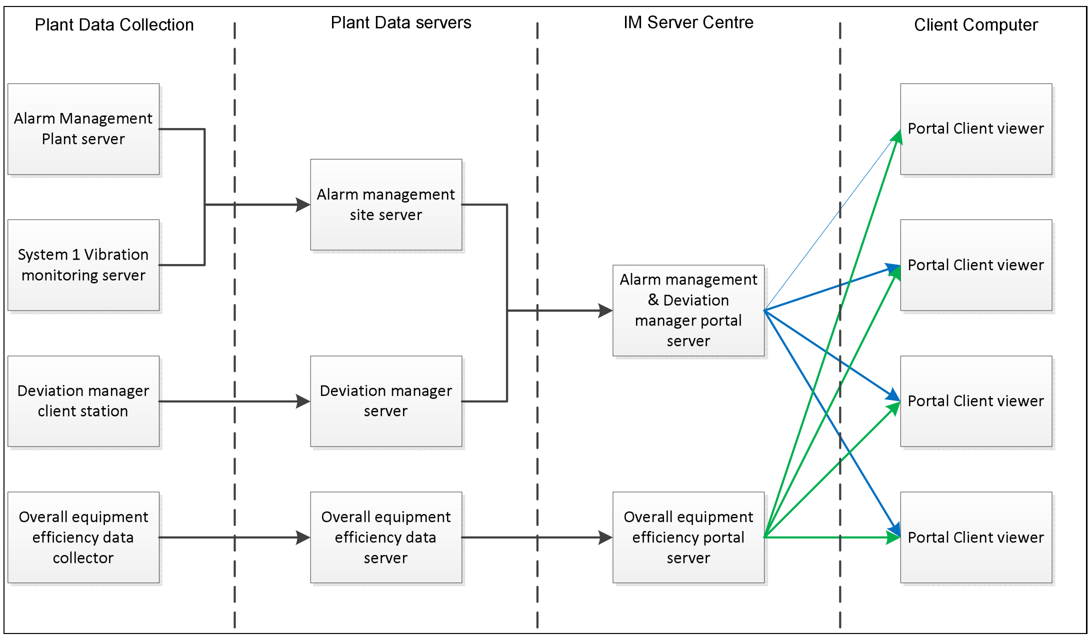


Figure 9: Data collection architecture

After approval was obtained from all the discipline managers, a log analysis was implemented on the alarm management and deviation management portal server. The approval document is located in Appendix C. Discipline managers were informed that their employees' actions on the maintenance information systems would be logged. The employees were not aware that their actions on the maintenance information systems were being logged. This was done in order to capture information in a normal working environment. The result might have been altered if the employees had known that their actions were being logged.

A log analysis was done on the alarm management and deviation management portal server. Each event was set up to capture the following information:

- date
- time
- user ID (user identification tag)
- portal name

- portal specific page

An example of a data entry in the log file is as follows:

12/07/2013,08:49:19,SASOLSCD\HICKMAID,Config_ATR,ATR Main

This information gives the actual usage per user, as well as a footprint of where the user was in the portal and how much time was spent on a specific page. The analysing logs captured data for a period of 35 days. Infragas shift systems consist of five shifts, each working a seven day shift. Data was captured for 35 days to complete one shift cycle.

The information gathered from the log analysis was designed to measure the following information:

- which personnel are utilising the maintenance and operational portals.
- what the average time spent on the different portals and portal specific pages is.
- which maintenance and operational portals are utilised most and least.
- which disciplines spend the most and least time on the different portals.

3.3 Questionnaire

The questionnaire was designed to gather personnel's views towards maintenance information systems. The questionnaire (Appendix B) consists of five sections (Section A – E).

Section A consists of biographical information. These questions gather information about the individual completing the questionnaire.

Section A:

Please answer with a **X**.

Department:

Process		Electrical:		Control Systems		Mechanical	

Age: ______________

Gender: ______________

Years' experience: ______________

Years at Sasol: ______________

Post level: ______________

Section B was designed according to the Money and Turner adapted technology acceptance model (TAM) (Money & Turner, 2004). Money and Turner's study focusses on decision support systems (DSS), where this study focusses on maintenance portals. The study was done by means of a questionnaire which consisted of multiple choice questions. The North West University statistical department reviewed the questionnaire and implemented some changes (Fourie, 2013). The standard five-point Likert scale was used in the first revision of the questionnaire (Losby & Wetmore, 2012):

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

After the questionnaire validation was completed, a decision was made to remove option three. Option three was removed so that no neutral answers could be given. Money and Turner's adapted technology acceptance model was adapted from the Davis technology acceptance model (Davis *et al.*, 1989). Section B consists of the questions from Money and Turner's technology acceptance test based on maintenance portals.

Section B:

Evaluation Scale:

(1)Strongly disagree (2) Disagree (3) Agree (4) Strongly agree

Any reference to maintenance portals includes Infragas Maintenance and DPM portals.

Please answer with a **X**.

Perceived usefulness

Using maintenance portals

1.	a) gives greater control over work?	1	2	3	4
2.	b) improves work performance?	1	2	3	4
3.	c) enables to accomplish tasks more quickly?	1	2	3	4
4.	d) supports critical aspects of work?	1	2	3	4
5.	e) improves work efficiency?	1	2	3	4
6.	f) improves the quality of work?	1	2	3	4
7.	g) makes it convenient to accomplish our strategies and goals?	1	2	3	4
8.	h) demonstrates inventiveness to our business partners?	1	2	3	4
9.	Overall, I find maintenance portals useful for work.	1	2	3	4

Perceived ease

Using maintenance portals

10.	a) is simple?	1	2	3	4
11.	b) is easy to understand?	1	2	3	4
12.	c) is intuitive?	1	2	3	4
13.	d) is flexible?	1	2	3	4
14.	e) does require a lot of effort?	1	2	3	4
15.	f) does require studying a manuals?	1	2	3	4
16.	g) gives information easily?	1	2	3	4
17.	Overall, I find maintenance portals easy to use?	1	2	3	4

Behavioral Intension

18.	I think that using maintenance portals is a good idea.	1	2	3	4
19.	I think that using maintenance portals is beneficial.	1	2	3	4
20.	I think that by using maintenance portals we would achieve certain strategic advantages.	1	2	3	4
21.	I intend to use maintenance portals periodically in the future.	1	2	3	4
22.	I intend to use maintenance portals routinely and regularly in the future.	1	2	3	4
23.	I intend to recommend the use of maintenance portals to our business partners.	1	2	3	4
24.	Overall, I have a positive perception towards using maintenance portals.	1	2	3	4

Actual use

25.	I use maintenance portals periodically.	1	2	3	4
26.	I use maintenance portals routinely and regularly.	1	2	3	4
27.	Our work is fully integrated with maintenance portals.	1	2	3	4
28.	I often recommend maintenance portals to our business partners.	1	2	3	4

Section B was divided into four sections: perceived usefulness, perceived ease, behavioural intention and actual use. An internal consistency (α) was performed on each of these sections by means of the Cronbach alpha test. This test is done to measure whether questions in a section correlate to the heading of each section. The Cronbach scale ranges from 0.00 to 1.00 (Brown, 2002). The closer the Cronbach alpha test results are to 1.00, the higher the internal consistency to the group. According to Money and Turner, an acceptable internal consistency value is between 0.6 and 0.7 when using this method of technology acceptance testing (Money & Turner, 2004).

A correlation analysis will be done between the questionnaire results and the Money and Turner technology acceptance model using the Pearson correlation coefficient (Money & Turner, 2004). The results will show whether there is a relationship between the results found by Money and Turner and the results gathered from the Infragas environment.

Section C contains general questions which correlated employees' views regarding maintenance portals and their influence towards plant and Infragas performance.

Section C:

Evaluation Scale:

(1) Strongly disagree (2) Disagree (3) Agree (4) Strongly Agree

Please answer with a **X**.

1.	Do maintenance portals add value to Infragas?	1	2	3	4
2.	Do maintenance portals improve plant availability?	1	2	3	4
3.	Do maintenance portals improve plant reliability?	1	2	3	4
4.	Maintenance portals are used on a daily basis?	1	2	3	4
5.	Are maintenance portals beneficial to Infragas?	1	2	3	4

The results gained from these questions provide a general indication of employees' views on maintenance portals and their influence at Infragas.

Section D gathers information about portal quality characteristics. The questionnaire asks to rank six quality characteristics from highest to lowest priority. The ratings are from one (highest) to (six) lowest.

<u>Section D:</u>

Rate the following portal quality characteristics from highest (1) to lowest (6)?

Efficiency: __________

Functionality: __________

Maintainability: __________

Portability: __________

Reliability: __________

Usability: __________

The results gathered from this section were then measured against the results of the study by Leurn based on the rating of specific portal characteristics (Leung, 2001). The comparison with the Leurn study gave an overview of maintenance portal quality characteristics in the Infragas environment. The results were also recorded which quality characteristics were most important to each discipline. A discussion of the results and recommendations follows in chapters four and five.

Section E allowed questionnaire participants to add further comments regarding maintenance portals in the Infragas environment. These comments were represented in the results and discussion section.

The experimental design consists of two segments. The first segment contains the maintenance information system users' actual usage tracking. The second segment is made up of the design of the questionnaire that Infragas employees were asked to complete. The next chapter contains the results and findings that were gathered from the experiments that were designed in this chapter. An overview of all the results is revealed and a detail discussion of the results follows in chapter five.

CHAPTER FOUR

FINDINGS

The results of the study were divided into two sections. The first section contained the actual usage results of the Sasol Infragas maintenance portals. The second section contained the findings from the questionnaire given to Sasol Infragas personnel. The results of the questionnaire were compared with the technology acceptance model. These results contain the general view of the maintenance information system users. The results concerned with the quality characteristics were measured against the results found by Leung. The final part of the questionnaire results consist of the comments made by the participants.

4.1 Actual usage results

A log analysis was completed on the Sasol Infragas maintenance portal. The aim of the log analysis was to ascertain whether the maintenance portal was being utilised and by whom. The maintenance portal contains information from both the ATR and Rectisol plants. The log analysis from the maintenance portal was gathered for a period of 35 days.

4.1.1 Maintenance portal page access counts

The Infragas maintenance portal consists of a total of 15 specific pages. The ATR plant has 10 of these pages. The results revealed the following access counts and average time spent on each page for the ATR plant portal (Figure 10). Access counts indicate how many times the specific page was accessed over the sample period.

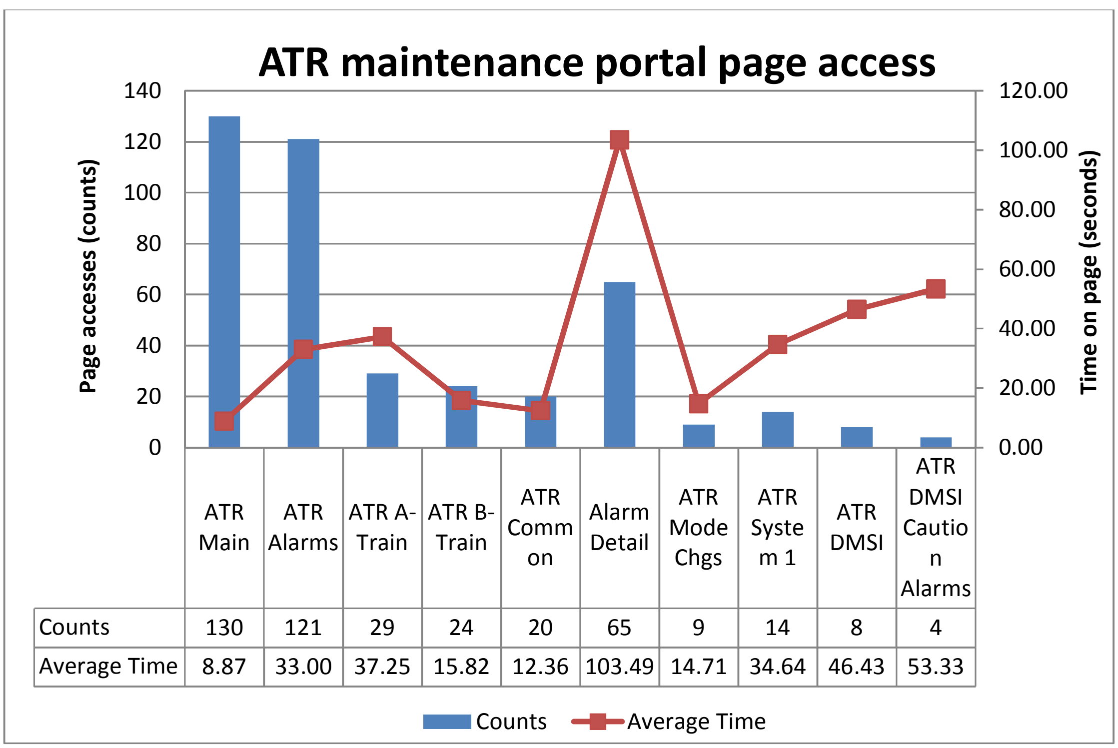
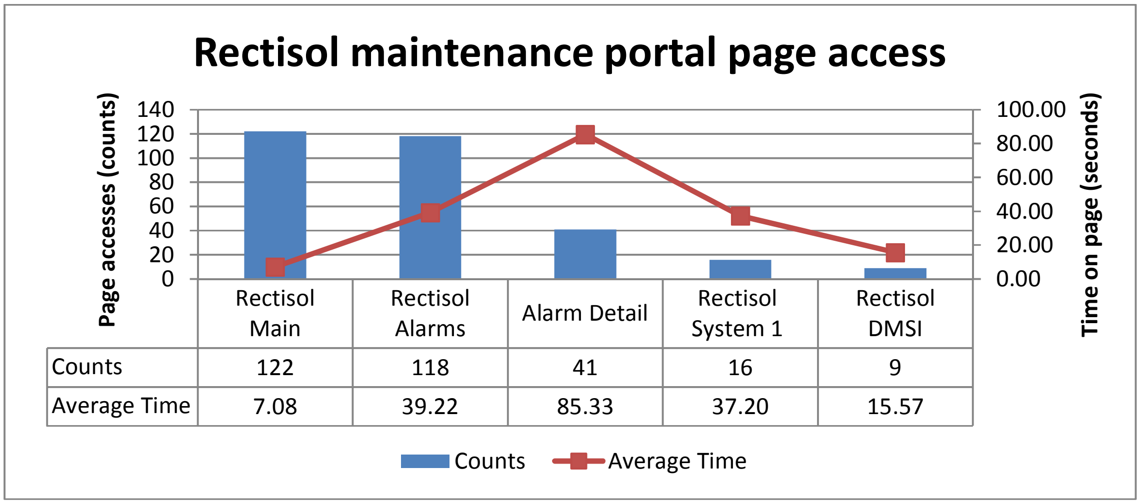


Figure 10: ATR maintenance portal page access counts and average access time

The Rectisol plant has the remaining five specific pages. The results revealed the following access counts and average time spent on each page of the Rectisol plant (Figure 11).



	Rectisol Main	Rectisol Alarms	Alarm Detail	Rectisol System 1	Rectisol DMSI
Counts	122	118	41	16	9
Average Time	7.08	39.22	85.33	37.20	15.57

Figure 11: Rectisol maintenance portal page access counts and average access time

4.1.2 Maintenance portal daily access counts

An analysis was done to calculate the average access counts of the Infragas maintenance portal per day (Figure 12). These access accounts are access to the maintenance portal irrespective of which pages were viewed by the personnel. The results were calculated using every access count by all employees, which include both day and operational personnel.

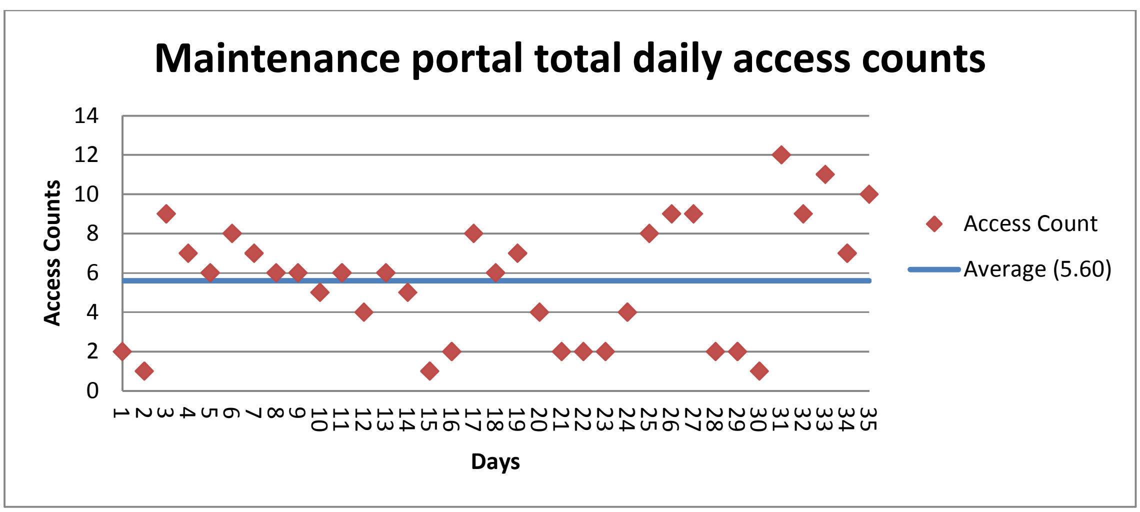


Figure 12: Maintenance portal total daily access counts

The average access counts for each day of the week were calculated for each week day of the sample period. The results revealed the following averages per day (Table 3). The sample period was the same period of 35 days, and so covered five weeks. Each day's average was calculated using an average of five access periods (weekdays).

Days	Access Counts
Monday	**7.6**
Tuesday	7.2
Wednesday	7.4
Thursday	6.8
Friday	5.2
Saturday	2.6
Sunday	***2.4***

Table 3: Maintenance portal average daily access counts

The daily access counts were calculated for the day personnel (Figure 13). This included all personnel with the exception of operational personnel. These access counts were counted irrespective of which pages the day personnel were viewing. Day personnel's working days are from Monday to Friday. The sample period is therefore only 25 days because of the exclusion of weekends. The red data points indicate that no access occurred for that specific day.

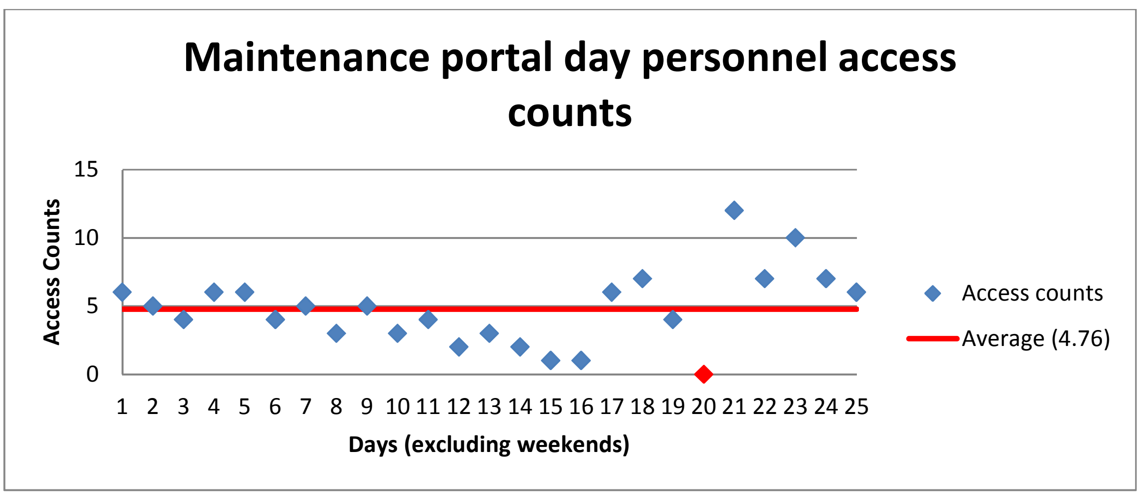


Figure 13: Maintenance portal day personnel access counts

Below is the average daily access count per weekday as calculated for day personnel (Table 4).

Days	Access Counts
Monday	**5.4**
Tuesday	5
Wednesday	**5.4**
Thursday	4.8
Friday	***3.2***

Table 4: Maintenance portal day personnel average daily access counts

A maintenance portal access count analysis for operational personnel (Figure 14) was complied. The red data points indicate no access counts for a specific day. The results were as follows:

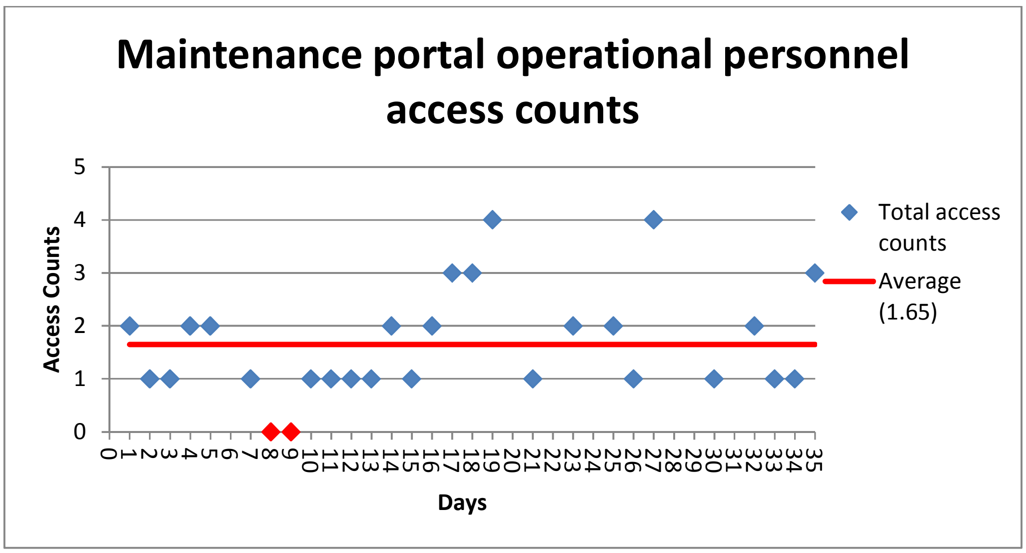


Figure 14: Maintenance portal operational personnel access counts

The average maintenance portal access counts per working day by operational personnel (Table 5) were determined. The results were as follows:

Days	Total counts
Monday	1.6
Tuesday	2
Wednesday	**1.8**
Thursday	**1.8**
Friday	**1.8**
Saturday	1.4
Sunday	***1.2***

Table 5: Maintenance portal operational personnel average daily counts

Plant-specific operational personnel access counts were also gathered. The total access counts for ATR operational personnel per day (Figure 15) revealed the following results. The red data points indicate no access for a specific day.

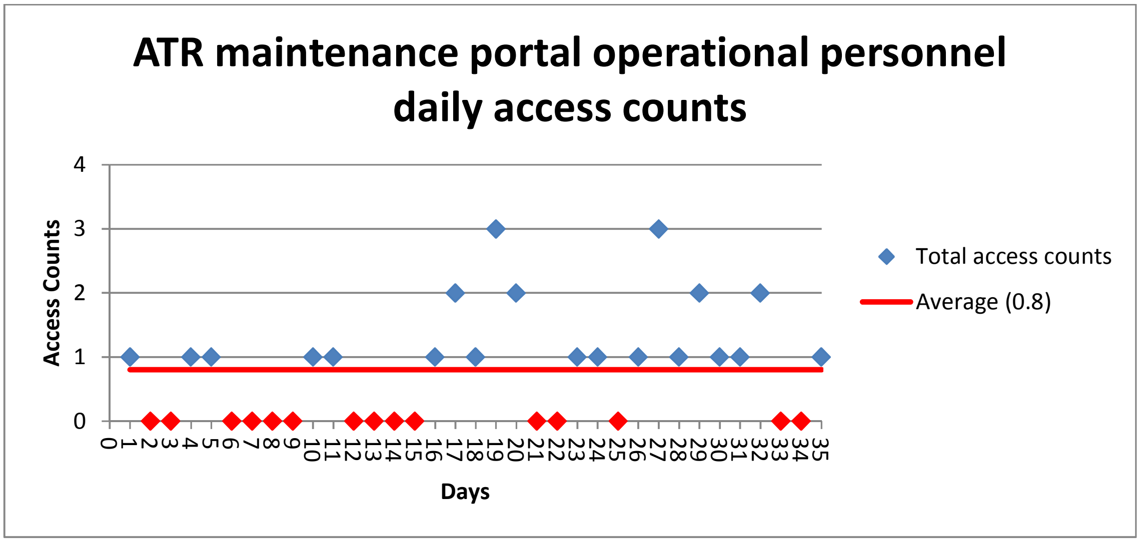


Figure 15: ATR maintenance portal operational personnel daily access counts

The average access counts per working day by ATR operational personnel on the maintenance portals (Table 6) are displayed below:

Days	Total counts
Monday	**1**
Tuesday	**1**
Wednesday	**1**
Thursday	**1**
Friday	***0.4***
Saturday	0.6
Sunday	0.6

Table 6: ATR maintenance portal operational personnel daily access counts

The total access count for Rectisol operational personnel per day (Figure 16) revealed the following results. The data points in red indicate no access for a specific day.

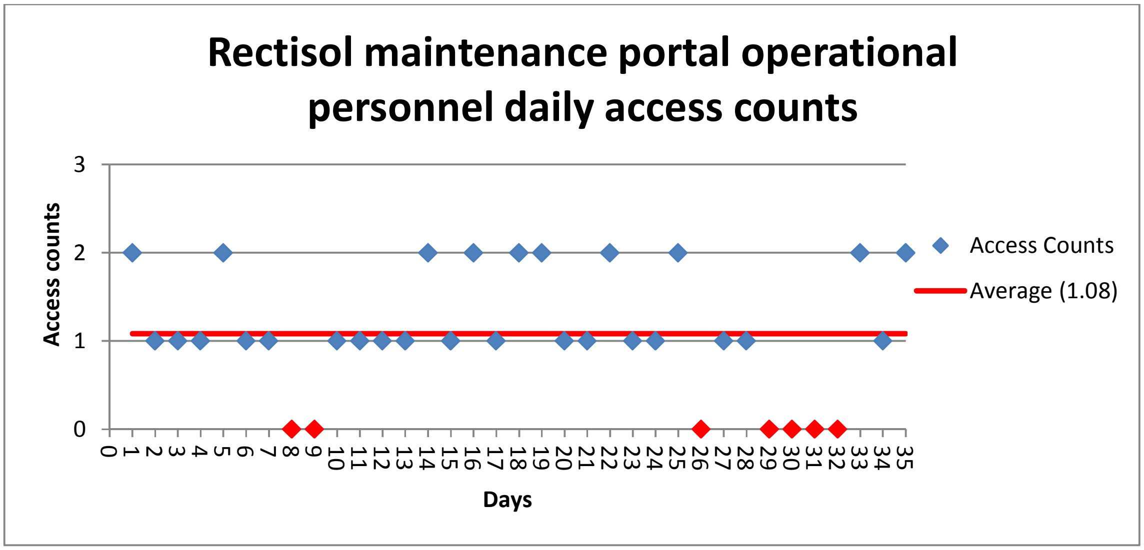


Figure 16: Rectisol maintenance portal operational personnel daily access counts

The maintenance portal average working day access count for Rectisol operational personnel (Table 7) is shown below:

Days	Total counts
Monday	***0.8***
Tuesday	1.2
Wednesday	**1.4**
Thursday	1
Friday	**1.4**
Saturday	1
Sunday	***0.8***

Table 7: Rectisol maintenance portal operational personnel daily access counts

4.1.3 Maintenance portal daily access times

The average daily access time per employee (Figure 17) was calculated. This is an indication of the average time spent on the maintenance portal daily. The average access time was calculated for all personnel who accessed the maintenance portal.

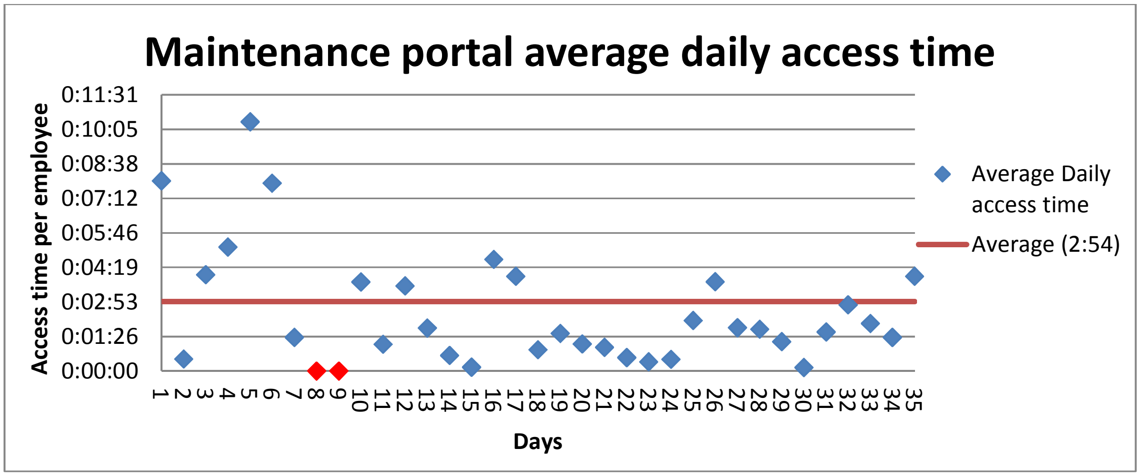


Figure 17: Maintenance portal average daily access time

The average access time per working day was calculated (Table 8). The average access time is displayed below:

Day	Time accessed
Monday	00:03:08
Tuesday	00:02:23
Wednesday	**00:03:52**
Thursday	00:03:04
Friday	00:02:14
Saturday	***00:00:45***
Sunday	00:02:33

Table 8: Maintenance portal average access time per working day

The average daily access time for day personnel (Figure 18) was calculated from the access log data. This is an indication of the average daily time spent on the maintenance portal by the day personnel.

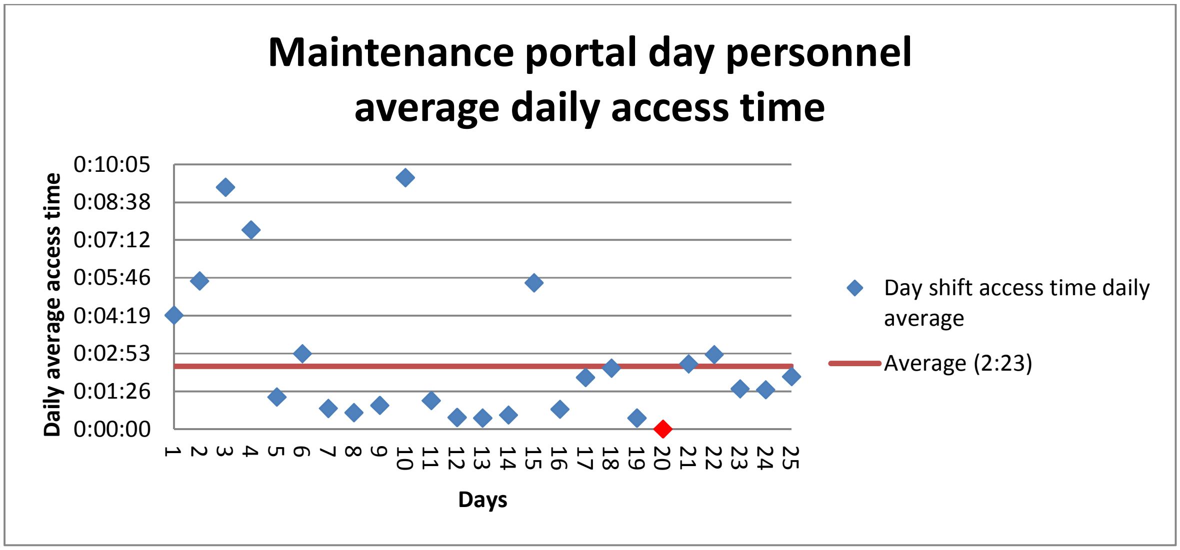


Figure 18: Maintenance portal day personnel average daily access time

The average access time for day personnel (Table 9) was calculated for each day of the week. The day personnel's work week compiled from Monday to Friday.

Days	Time accessed
Monday	00:02:45
Tuesday	00:02:35
Wednesday	00:02:06
Thursday	**00:02:47**
Friday	***00:01:32***

Table 9: Maintenance portal day personnel average daily access time

The average daily access time for operational employees (Figure 19) was calculated from the access log. This is an indication of the average time spent by the operation personnel on the maintenance portal daily. The two red indicators designate days when the maintenance portal was not accessed by operational personnel.

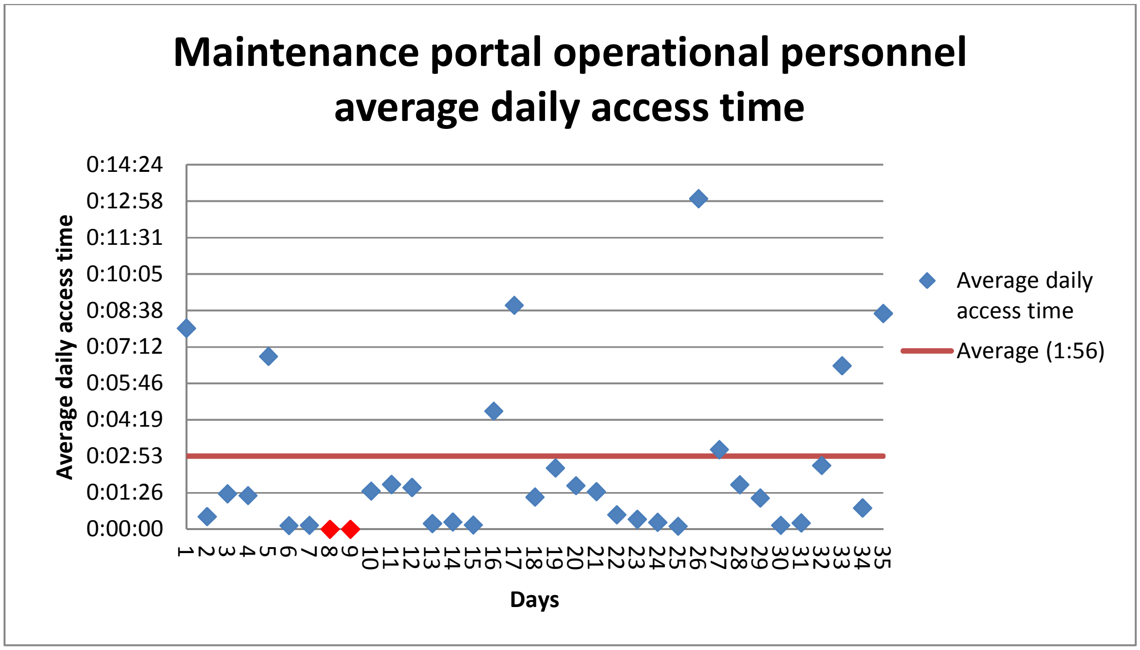


Figure 19: Maintenance portal operational personnel average daily access time

The average access time for operational personnel per working day (Table 10) was calculated. The results of the daily access time follow:

Days	Time accessed
Monday	00:04:17
Tuesday	***00:01:15***
Wednesday	**00:04:56**
Thursday	00:01:55
Friday	00:03:28
Saturday	00:02:27
Sunday	00:01:47

Table 10: Maintenance portal operational personnel average daily access time

Data collected from the log was also analysed to observe daily access time per plant. An analysis was done on average daily access time for the ATR and the Rectisol plants. The red indicators signify days that the maintenance portal was not accessed by ATR operational personnel. The average daily access time of the ATR plant operational personnel (Figure 20) is as follows:

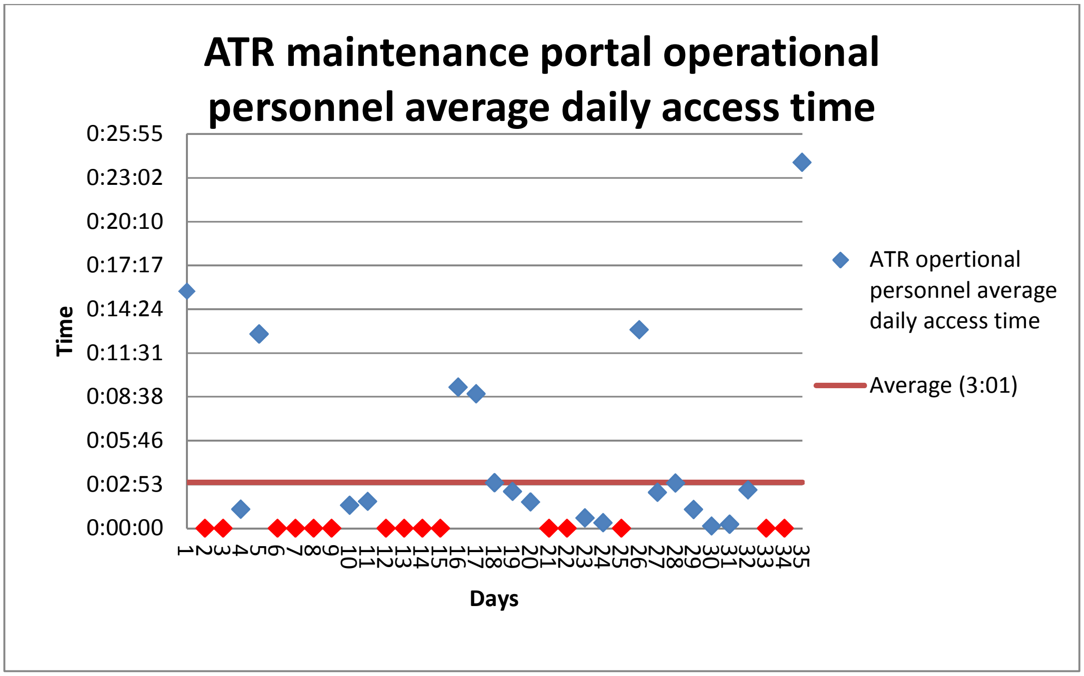


Figure 20: ATR maintenance portal operational personnel average daily access time

The average daily access time per week was calculated from the log analysis. The ATR operational personnel results (Table 11) follow:

Days	Time accessed
Monday	00:04:03
Tuesday	00:01:26
Wednesday	00:04:26
Thursday	***00:01:19***
Friday	**00:05:24**
Saturday	00:03:00
Sunday	00:02:01

Table 11: ATR maintenance portal operational personnel average daily access time

The average access time for the Rectisol operational personnel was captured from the log analysis. The red indicators specify days that the maintenance portal was not access by the Rectisol operational personnel. The average daily access time of the Rectisol plant operational personnel (Figure 21) follows:

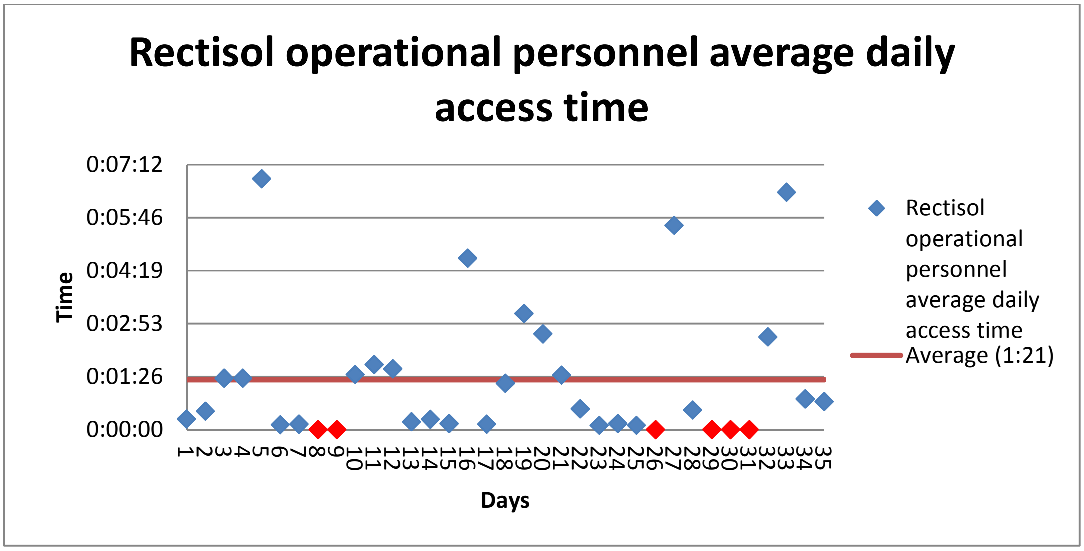


Figure 21: Rectisol maintenance portal average daily access time

The average daily access time per week was calculated from the log analysis. The Rectisol operational personnel result (Table 12) follows:

Days	Time accessed
Monday	00:00:39
Tuesday	00:01:21
Wednesday	**00:04:00**
Thursday	00:01:49
Friday	00:00:36
Saturday	***00:00:16***
Sunday	00:01:39

Table 12: Rectisol maintenance portal operational personnel average daily access time

4.1.4 Maintenance portal non-operational usage

Data was gathered from the log analysis to analyse the maintenance portal usage by non-operational personnel. These are all day personnel and only represent 25 days of the sample period. This includes managerial, instrumentation, electrical, mechanical, and process technical personnel. The results were as follows (Figure 22):

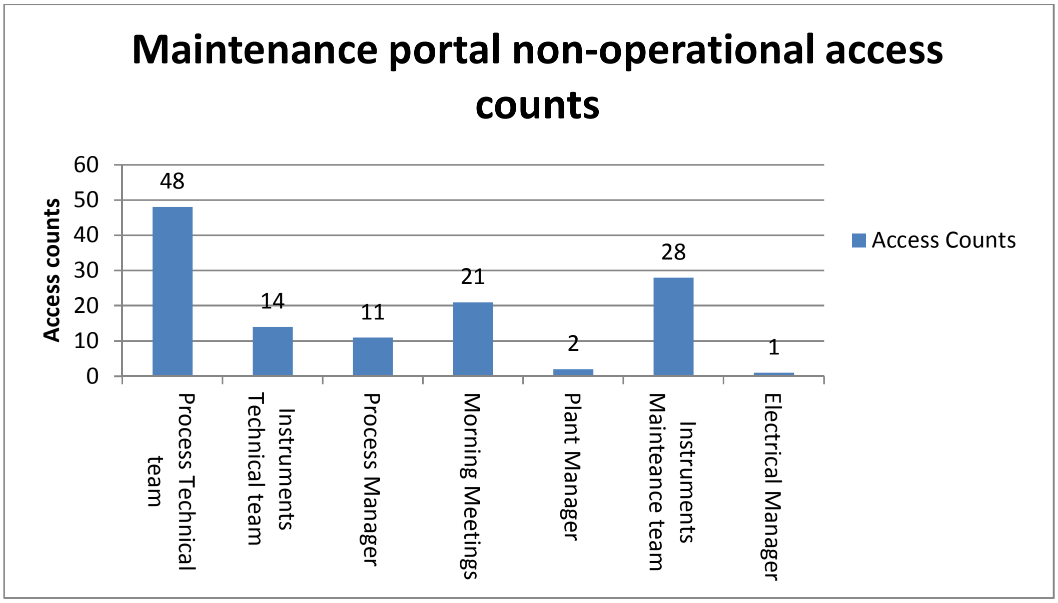


Figure 22: Maintenance portal non-operational access counts

The average time spent on the maintenance portal by non-operational personnel was as follows:

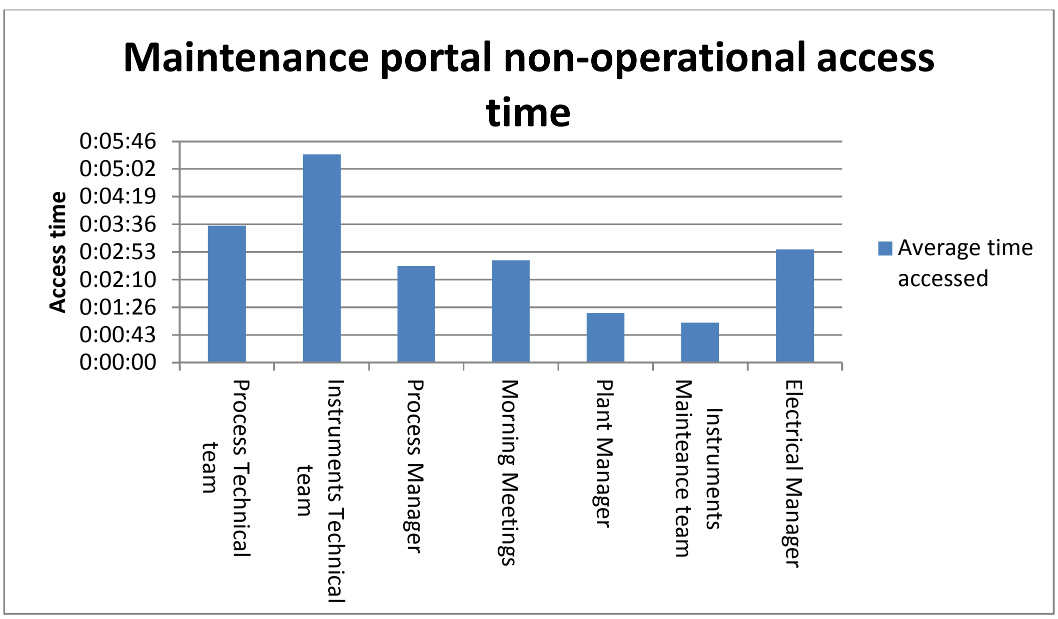


Figure 23: Maintenance portal non-operational personnel average access time

4.2 Questionnaire results

The questionnaire sample size was 80 participants. Only 59 of the 80 participants completed the questionnaire. The participation rate of the questionnaire was therefore 73.75%. The questionnaire was completed by 57 (96.61%) males and 2 (3.39%) females.

The personnel that completed the questionnaire were as follows (Table 13):

Personnel	Numbers	Percentage
Operational personnel	37	62.71%
Mechanical personnel	8	13.56%
Instrumentation personnel	7	11.86%
Electrical personnel	3	5.08%
Management personnel	4	6.78%

Table 13: Sample allocation for questionnaire

The average age of the personnel that completed the questionnaire was 39 years. The youngest participant was 21 and the oldest participant was 61 years old. The average number of years of experience in the trade was 16.46 years and years' experience at Sasol was 15.93 years.

The results of the questionnaire were divided into four sections. These sections are the technology acceptance test (TAM), participants' view of maintenance information systems (MIS), portal quality characteristics, and general comments made by participants in the questionnaire.

4.2.1 Technology Acceptance Test (TAM)

The results of the TAM were divided into five sections. The first section contains descriptive statistics regarding the four single constructs (perceived usefulness, perceived ease of use, behavioural intention, and actual use). In the second section, an internal consistency analysis was carried out on the results of each of these four constructs. The third section contains a correlation analysis of the technology acceptance test and the final section is made up of a regression analysis on the hypothetical relationships of the TAM.

Descriptive Statistics

The following descriptive statistics were obtained from the TAM section of the questionnaire:

Single constructs	S	Minimum	Maximum	Mean	Standard Deviation
Perceived usefulness	9	1.89	4	3.32	0.115
Perceived ease	8	1.38	4	3.07	0.234
Behavioural Intention	7	2	4	**3.38**	0.047
Actual use	4	1.25	4	***2.96***	0.113

Table 14: Descriptive statistics of TAM results

S is the number of questions related to a single construct. The minimum, maximum, mean, and standard deviation give an indication of the answers of each participant toward each construct.

Internal consistency

Internal consistency is calculated to measure whether the questions correlate to a main construct (Table 15). This analysis was carried out on all four constructs. Internal consistency is calculated by using the Cronbach alpha reliability coefficient (α). The average Cronbach alpha reliability coefficient for the study was 0.848. The following results were obtained:

Single constructs	S	Cronbach alpha (α)
Perceived usefulness	9	0.927
Perceived ease	8	0.775
Behavioural intention	7	0.909
Actual use	4	0.782

Table 15: Cronbach's alpha reliability coefficients

Correlation matrix

A correlation matrix was obtained from the results of the questions on the TAM (Table 16). The matrix provides the correlation between each construct (correlation coefficient, R) and the statistical significant (p-value) between the correlations. The correlation method used is the Pearson correlation method and the p-value was obtained using a regression analysis. The analysis was done on the 59 completed questionnaires received back from the participants.

	Perceived ease	Perceived usefulness	Behavioural intention	Actual use
Perceived ease	1	0.615 (0.007)	0.682 (0.018)	0.538 (<0.0001)
Perceived usefulness	0.615 (0.007)	1	0.521 (<0.0001)	0.543 (<0.0001)
Behavioural intention	0.682 (0.018)	0.521 (<0.0001)	1	0.595 (<0.0001)
Actual use	0.538 (<0.0001)	0.543 (<0.0001)	0.595 (<0.0001)	1

Table 16: Correlation matrix of TAM – correlation coefficient and (p-value)

The correlation between these constructs and the six relationships of the adapted TAM model, are discussed in Chapter five.

Regression analysis

A regression analysis was completed to verify the data of the correlation analysis. The first analysis was done to verify whether the results correspond with the TAM relationships 2, 3 and 5 (Table 17).

Condition	**β Perceived Ease of use & (p-value)**	**β Perceived Usefulness & (p-value)**	**R^2**
Behavioural Intention= *f*(Perceived Ease of use)	0.637 (<0.0001)	N/A	0.465654
Usefulness = *f*(Perceived Ease of use)	0.513 (<0.0001)	N/A	0.378226
Behavioural Intention = *f*(Perceived Ease of use & Perceived Usefulness)	0.544 (<0.0001)	0.182 (0.18)	0.482061

Table 17: Regression results (relationships 2, 3 and 5)

The second analysis was done to verify the results corresponding to TAM relationship 6 (Table 18).

Condition	**β Perceived ease of use & (p-value)**	**β Perceived usefulness & (p-value)**	**R^2**
Actual Usage = *f*(Ease of use)	0.612 (<0.0001)	N/A	0.288
Perceived Usefulness = *f*(Perceived Ease of use)	0.513 (<0.0001)	N/A	0.378
Actual Usage = *f*(Perceived Ease of use & Perceived Usefulness)	0.373 (0.018)	0.466 (0.014)	0.361

Table 18: Regression results (relationship 6)

R-square or the coefficient of determination is an indication of fit for purpose or the proportion of variation. R-square gives a representation of data point deviation from the mean value. If R^2 is 1 then all data points are linear with the mean value (Greene, 2007). Beta (β) is the standardised coefficient or regression coefficient. Beta gives an indication as to whether or not the independent variable has a greater effect on the dependant variable (Davis, 1985). The results of the regression analysis are discussed in Chapter five.

4.2.2 Participants' perception of maintenance information systems (MIS)

Section C of the questionnaire involved understanding participant's general views of maintenance information systems and whether they are beneficial to the plant environment. The results from the questionnaire are as follows:

From the sample size of 80, 59 participants answered the questionnaire. The following results were gathered. The 59 participants answered as follows (Table 19):

Nr.	Question	Min	Max	Standard Deviation
1	Do maintenance portals add value to Infragas?	2	4	0.57
2	Do maintenance portals improve plant availability?	1	4	0.77
3	Do maintenance portals improve plant reliability?	1	4	0.69
4	Maintenance portals are use on a daily basis.	1	4	0.70
5	Are maintenance portals beneficial to Infragas?	1	4	0.68

Table 19: Questionnaire respondents: general view towards MIS

From these results, the average rating for each question was calculated (Table 20):

Nr.	Question	Average score	Percentage
1	Do maintenance portals add value to Infragas?	3.46	86.25%
2	Do maintenance portals improve plant availability?	3.22	80.50%
3	Do maintenance portals improve plant reliability?	3.34	83.50%
4	Maintenance portals are use on a daily basis.	3.44	86.00%
5	Are maintenance portals beneficial to Infragas?	3.44	86.00%

Table 20: Questionnaire respondents: general view towards MIS (%)

From the 59 participants who completed the questionnaire, 39 were operational personnel. Operational personnel had the following general views towards maintenance information systems (Table 21):

Nr.	Question	Min	Max	Standard Deviation
1	Do maintenance portals add value to Infragas?	2	4	0.56
2	Do maintenance portals improve plant availability?	1	4	0.83
3	Do maintenance portals improve plant reliability?	1	4	0.72
4	Maintenance portals are use on a daily basis.	1	4	0.75
5	Are maintenance portals beneficial to Infragas?	2	4	0.60

Table 21: Questionnaire respondents: general view of operational personnel towards MIS

The average rating for each question was calculated from these results (Table 22):

Nr.	Question	Average score	Percentage
1	Do maintenance portals add value to Infragas?	3.47	86.75%
2	Do maintenance portals improve plant availability?	3.18	79.50%
3	Do maintenance portals improve plant reliability?	3.39	84.75%
4	Maintenance portals are use on a daily basis.	3.39	84.75%
5	Are maintenance portals beneficial to Infragas?	3.47	86.75%

Table 22: Questionnaire respondents: general view of operational personnel towards MIS (%)

The non-operational personnel's general view was as follows (Table 23):

Nr.	Question	Min	Max	Standard Deviation
1	Do maintenance portals add value to Infragas?	2	4	0.60
2	Do maintenance portals improve plant availability?	2	4	0.64
3	Do maintenance portals improve plant reliability?	2	4	0.62
4	Maintenance portals are use on a daily basis.	2	4	0.60
5	Are maintenance portals beneficial to Infragas?	1	4	0.80

Table 23: Questionnaire respondents: general view of non-operational personnel towards MIS

The average rating for each question was calculated from these results (Table 24):

Nr.	Question	Average score	Percentage
1	Do maintenance portals add value to Infragas?	3.43	85.75%
2	Do maintenance portals improve plant availability?	3.29	82.25%
3	Do maintenance portals improve plant reliability?	3.24	81.00%
4	Maintenance portals are use on a daily basis.	3.52	88.00%
5	Are maintenance portals beneficial to Infragas?	3.38	84.50%

Table 24: Questionnaire respondents: general view of non-operational personnel towards MIS (%)

4.2.3 Portal quality characteristics

The sample size was 80 people. Only 59 people were available to answer the questionnaire. Of the 59, 46 completed Section D. The participants were asked to rate 6 quality characteristics from highest to lowest priority. The highest priority was 1 and the lowest priority was 6.

The averages for the total participating group are reflected in Table 25:

Quality characteristics	Average	Ranking
Efficiency	2.78	1
Reliability	2.98	2
Functionality	3.24	3
Usability	3.61	4
Maintainability	3.85	5
Portability	4.50	6

Table 25: Portal quality characteristics

The averages for operational personnel are reflected in Table 26:

Quality characteristic	Average	Ranking
Efficiency	2.65	1
Reliability	2.73	2
Functionality	3.42	3
Usability	3.73	4
Portability	4.15	5
Maintainability	4.23	6

Table 26: Portal quality characteristics for operational personnel

The averages for non-operational personnel are reflected in Table 27:

Quality characteristic	Average	Ranking
Efficiency	3	1
Portability	3.3	2
Functionality	3.35	3
Reliability	3.45	4
Usability	3.73	5
Maintainability	4.95	6

Table 27: Portal quality characteristics for non-operational personnel

The results of Section D are discussed in detail in chapter five.

4.2.4 General comments

Section E of the questionnaire provided an opportunity for participants to add comments with regards to maintenance portal usage. This section was optional. The following comments were made.

- "Training and goal overview to production employees to be given if possible about DPM etc. It will add more value towards production in a broader perspective as everyone will be involved."
- "Maintenance portals and DPM are more geared towards predictability and reliability. From a reliability centred perspective these tools assist in finding/identifying a problem before it results in an actual failure (maintenance portal). The DPM keeps the focus on the important parameters. Left unwatched to deteriorate without action results in reduced performance and subsequently loss of income/inefficient operations."
- "Do not use for view only. Must operate on portals. Set goals what to achieve from portals."
- "Updating + adding of new dials can be cumbersome. This is because of current systems used by IM department."
- "If configured correctly and used for maintenance they work perfectly."

The findings of the empirical investigation have been summarised. Chapter five will provide a detailed analysis of these findings. Each result, as well as the information it revealed, will be discussed.

CHAPTER FIVE
DISCUSSION AND INTERPRETATION

The discussion and interpretation of the findings are divided into two sections. The first section contains the interpretation of the actual usage findings of the maintenance portal. The second section involves the interpretation and discussion of the questionnaire findings.

5.1 Maintenance portal actual usage discussion

The Infragas maintenance portal usage was measured for 35 days using web log analysis. Each time a page was accessed, a log entry was created stating the date, time, user identity, portal name and specific page name.

The log analysis captured each request for a page. The time difference between each request was considered as the time spent on each page. The final request by a user was counted as a page access; however no time was allocated to this access as the log analysis only provided page request log items.

Each discipline managers were aware of the log analysis taking place but employees were not informed that maintenance portal activity was being monitored. This was to ensure that the measurement could take place with no interference from management. In addition, not informing the employees of the monitoring meant the results provided an indication of normal interaction.

5.1.1 Maintenance portal page access discussion

The maintenance portal page access information was divided into two sections. The sections were the ATR maintenance portal pages (Figure 10) and the Rectisol maintenance portal pages (Figure 11). The ATR maintenance portal consists of ten pages and the Rectisol maintenance portal consists of five pages.

The total page access count for the ATR maintenance portal was 424 page requests. This is an average of 12 page requests per day over the 35 day sample period. A total of 223 hours was spent on the ATR maintenance portal, which equates to an average of 6.38 hours per day. Over the sample period, the average time spent on a page was 36 seconds. The sample size of personnel who used the maintenance portal was 80.

The ATR maintenance portal was used most frequently to monitor the daily alarms. The alarm details' page provides an event-based view for a selected alarm. On average, the most time was spent on average on the alarm details' page. This indicates that the ATR maintenance portal is used for fault-finding and process analysis and assist with viewing what events occurred during a certain process upset.

The alarm and alarm detail pages were accessed most as they supply the ATR operational personnel the core information they require. The information displayed on these pages provides the ATR operational personnel with a summary of the previous day's operation and illustrates if there were any deviations from the proposed operation of the previous day.

The ATR DMSI caution alarms' page offers a detailed view of the events captured by the deviation management package. The access count on this page was lower on this page; however, more time was spent on the page, to do a full analysis of the deviation captured.

The ATR System 1 page and the ATR DMSI page were accessed the least. The ATR System 1 page contains information alarms about rotating equipment, which is critical equipment for the ATR plant.

The ATR alarm page also displays process alarms with regards to the rotating equipment, but the ATR System 1 portal displays detail information about monitoring devices in addition to this. These deviations could hold valuable information and early failures could be detected using this information.

The DMSI pages and the System 1 pages are more important to maintenance personnel but they must also be viewed by operational personnel. The page access counts demonstrated that operational personnel focus more on operational alarms and not equipment deviation alarms. The infrequency of these access counts should be addressed.

The Rectisol maintenance portal pages (Figure 11) showed the same access trend as the ATR maintenance portal. The Rectisol maintenance pages were accessed 306 times. The Rectisol maintenance portal consists of five pages. On average eight pages were accessed per day. The total time spent on the Rectisol maintenance pages was 69 hours. An average time of 37 seconds was spent on each Rectisol page.

The Rectisol main and Rectisol alarm details' pages were accessed the most frequently. On average, the Rectisol alarm details' page was accessed for the longest period. This also indicates that personnel using the portal do alarm analyses to ascertain why certain events caused alarms. Rectisol operational personnel's main focus is operational alarms, in a similar way to the ATR operational personnel.

The Rectisol System 1 and Rectisol DMSI pages were accessed least. These pages contain information about rotating equipment and deviations found on Rectisol. Deviations that were missed could cause unnecessary down time, in addition to deviations on rotating equipment.

5.1.2 Maintenance portal daily access counts discussion

The maintenance portal daily access counts analysis has been divided into three sections. An overall access count was conducted on the Infragas maintenance portal. This analysis provides an overview of total access counts of the sample group within the sample time. An access count is recorded when an Infragas employee send a portal request, irrespective of which pages they viewed or time spent on a specific page. The second part of the analysis was carried out on day and non-operational personnel's access counts; this included the maintenance and support personnel. The final analysis was performed on the access counts by ATR and Rectisol operational personnel.

The overall access counts on the Infragas maintenance portal (Figure 12) shows that an average of 5.6 access counts took place per day over the 35 day sample period. The average access count per weekday was calculated (Figure 24): the highest number of access counts took place on Mondays, and decreased as the week progressed. The lowest number of access counts took place over the weekends, as only the operational personnel accessed the maintenance portal over this period.

The Infragas maintenance portal was utilised at least once every day during the sample period. As the employees were unaware that the maintenance portal access was being tracked, it appears that the Infragas maintenance portal was utilised by Infragas personnel on a daily basis.

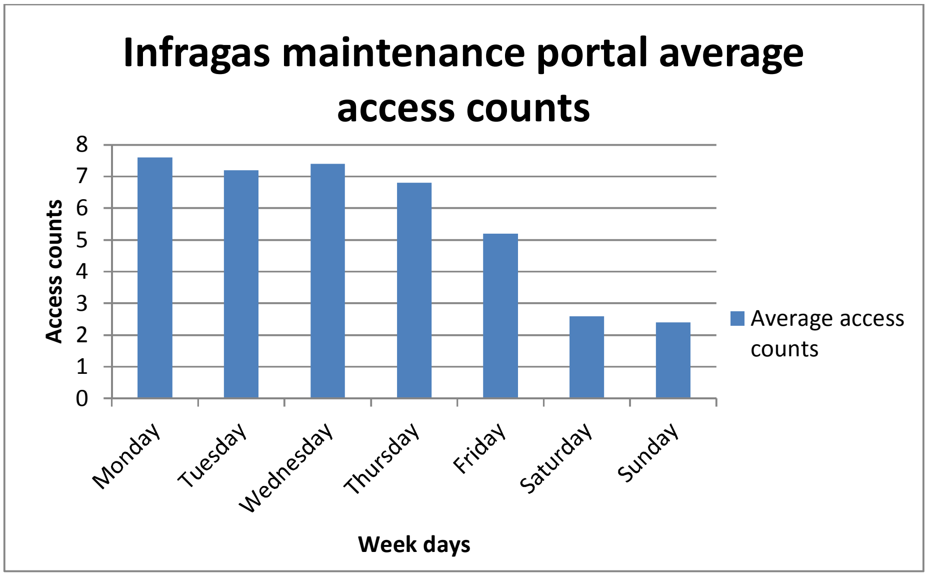


Figure 24: Maintenance portal average weekday access counts

The day personnel's average access count (Figure 13) was on average 4.76 per day. Day personnel work days are from Monday to Friday; this meant that their sample period was only 25 days. The daily averages were calculated for each working day (Figure 25).

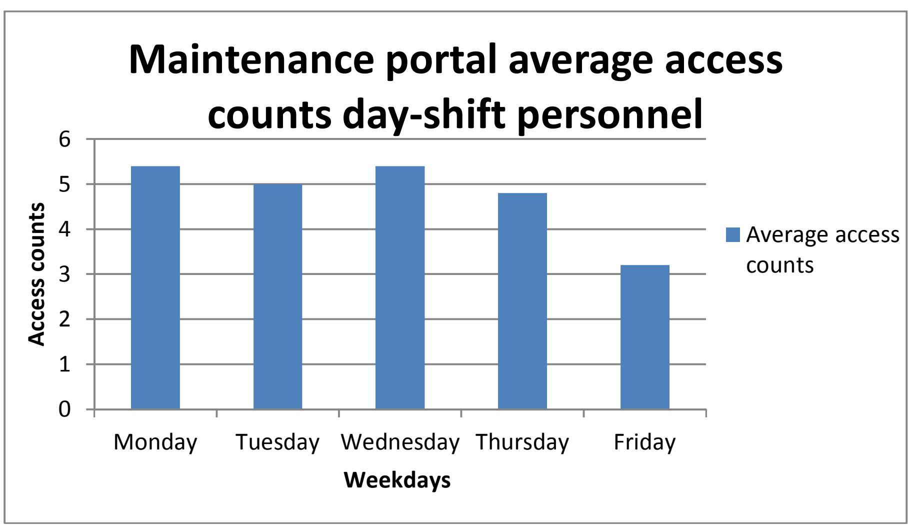


Figure 25: Maintenance portal day personnel average access counts

The average daily access count by day personnel amounted to five accesses from Monday to Thursday. The access counts were lower on Fridays, only averaging 3.2. During the 25 day sample period, there was only one day on which the Infragas portal was not accessed by day personnel. The contact ratio between the Infragas maintenance portal and non-operational personnel is 96%. This is an indication that day personnel also utilise the Infragas maintenance portals.

The operational personnel's access counts were analysed (Figure 14). The average access counts per day were 1.65. Shift handover for operational personnel takes place every 12 hours. Theoretically there should be an average of four access counts, two for each plant, per day. Only twice was the maintenance portal was accessed four times. During the sample period there were only two days when the maintenance portal was not accessed. The average weekday access counts by operational personnel are displayed below (Figure 26):

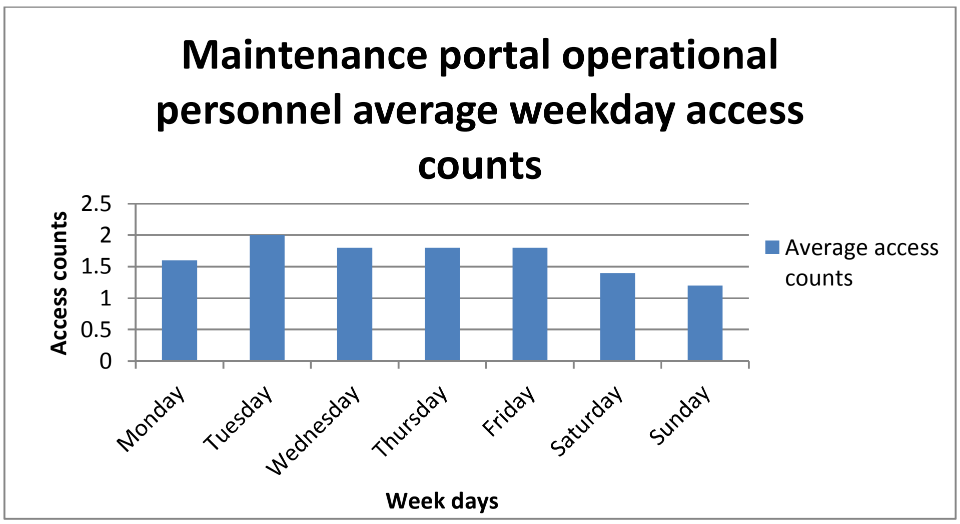


Figure 26: Maintenance portal operational personnel average weekday access counts

The average access count was 1.8 from Monday to Friday, but the access counts decreased over the weekend to an average of 1.3 per day. The access counts were calculated for the ATR operational (Figure 15) and Rectisol operational (Figure 16) personnel. Theoretically each plant should access the maintenance portal twice per day. The average access count for the ATR operational personnel was 0.8. The week day averages were as follows (Figure 27):

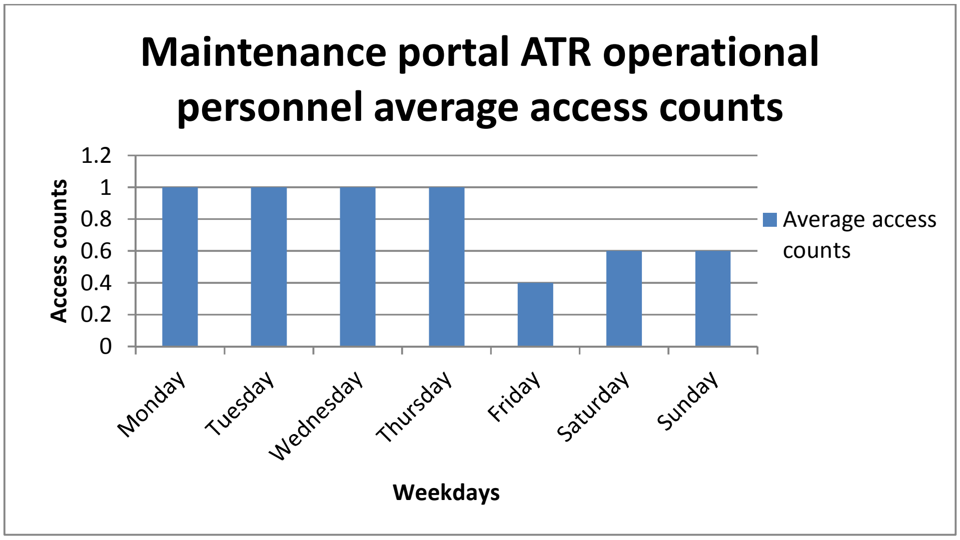


Figure 27: ATR maintenance portal operational personnel average access counts

The average access count for Rectisol operational personnel was 1.08 (Figure 16). This is higher than the ATR personnel but still lower than the theoretical required twice per day. The weekday average access count for Rectisol operational personnel is displayed below (Figure 28):

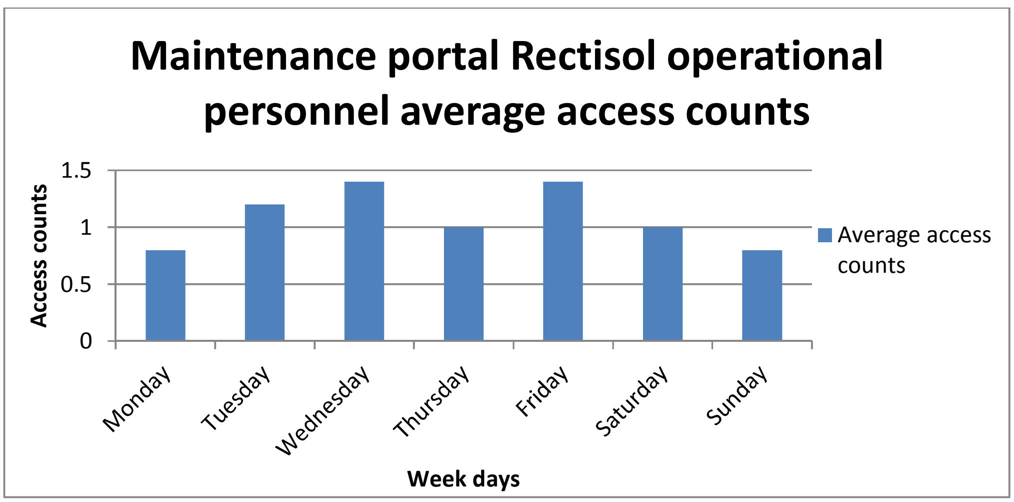


Figure 28: Rectisol maintenance portal operational personnel average access counts

5.1.3 Maintenance portal daily access times discussion

The average access time for the maintenance portal was also divided into three sections. The first section included the overall access time on the maintenance portal, the second included access times only for day personnel and finally the access counts for operational personnel.

An average daily access time analysis was calculated from the log analysis results (Figure 17). The average time spent on the maintenance portal is an indication of how much information is gathered by users and demonstrates whether this information adds quality to their work environment. The average time spent each day on the maintenance portal was 2:54 minutes. During the sample period there were two days were the maintenance portal was not accessed at all. This was during on a Saturday and Sunday. The contact ratio of Infragas personnel towards the maintenance portal is 94.28%.

The average time spent on the portal each weekday was calculated (Figure 29). The maintenance portal is only accessed by operational personnel on Saturday and Sunday. The average time spent is at its lowest on Saturday. However the average access time for the rest of the weekdays is still high at 2:54 minutes.

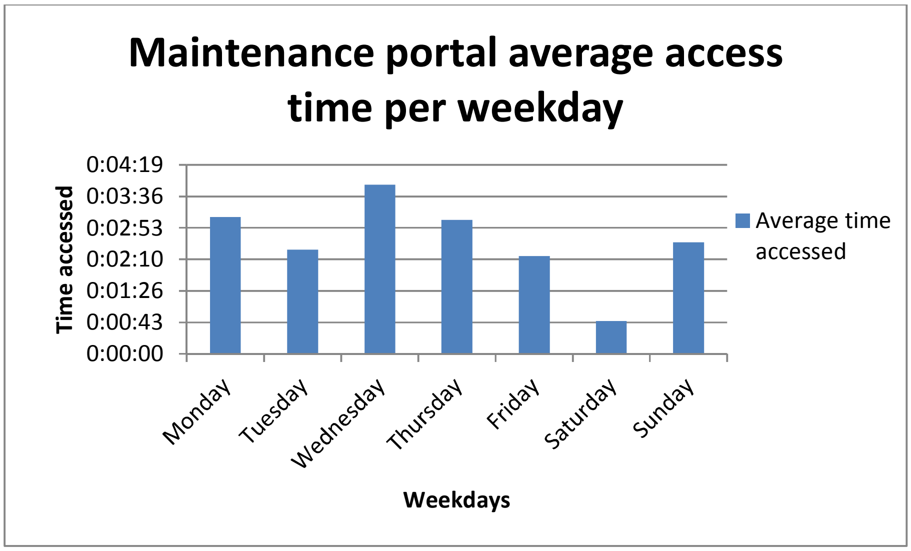


Figure 29: Maintenance portal average access time per weekday

The day personnel's average daily access time was 2:23 minutes. There was only one day during the 25 day sample time when the maintenance portal was not accessed by day personnel. This demonstrates a day personnel portal contact percentage of 96%. An analysis was done to establish the weekday averages for day personnel (Figure 30).

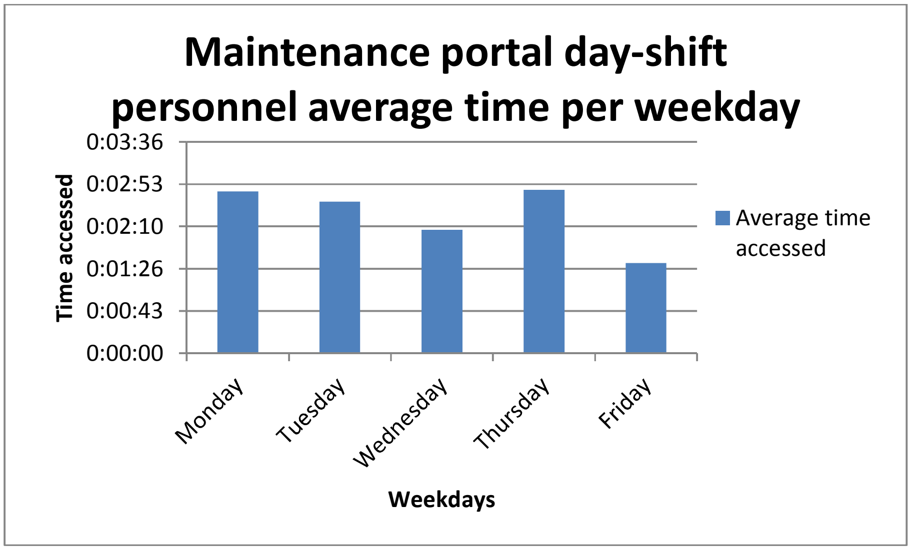


Figure 30: Maintenance portal day personnel average access time per weekday

The average access time varied from 1:32 minutes to 2:47 minutes. This is a positive average access time figure. This is an indication that day personnel are using the maintenance portal based on the average time spent on the maintenance portal.

The average time spent on the maintenance portal by operational personnel was 1:56 minutes (Figure 19). The reason for the lower access time is that operational personnel open each page only to print it. Each page is then discussed at the shift handover meeting, held every 12 hours. The average access time per weekday was calculated from the log analysis for operational personnel (Figure 31).

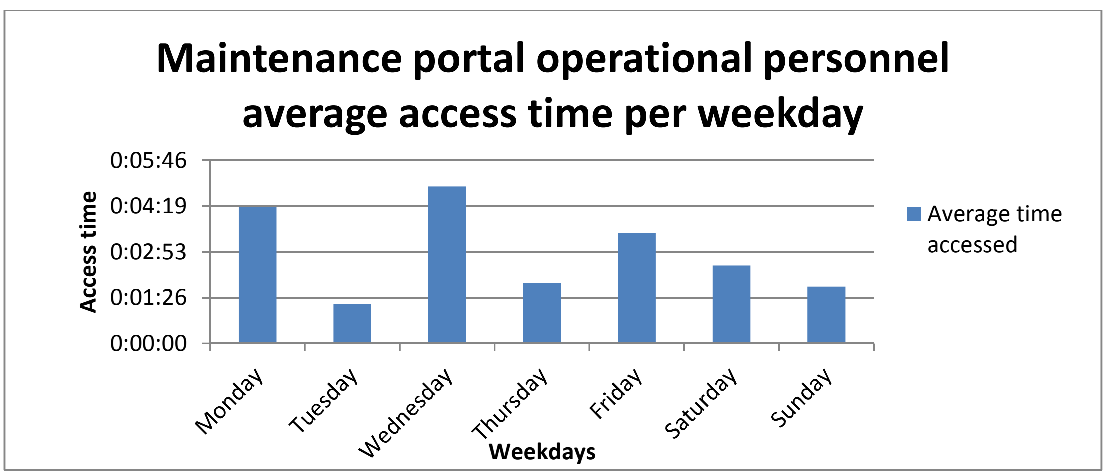


Figure 31: Maintenance portal operational personnel average access time per weekday

The average time spent on the portal by the ATR (Figure 20) and Rectisol operational personnel (Figure 21) was also calculated. The average time for the ATR operational personnel was 3:01 minutes. On the last day of the sample period a user accessed the maintenance portal actively for 24:03 minutes, which did improve the average access markedly. This was the longest time a user actively accessed the maintenance portal. The average access time, without this user's activity, would have been 2:20 minutes.

During the 35 day sample period there were 15 days during which the maintenance portal was not accessed by ATR operational personnel at all. This made the maintenance portal contact ratio only 57.14%. The average access time per weekday was thus calculated (Figure 32).

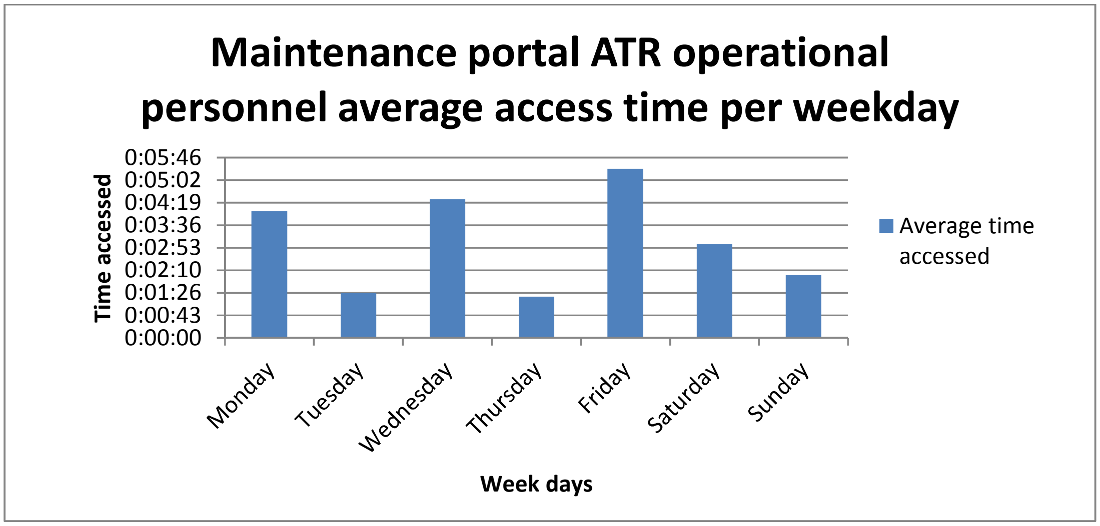


Figure 32: ATR maintenance portal operational personnel average access time per weekday

The average time spent on the maintenance portal by Rectisol operational personnel was 1:21 minutes. There were six days when Rectisol personnel did not access the maintenance portal. The contact ratio for Rectisol personnel is 82.85%. The average weekday access for Rectisol operational personnel was thus calculated (Figure 33).

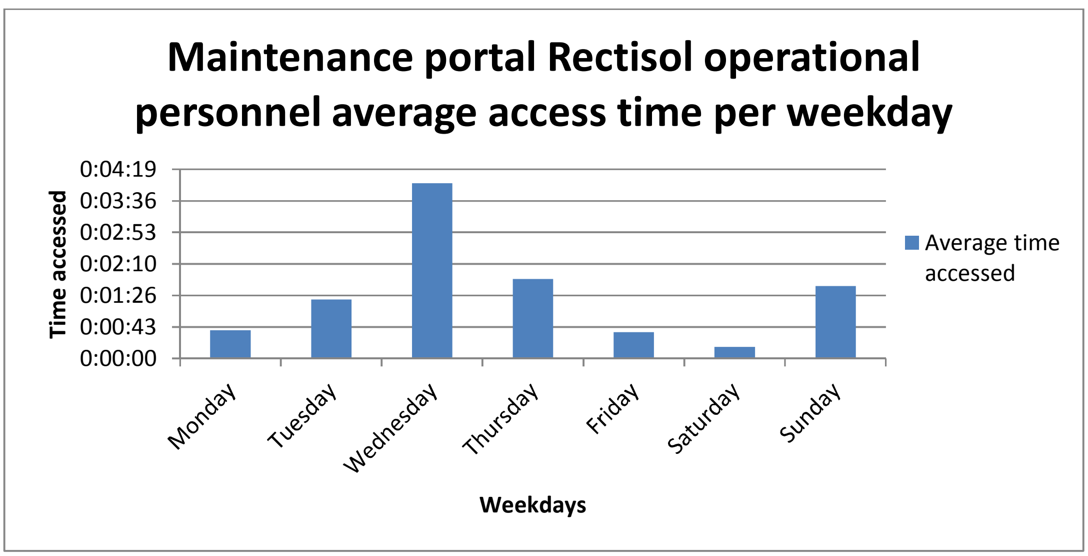


Figure 33: Rectisol maintenance portal operational personnel average access time per weekday

5.1.4 Maintenance portal non-operational personnel usage discussion

The access count by non-operational personnel was calculated as shown in (Figure 22). If the actual usage was normalised per person (Figure 34), it shows that process technical team members had the highest maintenance portal access count.

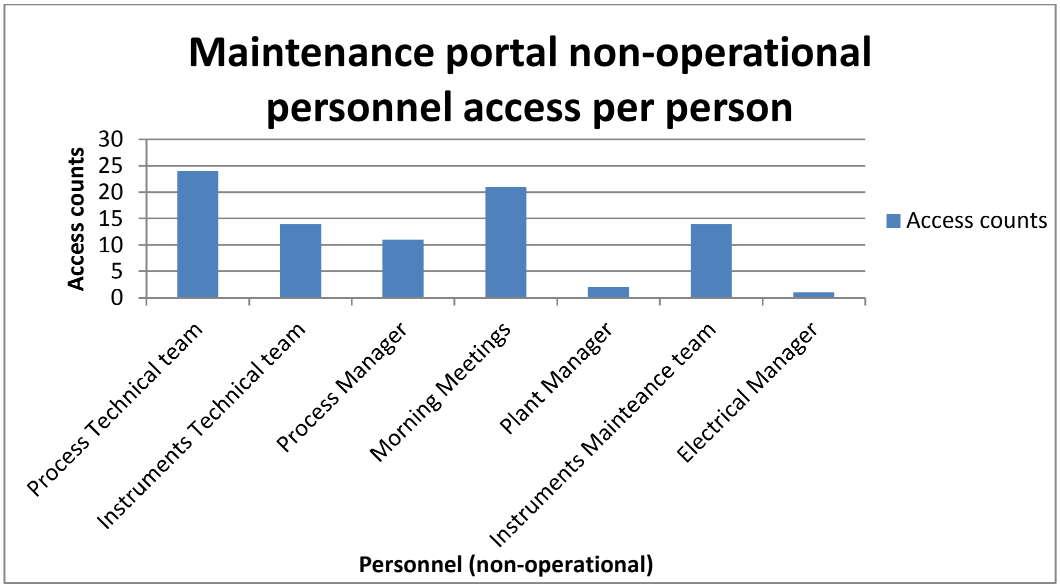


Figure 34: Maintenance portal non-operational access per maintenance groups

The contact ratio was calculated for the process technical team, instrument technical team and morning meetings (figure 35). The process, plant, electrical and instrumentation managers access the maintenance portal during morning meetings and their contact ratio for these participants were not calculated separately. The electrical maintenance team and mechanical maintenance teams did not use the maintenance portal during the sample period.

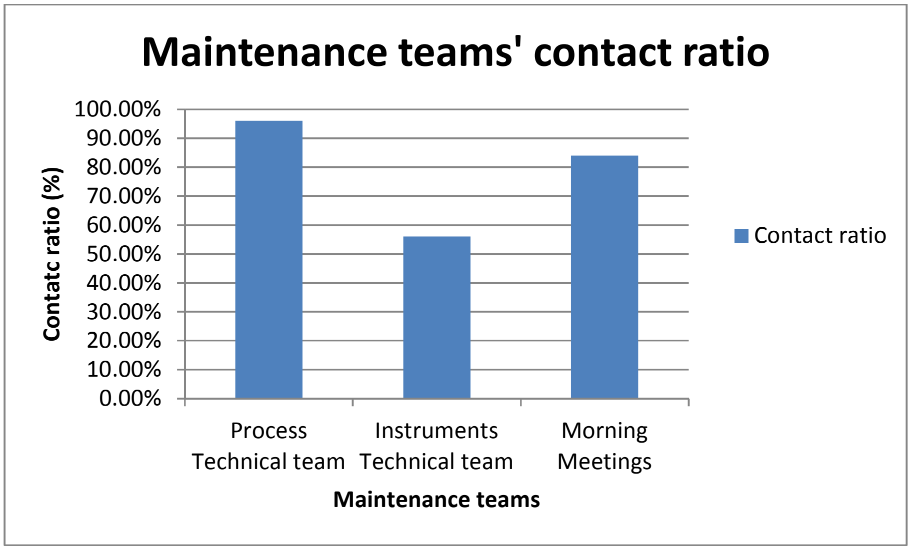


Figure 35: Maintenance teams' contact ratio

The average time spent by each non-operational maintenance team was calculated (Figure 23). On average the instrumentation teams spend the most time on the maintenance portal, this time was spent on each plants alarms and alarm details. The process technical team used the maintenance portal only for viewing plant alarms and conducting alarm investigations when process upsets had taken place. Morning meetings were used as a brief overview of all the alarms on the plants as well as the deviation manager and System 1 alarms.

The following summary was made regarding the actual usage of the maintenance portal. The maintenance portal was being utilised daily by Infragas personnel. On average the operational personal have a contact ratio of 94.28%. The access counts by operational personnel are well below standard at 1.65, considering it should be at four access counts per day.

The ATR operational personnel contact ratio is very low at 57.14%. The average access count is at 0.8 where it should be at two per day. The Rectisol operational personnel contact ratio is at 82.15%. The average was 1.08, where it should also be at two per day. The reason for the access counts per day is because there are 2 shifts working per day. Non-operational or maintenance team personnel have a contact ratio of 96%.

The average time spent on the maintenance portal by Infragas personnel is 2:23 minutes. Operational personnel spend on average 1:56 minutes on the maintenance portal. ATR operational personnel and Rectisol operational personnel spend on average 3:01 minutes and 1:21 minutes on the maintenance portals respectively. All of these average times show that the Infragas maintenance portal is being utilised.

The maintenance pages that were accessed the most on ATR and Rectisol plants are the alarm pages. The alarm pages provide personnel with an overview of the previous day's operation activities and information regarding any operational upsets or deviations. The most time was spent on the alarm details' pages for both ATR and Rectisol plants. This was an indication that the maintenance portal is being used for alarm and process analyses. From this information the plant can be more fully optimised and maintenance tasks better scheduled. The pages that were accessed least were the System 1 and deviation management (DMSI) pages. Critical information is displayed on these pages.

5.2 Questionnaire discussion

The questionnaire was developed to gather information from the participants regarding maintenance information systems. The participants' views were measured against the Money and Turner adapted technology acceptance test (Money & Turner, 2004). The second section of the questionnaire gathered a participants' general view of maintenance information systems (MIS). The third section of the questionnaire measured the six portal quality characteristics by rating them from highest to lowest according to their importance. The results were measured against the results that Leung found in his study (Leung, 2001). Finally the questionnaire gave the respondents the opportunity to give comments regarding the maintenance information systems.

The discussion was divided into four sections. The first discussion pertains to the results gathered from the questionnaire regarding the technology acceptance test. The second section is a discussion on the general views of the participants towards maintenance information systems. The second last section discusses the results found on quality characteristics in maintenance information systems. The last section is a discussion on comments submitted by the participants.

5.2.1 Technology acceptance test (TAM) discussion

The results of the TAM are analysed by three analyses. The first analysis is the Cronbach reliability alpha test which measures the internal consistency of a group of questions to a single construct. The second analysis is the Pearson correlation matrix which calculates the direct relationship between each construct. The final analysis is a regression analysis which also analyses the correlation between constructs. The regression analysis is a verification of the Person correlation matrix.

The Cronbach alpha test was first done on the results of the questionnaire (Table 15). The Cronbach alpha test measured internal consistency of a range of questions towards a single construct. George and Mallery provided the following measurements of the Cronbach alpha test. These measurements range from "> .9 Excellent, > .8 Good, .7 Acceptable, > .6 Questionable, > .5 Poor and < .5 Unacceptable" (George & Mallery, 2003).

The average alpha value for the study was 0.845, which fell into the good category. Perceived usefulness (S=9) and behavioural intention (S=7) were above 0.9 which showed a high internal consistency. Perceived ease (S=8) and actual use (S=4) revealed an alpha value of $0.7 > \alpha < 0.8$ which is also a good internal consistency. The internal consistency of all the constructs was above 0.7 which showed a good consistency towards each construct.

A correlation matrix was calculated from the results of the questionnaire. The correlation coefficient (r) for all the correlations between constructs was moderately positive, ranging from between 0.538 and 0.683. The p-value can be defined as "the probability of obtaining the observed effect under a 'null hypothesis'" (Higgins & Green, 2011). The lower the p-value, the lower the chance that the results were a coincidence. Davis' TAM shows that only correlation with a significance value of less than 0.5 can be seen as an effective correlation (Davis, 1985). All the significance values of the correlation matrix were below 0.5

A regression analysis was carried out between each variable to verify the relationship between constructs. These regression analyses were also done to verify the correlation between each relationship of the TAM model.

The following results were obtained against the six relationships of the adapted Money and Turner technology acceptance test. These results were gathered from the correlation matrix and the regression analysis. The hypothetical model, according to Money and Turner's TAM, states the following (Money & Turner, 2004):

- H1: Perceived usefulness will exhibit a significant positive relationship with behavioural intention to use.

This was verified by the correlation matrix with a positive correlation of 0.521 and a very high significance level (p) of (<0.0001). The correlation is moderate and positive.

- H2: The effects of perceived ease of use on behavioural intention will be significant and positive but slightly mediated by perceived usefulness.

This was verified by the regression analysis between behavioural intention, perceived usefulness and perceived ease of use. The correlation between perceived ease of use (β=0.544) and perceived usefulness (β=0.182) to behavioural intension was (R^2= 0.48). Perceived usefulness has a smaller effect on behavioural intention than on perceived ease of use.

- H3: Perceived ease of use will have a smaller but significant positive direct relationship with behavioural intention to use when perceived usefulness is controlled for.

This relationship was confirmed. The direct correlation of perceived ease of use was (β=0.637) to behavioural intention (R^2= 0.46). The correlation for perceived ease of use is smaller when perceived usefulness (β=0.544) and perceived ease of use (β=0.182) are correlated to behavioural intention (R^2= 0.48)

- H4: Behavioural intention will have a significant positive relationship with system usage.

This relationship was verified by the correlation coefficient of 0.595 and a high significance level of (<0.0001).

- H5: Perceived usefulness and perceived ease of use will have a significant combined positive relationship with behavioural intention.

This relationship was confirmed in Table 17. The regression coefficient was 0.48 or (48%). The relationship is moderately positive.

- H6: Perceived usefulness and perceived ease of use will have a significant combined positive relationship with system usage.

The relationship was positive (R^2= 0.361) or 36.1%. This relationship is a weak to moderately positive relationship.

The summary of the correlations and significant levels (p-values) is displayed below:

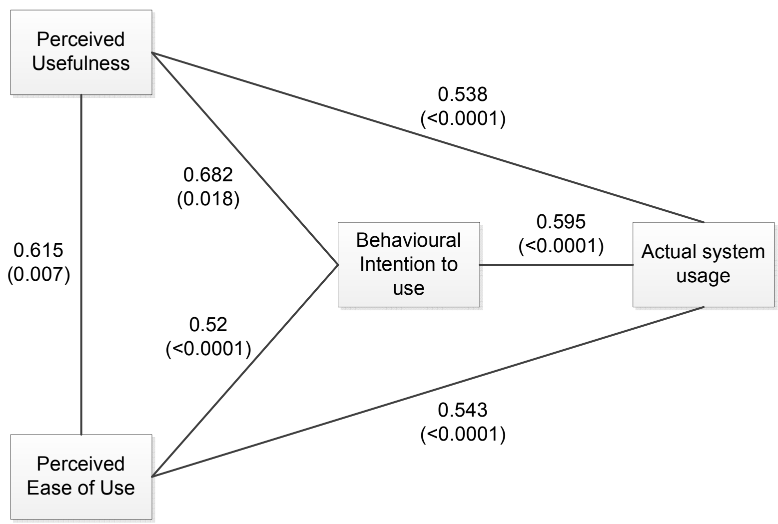


Figure 36: TAM with correlations (p-values)

The results from the TAM study support the results of the actual usage audit. The actual usage audit showed that the maintenance information systems were being utilised on a daily basis. For technology to be of use, the technology must first be accepted. The results from the TAM showed that maintenance information systems were accepted as a technology by the Infragas personnel. The six TAM relationships were confirmed. The actual usage results also confirmed that the technology is accepted, as indicated by the interaction figures.

5.2.2 Participants views on MIS discussion

This section consists of five questions to gain a general understanding of participants' views towards maintenance information systems. Of the 80 person sample design, 59 (73.75%) completed this section. The results were divided into Infragas personnel, operational personnel and non-operational personnel.

The first question asked was: "Do maintenance portals add value to Infragas?" The average score was 3.41, which illustrates that 85.25% of participants agreed that MIS added value to Infragas. The standard deviation on this answer was 0.57 (14.25%), which is very low.

The average among process personnel was: 86.75% with a 0.60 (15%) standard deviation. For non-operational personnel it was 85.75% with a 0.56 (14%) standard deviation. These results verify that Infragas personnel believe that the MIS add value to Infragas.

The second and third questions both concerned plant performance. These questions asked whether "MIS improve plant availability and plant reliability." Both of these factors are improved by effective maintenance and optimisation of plant equipment.

The average result for availability was 3.2 (80%), with a standard deviation of 0.77 (19.25%). Reliability averaged 3.33 (83.25%), with a standard deviation of 0.69 (17.25%). These high percentages show that MIS does improve reliability and availability of the ATR and Rectisol plants.

The third question obtained a general view as to whether Infragas personnel are using MIS on a daily basis. The average score for the question was 3.45 (86.25%) with a standard deviation of 0.70 (17.50%). Operational personnel's average score was lower than average at 3.39 (84.75%) with a standard deviation of 0.60 (15%) while non-operational personnel's average score was higher at 3.52 (88%) with a standard deviation of 0.75 (18.75%). These figures correlate with the actual usage results, which indicate that the maintenance portal is accessed 5.6 times per day on average.

The actual usage results correlated with question three's results. The actual usage result showed that the maintenance portal's average access time per day was 5.6 times over the 35 day sample period with at least one access per day. The results showed that 86.25% of the respondents agreed that the maintenance portal was accessed daily. These two figures verify that maintenance information systems are being used daily.

The last question investigated whether maintenance portals are beneficial to Infragas. The average answer to this question scored 3.47 (86.75%) with a standard deviation of 0.80 (20%). This was the largest standard deviation. However, this result still proves that maintenance portals are beneficial to Infragas plants.

5.2.3 Quality Characteristics discussion

The aim of the quality characteristics rating in the questionnaire was to understand which characteristics are most important to the Infragas MIS users. In the literature study, Leung applied Van Ziest and Hendriks' extended ISO model and found the following six quality characteristics to be most important to intranet users (Leung, 2001). The importance ranking of the Leung quality characteristics were as follows:

Quality Characteristic	Ranking
Reliability	1
Functionality	2
Efficiency	3
Usability	4
Maintainability	5
Portability	6

Table 28: Leung's importance ranking of quality characteristics (Leung, 2001)

The results from the questionnaire were measured against Leung's quality characteristics (Leung, 2001) and the following was discovered:

Leung Quality Characteristics	
Quality Characteristic	Ranking
Reliability	1
Functionality	2
Efficiency	3
Usability	4
Maintainability	5
Portability	6

Infragas Quality Characteristics		
Quality Characteristics	Average	Ranking
Efficiency	2.783	1
Reliability	2.978	2
Functionality	3.239	3
Usability	3.609	4
Maintainability	3.847	5
Portability	4.500	6

Table 29: Leung's quality characteristics compared to Infragas' quality characteristics

Efficiency was rated highest by Infragas participants. According to the Leung study, efficiency was only rated the third most important quality characteristic. Reliability and functionality were both one importance level down in comparison to Leung's findings. Usability, maintainability and portability were rated identically to the Leung study.

The Infragas quality characteristics' results were similar to the Leung study, apart from efficiency, which was rated more highly by the Infragas personnel. According to the ISO model, efficiency is defined as "The relationship between the level of performance of the software and the amount of resources used under stated conditions." (Leung, 2001).

The information gathered from operational personnel was as follows:

Leung Quality Characteristics	
Quality Characteristic	Ranking
Reliability	1
Functionality	2
Efficiency	3
Usability	4
Maintainability	5
Portability	6

Infragas Operational Quality Characteristics		
Quality characteristic	Average	Ranking
Efficiency	2.65	1
Reliability	2.73	2
Functionality	3.42	3
Usability	3.73	4
Portability	4.15	5
Maintainability	4.23	6

Table 30: Leung's quality characteristics compared to Infragas' operational personnel's quality characteristics

The results from the Infragas operational personnel versus Leung's results were the same as the overall results except portability was ranked higher than maintainability. As operational personnel do not maintain maintenance information systems this is not a priority to them.

The information gathered from non-operational personnel was as follows:

Leung Quality Characteristics	
Quality Characteristic	Ranking
Reliability	1
Functionality	2
Efficiency	3
Usability	4
Maintainability	5
Portability	6

Infragas non-operational Quality Characteristics		
Quality characteristic	Average	Ranking
Efficiency	3.00	1
Portability	3.3	2
Functionality	3.35	3
Reliability	3.45	4
Usability	3.73	5
Maintainability	4.95	6

Table 31: Leung's quality characteristics compared to Infragas' non-operational personnel's quality characteristics

The results from the Infragas non-operational personnel differed from both the operational personnel and the Leung study. The results of the first five quality characteristics only differ by 0.37. Efficiency was still rated as the most important quality characteristic.

Portability, which is the least important quality characteristic in Leung's study, was the second most important quality characteristic for non-operational personnel. Portability is defined as "The ability of the software to be transformed from one environment to another." (Leung, 2001). Each employee has access to the maintenance information systems on their personal work computer. A reason for this could be that every person requires portal information for their specific need.

Reliability, which was rated the most important quality characteristics by Leung was rated the fourth most important quality characteristic in this study. Reliability was followed by usability and maintainability. The results of the non-operational quality characteristics were very close to each other. Further research should be done to gain a better understanding of quality characteristics as required by non-operational personnel.

5.2.4 Questionnaire comments discussion

A number of general comments were made about the maintenance information systems in Infragas. One comment stated that there was a need for MIS training within the Infragas environment. Not all personnel are familiar with the manner in which information is gathered or values are calculated for the MIS. Some employees would like to know how they can contribute to improving the MIS figures. This will be addressed in future.

The maintenance portal was identified as a system that could assist with identifying problems before actual failures had taken place. The actual usage results collected illustrated that only certain pages were being accessed. This means that the pages that were accessed infrequently might contain information which could be overlooked and so cause a failure. Personnel must be made aware of the importance of all the portal pages and that they must be encouraged to access them all so as not to miss critical information.

Another comment suggested setting goals for MIS. Presently, the MIS simply displays information. Personnel can react to this information once they receive it. Goal aspiration could be incorporated into the MIS to motivate operational and non-operational personnel to work towards achieving specific goals. The goals should be created to encourage personnel to improve maintenance and optimisation of the Infragas environment.

5.3 Verification of result findings

The research was conducted with the use of two different methods of investigation. The first method focussed on the actual use of MIS in the Infragas environment and the other method on the views by the employees towards MIS.

With the use of a log analysis every event of the MIS was traced. Statistical analysis from the log analysis indicated that MIS is used on a daily basis. The Money and Turner TAM model used a Pearson correlation analysis and regression analysis. These methods indicated a strong correlation and relationship between the different construct of TAM. The results from the last mentioned methods corresponded, verified that the analysis was carried out correctly.

The results from the questionnaire confirmed that MIS was accepted and utilised on a daily basis. The utilisation was verified by the actual usage audit. The actual usage audit showed that the information displayed on the MIS is used on a daily basis. This was verified by the results of the questionnaire showing that MIS improve reliability and availability of the Infragas plants in the view of Infragas employees.

The questionnaire revealed that MIS is beneficial to the Infragas environment in the view of Infragas personnel. The actual usage audit verified the benefit by indicating that the MIS was used in various fields by different disciplines and improved the quality of work done by operational and maintenance personnel.

By the completion of the questionnaire the Infragas employees rated Leung's quality characteristics. The results differ from those found in Leung's study however the quality characteristics followed the same sequence as in the last mentioned study. Efficiency proved to be the highest quality and the remaining quality characteristics remained in the same order.

The conclusion and recommendations follows in Chapter Six. The aims and objections of the research are discussed and provided recommendations for use in further research are made.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The research aims of this study were to investigate the interaction between the Sasol Infragas personnel and the maintenance information systems in their working environment and to establish the general attitude of employees towards these systems.

The research was begun by gathering information about web portal characteristics and web portal quality characteristics. Web portal activities were then measured and analysed and finally information regarding the general views of web portal users was collected.

Two research methods were utilised. The first method included an actual usage measurement which tracked activities on the Sasol Infragas maintenance portal. This was achieved using log analysis on the maintenance portal server.

The second method was a questionnaire. The questionnaire gathered personal information from the participants. The users were requested to answer multiple choice questions that formed part of a technology acceptance test. They were also asked general questions about maintenance information systems. The questionnaire also required the participants to rate six portal quality characteristics. Finally, the participants were asked to submit any additional comments they might have had on maintenance information systems.

The results of the web log analysis were analysed and a conclusion was formed about the actual usage of the Sasol Infragas web. When the questionnaire data was examined it revealed information regarding the general views of Sasol Infragas employees towards maintenance information systems.

Each research objective is discussed in further detail below:

The first objectives involved measuring the efficiency and quality of the maintenance information systems in the Sasol Infragas environment by means of interaction, focussing on the Sasol ATR and Rectisol plants in Sasolburg.

The second objectives entailed measuring the utilisation of maintenance information systems, including both the frequency at which the different systems are utilised and also which maintenance information systems is utilised most and least.

Both these objectives were achieved by means of a web portal analysis. The results showed that the maintenance portals were used on a daily basis with adequate time spent on specific pages. The maintenance portals were used mainly for alarm analyses of the ATR and Rectisol plants. Detailed alarm analyses were done on the maintenance portal, as seen from the results of the portal log analysis.

Certain areas of the maintenance portal were not accessed as frequently as the alarm portal pages. These included both the System 1 rotating equipment and the deviation management (DMSI) pages. Even though these pages contain critical information that could result in excessive financial damage, and even loss of life, they were accessed at a very low frequency.

The web portal analysis also revealed the frequency at which the maintenance portal was accessed. Operational personnel are required to view the maintenance portal at least twice per day - once per shift, per day. However, the average access count for operational personnel was only 0.8 for the ATR plant and 1.08 for the Rectisol plant.

The next five objectives were successfully met through the use of a questionnaire given to the Sasol Infragas employees. These objectives were as follows:

- Investigate the general view of maintenance and operational personnel towards maintenance information systems in the Sasol Infragas environment.
- Investigate whether the various maintenance information systems are beneficial in the Sasol Infragas environment.
- Investigate whether maintenance information systems in the Sasol Infragas environment improve plant availability and reliability from the maintenance, operational and managerial personnel's perspective.
- Investigate whether maintenance and operational personnel believe that maintenance information systems are being utilised to their best potential.
- Investigate whether maintenance information systems are an accepted maintenance and operational technology in the Infragas environment.

Of the entire design sample size, 73.75% completed the questionnaire. The first four objectives were met using information from two sections of the questionnaire. The first section asked general questions about maintenance information systems and the second section gave participants the opportunity to provide general comments about maintenance information systems used at Sasol Infragas.

The questionnaire examined whether maintenance information systems in Sasol Infragas are beneficial: 86.75% of the participants agreed that these systems are beneficial. The actual usage monitoring also indicated that the maintenance information systems are beneficial to Sasol Infragas, the frequency at which the portal was utilised indicated that the maintenance portal was adding value.

The participants were asked whether the maintenance information systems improved availability and reliability of the Infragas plants. The results showed that 80.00% of participants agreed that maintenance information systems improved availability and 83.25% agreed that maintenance information systems improved the reliability. The participants' views were positive. The log analysis also showed that the majority of time was spent on the alarm details' page.

The questionnaire also asked the participants whether the maintenance information systems were used on a daily basis. The response from the employees demonstrated that 86.25% agreed that maintenance information systems were being used daily. The actual web portal usage log corresponded with this response, and showed that the maintenance portal was accessed at least once every day of the sample period.

The quality characteristics for maintenance information systems were gathered by using questionnaires. These were compared to a study that was done on quality characteristics on an intranet by Leung. The most important quality characteristic for Infragas personnel was efficiency.

The last objective was achieved by using Money and Turner technology acceptance model to verify whether Infragas employees accepted maintenance information systems as a viable technology. This was accomplished by examining the relationship between perceived usefulness, perceived ease of use, behavioural intentions, and Sasol Infragas employees' actual system usage. The technology acceptance model shows six relationships between these four constructs. The results of the questionnaire were compared to these six relationships and every relationship was verified. This evidence indicates that maintenance information systems are perceived to be useful and easy to use and this results in actual system usage.

The research aims included gaining a clear understanding of maintenance information systems' use in the Sasol Infragas environment. As well as understanding the Infragas maintenance and operational personnel's mind-set regarding maintenance information systems.

Infragas personnel are using the maintenance information systems. However, the questionnaire established that training on the systems was required and that system-specific goals need to be set. The personnel attitude is set to use the maintenance portals but employees want more information about the maintenance portals and using them as measurement tools to improve the plant's reliability.

6.2 Recommendations

A number of recommendations will be made to the managerial team of Sasol Infragas. These recommendations should be communicated to all employees and could improve the mind-set of Infragas employees towards maintenance information systems.

The results of the actual usage audit indicated that the Infragas maintenance portal was indeed being utilised by the employees, however there were some inconsistencies with regards to the personnel interaction with the maintenance portals. On both plants the deviation management system (DMSI) and the System 1 rotating equipment portal access counts were very low.

These pages display critical plant deviations as well as rotating equipment faults or deviations. If any of these are missed, they could cause high financial loss. The interaction with these portal sites should be improved, and moving forward, interaction with these portals should be monitored to see if there are improvements. Further research can also be done to identify why the interaction rate with these portals is so low.

The average access counts and time spent on the portals are of an adequate standard, however, the actual usage audit showed that certain operational shifts do not used the portal as frequently as others. An awareness of the information available on the portal and the importance of this information should be communicated to each shift. This could improve the operational personnel's attitude towards the maintenance portal, which could in turn increase interaction.

The quality characteristics results indicated that there were different quality needs among the personnel at Infragas. Further research needs to be conducted to establish how these quality characteristics can be applied to the current maintenance information systems in order to improve interaction between Infragas employees and the systems. This could increase the quality of the system information that Infragas have access to, which in turn could increase the reliability of the Infragas plants.

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Appendix A – maintenance portals

Infragas ATR and Rectisol web portals

The Infragas maintenance portal consists of the following: the ATR alarm portal, the Rectisol alarm portal, the ATR DMSI inspection portal, the Rectisol DMSI inspection portal, the ATR rotating equipment portal, and the Rectisol rotating equipment portal. Each portal view has a specific identification name which can be tracked. These names were used to identify where on the portal a user had been. A screenshot is provided below of each portal view.

Infragas maintenance portal main page:

Figure 37: Infragas maintenance portal

ATR alarm portal:

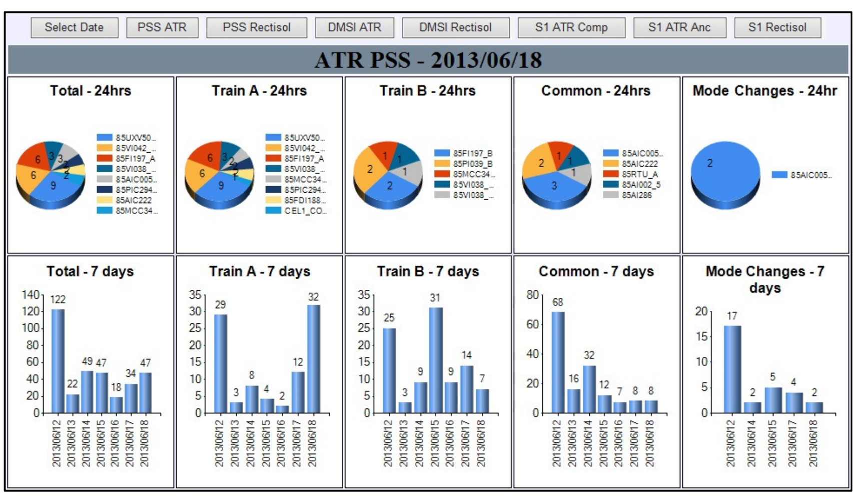

Figure 38: ATR alarm portal

Rectisol alarm portal:

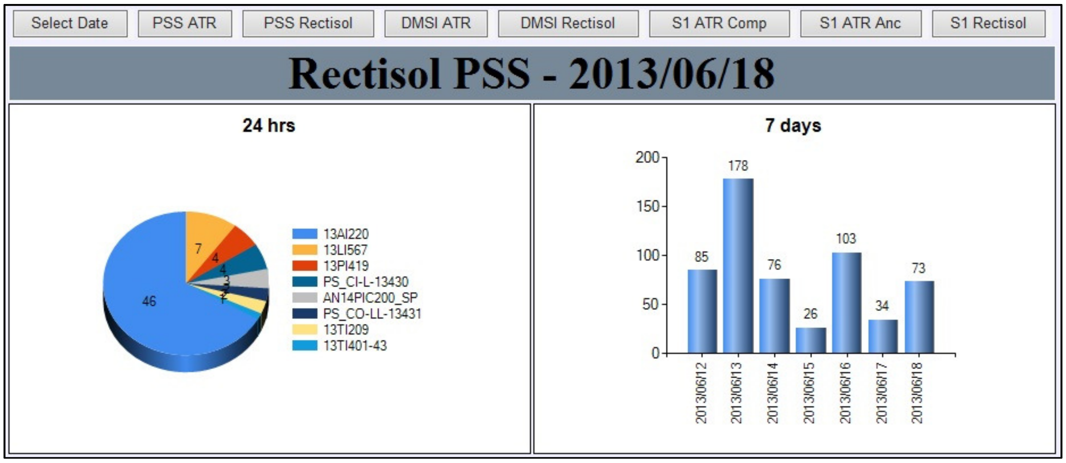

Figure 39: Rectisol alarm portal

ATR DMSI inspection portal:

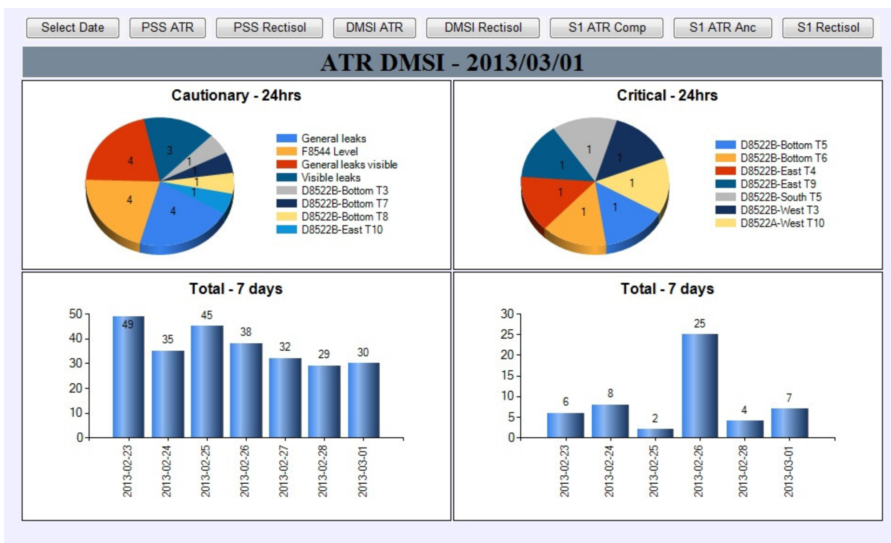

Figure 40: ATR DMSI portal

ATR rotating equipment portal:

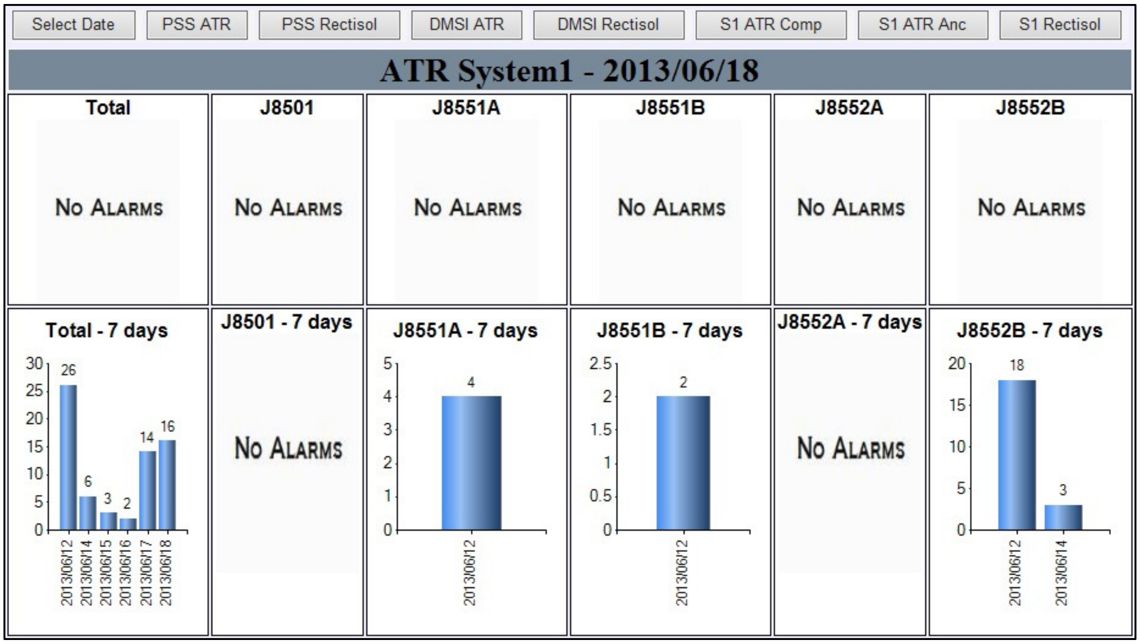

Figure 41: ATR rotating equipment portal

ATR OEE Portal

The ATR OEE portal is made up of the five ATR performance indicators. These are the energy efficiency dial, the cost indicator, the OEE indicator, the energy intensity indicator and the flaring of ATR indicator. The energy efficiency dial, cost indicator and OEE indicator can be drilled down to access more information. Each of these pages has specific identification names which can be tracked. The names are used to identify where on the portal a user has been. A screenshot of each portal view is provided below.

ATR performance overview page:

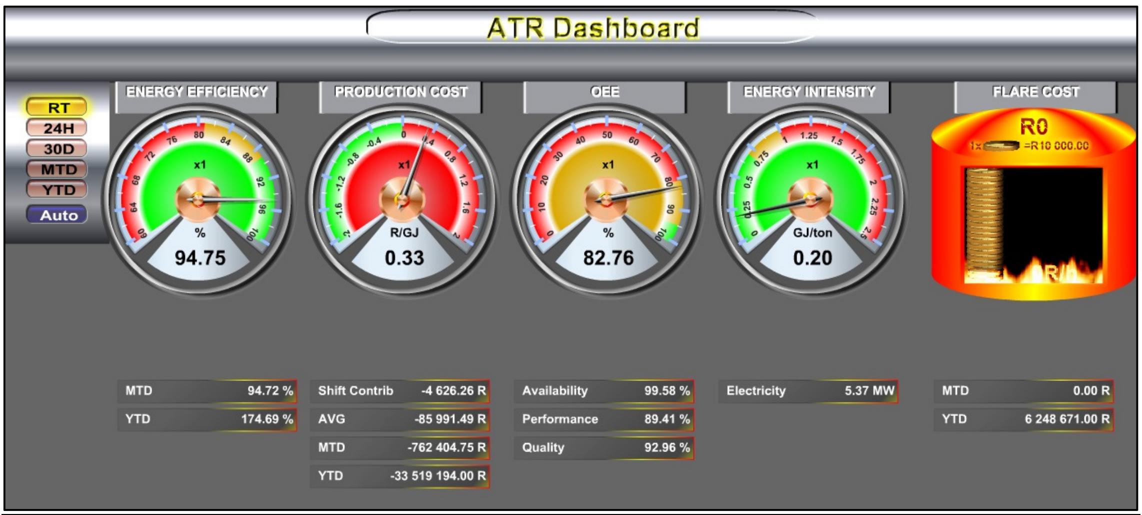

Figure 42: ATR performance dashboard

Energy efficiency page:

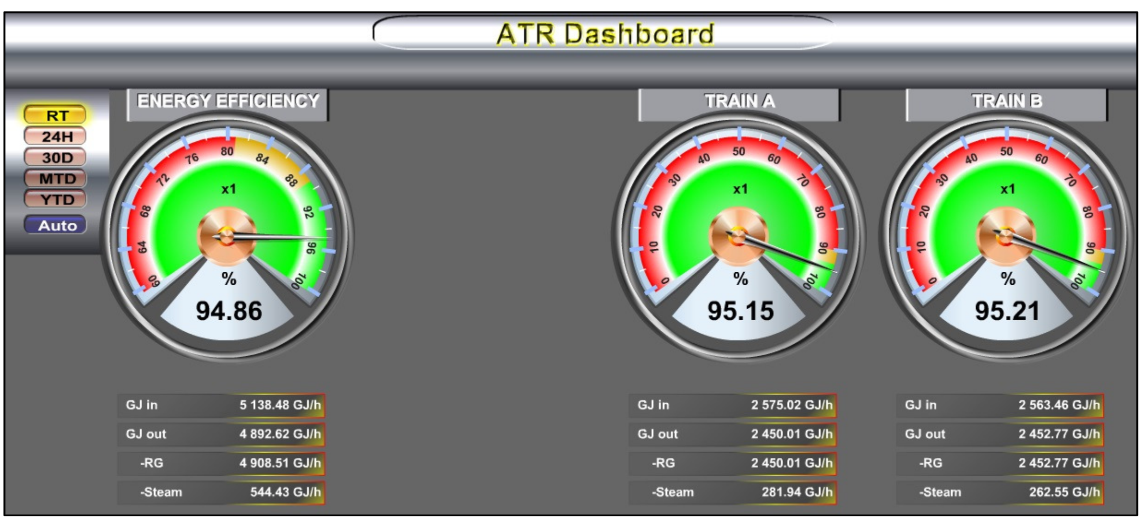

Figure 43: ATR energy efficiency portal

Cost indicator:

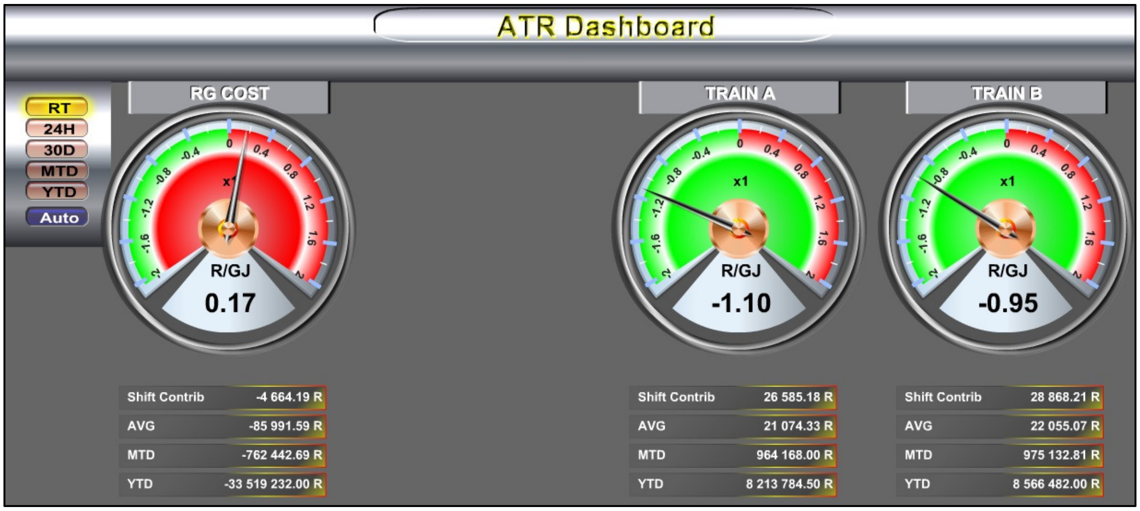

Figure 44: ATR cost indication portal

OEE indicator page:

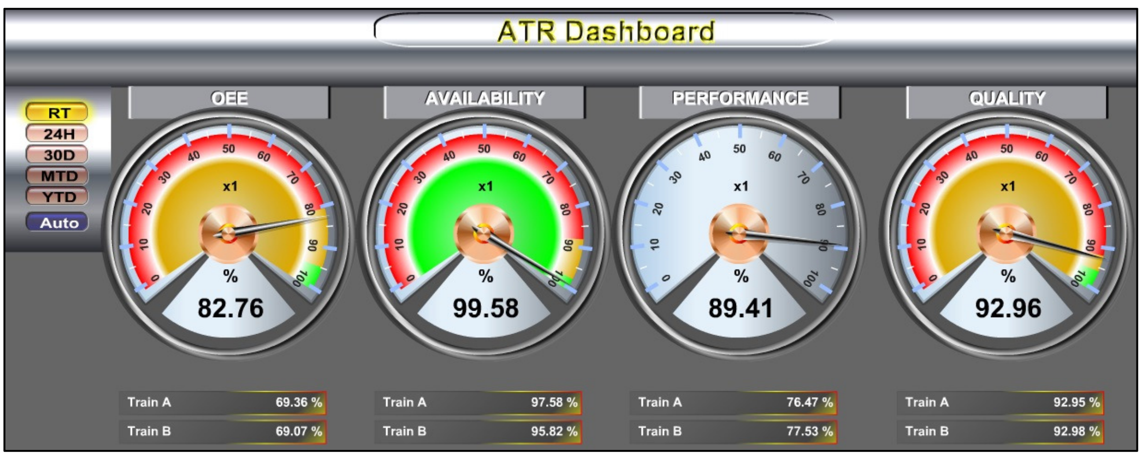

Figure 45: ATR OEE indication portal

Rectisol OEE Portal

The Rectisol OEE portal contains the four Rectisol performance indicators. The indicators are the energy efficiency dial, CO_2 removed, OEE indicator, and energy intensity indicator. A screenshot of the portal view is provided below.

Rectisol OEE overview page:

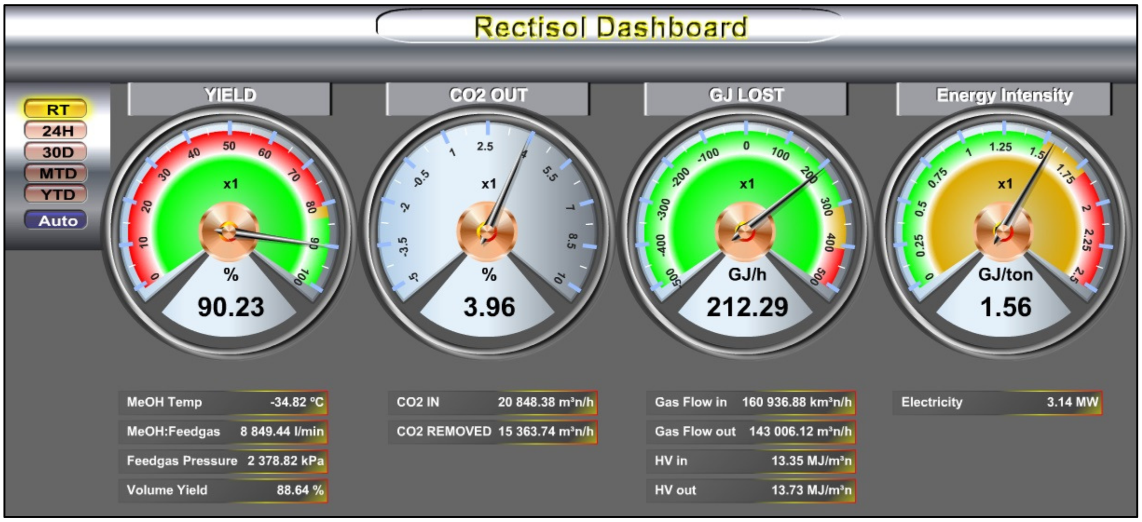

Figure 46: Rectisol OEE portal

Appendix B – Questionnaire

Experimental questionnaire sheets

Infragas Maintenance and DPM portal evaluation

Section A:

Please answer with a **X**.

Department:

Process		Electrical:		Control Systems		Mechanical	

Age: ______________

Gender: ______________

Years' experience: ______________

Years at Sasol: ______________

Post level: ______________

Section B:

Evaluation Scale:

(1) Strongly disagree (2) Disagree (3) Agree (4) Strongly Agree

Any reference to maintenance portals includes Infragas Maintenance and DPM portals.

Please answer with a **X**.

Perceived usefulness

Using maintenance portals

1.	a) gives greater control over work?	1	2	3	4
2.	b) improves work performance?	1	2	3	4
3.	c) enables to accomplish tasks more quickly?	1	2	3	4
4.	d) supports critical aspects of work?	1	2	3	4
5.	e) improves work efficiency?	1	2	3	4
6.	f) improves the quality of work?	1	2	3	4
7.	g) makes it convenient to accomplish our strategies and goals?	1	2	3	4
8.	h) demonstrates inventiveness to our business partners?	1	2	3	4
9.	Overall, I find maintenance portals useful for work.	1	2	3	4

Perceived ease

Using maintenance portals

10.	a) is simple?	1	2	3	4
11.	b) is easy to understand?	1	2	3	4
12.	c) is intuitive?	1	2	3	4
13.	d) is flexible?	1	2	3	4
14.	e) does require a lot of effort?	1	2	3	4
15.	f) does require studying a manuals?	1	2	3	4
16.	g) gives information easily?	1	2	3	4
17.	Overall, I find maintenance portals easy to use?	1	2	3	4

Behavioural Intension

18.	I think that using maintenance portals is a good idea?	1	2	3	4
19.	I think that using maintenance portals is beneficial?	1	2	3	4
20.	I think that by using maintenance portals we would achieve certain strategic advantages.	1	2	3	4
21.	I intend to use maintenance portals periodically in the future?	1	2	3	4
22.	I intend to use maintenance portals routinely and regularly in the future?	1	2	3	4
23.	I intend to recommend the use of maintenance portals to our business partners?	1	2	3	4
24.	Overall, I have a positive perception towards using maintenance portals?	1	2	3	4

Actual use

25.	I use maintenance portals periodically?	1	2	3	4
26.	I use maintenance portals routinely and regularly?	1	2	3	4
27.	Our work is fully integrated with maintenance portals?	1	2	3	4
28.	I often recommend maintenance portals to our business partners?	1	2	3	4

Section C:

Evaluation Scale:

(1) Strongly disagree (2) Disagree (3) Agree (4) Strongly Agree

Please answer with a **X**.

1.	Do maintenance portals add value to Infragas?	1	2	3	4
2.	Do maintenance portals improve plant availability?	1	2	3	4
3.	Do maintenance portals improve plant reliability?	1	2	3	4
4.	Maintenance portals are used on a daily basis?	1	2	3	4
5.	Are maintenance portals beneficial to Infragas?	1	2	3	4

Section D:

Rate the following portal quality characteristics from highest (1) to lowest (6)?

Efficiency: ___________

Functionality: ___________

Maintainability: ___________

Portability: ___________

Reliability: ___________

Usability: ___________

Section E:

If you have any additional comments you wish to make about maintenance portal usage, please add them here.

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Appendix C – Managers' approval document

sasol
reaching new frontiers

TO: Infragas Management team

I am doing my master degree at North West University. My master dissertation title is "Assessment of information availability, maintenance and operations portals. Sasol Infragas as case study." The study consist of the measuring the interaction of maintenance and operational web portals in the Infragas environment.

I hereby ask permission to measure the utilisation of the web portals in the Infragas environment. The portals that will be measured are the Alarm management and DPM web portal. The measurements include the following information. Every event shall be tracked on the web portal. This include who is utilising the web portals and parameters like Date, Time, IP address, Dwell time and Sasol user ID.

I, kindly ask your approval of this measurement.

B. Stinton Infragas Plant Manager	Signature: ____________	Date: 18/6/2013
D. janse van Rensburg Infragas Area Manager	Signature: ____________	Date: 10/6/13
P. Storm Infragas Area Manager	Signature: ____________	Date: 10/06/13
M. Mostert Infragas Area Manager	Signature: ____________	Date: 10/06/13
C. Watkins Infragas Area Manager	Signature: ____________	Date: 10/6/13

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