Cape Peninsula University of Technology

Continuous improvement practices within a nanosatellite manufacturing capability

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Thesis submitted in fulfillment of the requirements for the degree

MASTER OF ENGINEERING IN QUALITY

In the Faculty of Engineering at the Cape Peninsula University of Technology

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Date: 06 June 2019

DECLARATION

I, Zukisa Nkonzo, declare that the content of this dissertation/thesis represents my own unaided work, and the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinion and not necessarily those of the Cape Peninsula University of Technology.

Z Nkonzo	06 June 2019
Signed	**Date**

ACKNOWLEDGEMENTS

Firstly, I would like to thank God for blessing me with the propensity and strength to complete this study. The extensive days and nights spent working on this project brought me closer to You.

I also wish to acknowledge the following people who enormously aided me in completing my research:

- I am extremely grateful to my mentors, Professor Gerard Hillmer, Professor Mellet Moll and Professor Stephen Bosman for their heartfelt encouragement, academic advice, tolerance, and time invested in this research and thoughtful guidance.
- I want to thank Professor Robert Van Zyl for allowing me to conduct research of this nature in such a fast growing engineering development and innovation environment and for his financial assistance; Ian Van Zyl and Cindy Engel for being a strong pillar in making sure that I get the support from the entire team, and lastly the entire sterling F'SATI and ASIC team of engineers.
- I want to thank Mr Nkosinathi Dlakavu and Mr R. Douglas for their contribution since the development of the research proposal of this study.
- I wish to thank my manager at SABS, Mr A.K. Mitchell for allowing me to take days off during the course of this research, my colleagues Mr S. Mnqayi, Mr E. Davids, Ms J Arnolds, Prof. F Magerman and .Mr N Mayman, for their support of my work activities during the course of this study.
- A special word of gratitude to my parents, Mr Nkosayiphatwa ('AA' Nyokinyel 'inyama Xhamela) and Mrs Maggie Nokondla (Mabhatshe) Nkonzo, your love and support is paramount to my academic and personal development. I could not ask for greater parents other than you, thank you very much for being the parents you've been till this far.
- I thank Mrs. Audry Steenkamp,Nomahomba, Madalas,Mandaba, Mayoyo, Siviwe, Bonani, Dakas'efolweni Nkonzo and all the Isijimbos for their love and selfless support since the beginning of this study.
- Finally, I would like to thank my partner Noludwe Ngcaluza, my kids S'nxezi, Z'nano and Zame' Nkonzo for their love, patience and support during the months that I was away from them while I was completing this study.

ABSTRACT

This study investigates the current innovation and development process approaches, with the intention of understanding and elucidating the internal dynamics of continuous quality improvement strategies within the disruptive technological innovation and development set-up of the French South African Institute of Technology (F'SATI) in the Cape Peninsula University of Technology (CPUT).

The research objectives were to look for answers within a innovation and development process approach by investigating the flexibility of the development process, setting up of an improvement targets, monitoring and measuring performance, applicability, and the use of risk-based thinking, lean manufacturing principle applications, and possible means to sustained good working practice for future innovation and development activities.

Mixed research methodology was used to obtain meaningful and value-added results. Data was collected through group interviews (n1= 3 groups), a structured questionnaire completed by innovation and development full-time employees (n2 = 10 employees) and thorough review of documented organisational knowledge. Thematic data analysis was used to analyse qualitative data from the interviews, SPSS software was also used to analyse the quantitative data, and Cronbach's Alpha was used to test quantitative dataset reliability. Furthermore, an expert judgment approach was used to validate the results obtained from the research study through presentation of research findings to the innovation and development team.

It was evident from the findings that even though continuous improvement approaches and a well-established systems engineering approach was in place, personnel capacity and resource capabilities, adopted organisational policies and procedures, and constant application of internal operational procedures remains a challenge within the F'SATI.

The study recommends that the innovation and development centre needs to increase personnel capacity, with respect to required technical and interpersonal skills, more resources that are fit for purpose, to making use of value-adding business relations with external providers through a benchmarking approach, and to be released from dependency on the CPUT procurement system, in order to improve turnaround and delivery times.

Key Words: Design review, evaluation, systems engineering, process approach, six sigma, lean, cubesat, nanosatellite, cost of poor quality

Glossary of Terms:

Cost of Poor Quality (CoPQ): the total of employments realised to ensure achievement of the expected quality level in a manufactured object, and the expenses incurred as a result of failure meet the expected quality level (Cheah, Shahbudina, and Taib, 2010:405).

CubeSat: a cubical miniature artificial satellite with standard geometric parameters of 10x10x10 cubic centimeters, with an approximate mass range of 1 – 16 kilograms which is technologically advanced from 1 Unit (1U), 2U, 3U up to 12U (Canadian Space Agency, 2017).

Design Review: the process of checking accuracy of a product being developed to view any possible interference and interference. Checking is defined as the process of examining the design (product under development) to see if different components in a product occupy the same space as per he required specification (Foster, 2013: 193).

Evaluation is a tool or process that is used to differentiate process, product or service performance against stated levels or performance (Foster, 2013:246).

Lean is viewed as a process approach that is implemented within the organization with a purpose to reduce/eliminate waste (Muda, in Japanese) within its innovation and development process (Dinis-Carvalho and Sousa, 2012:220).

Nanosatellites: very small satellites that are developed to orbit the earth, in an effort to conduct to a specific mission for which it is developed. The nanosatellite mass standard ranges from 1 – 180 kilograms (NASA, 2015).

Process Approach is the application of current process together with identified interactions of the current sub-process to deliver desired outcomes (ISO9001, 2008: V).

Six Sigma is defined as a collection of managerial and statistical concepts and techniques that focus on reducing variation in an established process to prevent or reduce the level of deficiencies in a product being developed (Gryna et al. (2007:67).

Systems Engineering is the discipline of an engineering system that is quantifiable, recursive, iterative and repeatable for development operations within the innovation development process approach (NASA/SP, 2007:276).

Abbreviations:

COTS: Commercial off-the-shelf

F'SATI: French South African Institute of Technology

CPUT: Cape Peninsula University of Technology

PCB: Printed Circuit Board

SEMP: Systems Engineering Management Plan

COPQ: Cost of Poor Quality

NASA: National Aeronautics and Space Administration

DMAIC: Define, Measure, Analyse, Improve and Control

DFSS: Design for Six Sigma

IDOV: Identify, Design, Optimise and Verify

TQM: Total Quality Management

SPSS: Statistical Package Social Science

ASIC: African Space Innovation Centre

ISO: International Organization for Standardization

DEDICATION

This thesis is dedicated to my late father Nkosayiphatwa “Mambetyu” Nkonzo, sister Thandazwa “Magcina” Nkonzo, Macebo “Cebos” Nkonzo and my aunt Nonzame Constance “D-Xhacks” Tshotsho.

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CHAPTER 1: SCOPE OF RESEARCH

1.1 INTRODUCTION

Engineering development companies are currently experiencing diverse and rising pressure due to more sophisticated markets, shifting customer preferences and global competition, making development more challenging and competitive. These companies need to provide products that are constantly improving, over a quicker timeframe, and to offer more quality and affordable products in order to meet customer needs and customer satisfaction. Continuous improvement of innovation and development system engineering processes is required to maintain quality assurance, best product performance and process measurement for effective development activities.

The purpose of quality assurance is to help the innovation engineering process to deliver expected quality measurement based on process analysis. Measurement and analysis are used to support management information needs. These instruments may be applied relevantly to continuous improvement of the system engineering process of nanosatellite development. The success and failures of the very first ever elementary satellite Sputnik, launched in 1958, triggered much interest and motivation for developers to deliver better performing artifacts. The success of Sputnik 1 actually formed the basis of innovation and develpment of nanosatellites, hence the birth of nanosatellites in unversity spaces.

The nanosatellite development programme is one of the fastest-growing areas within the university environment and it is noted as an effective way to transfer technical knowledge and skills at minimum cost; therefore continuous improvement is required to maintain a leading position within this innovation environment and to remain competitive throughout the entire technology enhancement project. The first ever successful university designed, developed and launched nanosatellite was by the University of Tokyo Intelligent Space Systems Laboratory (ISL). It was launched on 30 June 2003 onboard on a Russian Rokoto missile (Peng et al., 2016:1; Swartwout, 2013:214). Therefore, a systems engineering process that deploys measurement of the existing processes capability, problem-solving, target setting and progress tracking is highly recommended in this disruptive innovation process development.

Systems engineering is an assembly that has two significant disciplines, which are Technical Engineering Management and System Engineering Management. Consequently, effective corrective or preventive and risk-based thinking should be entrenched in our nanosatellite development process cycle to improve human working conditions, innovation, and development operational activities in pursuing the quality of processes and products for better performance in all related quality dimensions. Actual success comes from an improvement process that is flexible enough to be examined to identify possible non-value added activities and waste. Therefore to maintain positive development, risks and opportunities that are associated with innovation activities as well as possible relevant countermeasures, quality initiatives must be premeditated within the innovation environment.

1.2 MOTIVATION

According to Besterfield and Juran (as cited in Yong and Wilkinson, 2002), the concept of quality assurance was initially used in the late 13th Century when craftsman began establishing guilds in medieval Europe to perform assessments of the reliability and durability of products. Product reliability or durability is always associated with a high price tag, while quality assurance is free. Costs are generally incurred in engineering development companies when the following are not properly determined and aligned in accordance with the output requirements: process approaches, risks associated with process outputs, dexterity of personnel performing work that affects the quality of an output, and incorrect actions or non-compliance (Crosby, 1979).

The research was conducted in an innovation and development research hub of the Cape Peninsula University of Technology (CPUT) in Cape Town. The CPUT F'SATI innovation and development systems engineering unit is involved in the process of impact design, development and manufacture of small satellites called nanosatellites. However, its innovation and development successes have been widely acknowledged, the institution seems to be unaware of the level at which quality costs prevail in the innovation and development process.

To achieve measurability of the said quality cost, proper alignment of activities with capacity resources needs to be established. The researcher takes initiatives to assess the effectiveness of the applied continuous quality improvement practices within this fast growing innovation and development set-up. On completion of the study, the research findings and recommendations will be presented to the research community concerned and it will be the prerogative of the innovation and development team to use the findings as an input to the daily planning innovation and development process activities, in an effort to improve and to decrease the level of non-conforming outputs as well as to establish the best suitable operational practice. Here, the main objectives of this research are as followings:

- To assess the level at which cost reduction process is applied to improve current innovation and development process.
- To view the level at which the current innovation and development process operates in delivering quality outputs.
- To view possibilities of tracking the progresss of small improvement increments that add value to current process against target settings.
- To learn and understand how quality is being considered within the development and innovation set-up.

This research intends to evaluate the effectiveness of the currently used innovation and development process in respect to development of quality products and possibly to present possible alternative tools for elimination of wastage. Juran (1951) cited in Dahlgaard and Dahlgaard-Park (2006:267), understands wastage as " loss of the gold in a mine''.or ''quality cost''; and as the century progresses he then (1989) refers to the same wastage as ''the cost of poor quality" (COPQ).

The study looks at efforts taken to implement quality controls within the Cape Peninsula University of Technology French South African Institute of Technology of (CPUT F'SATI) innovation and development systems engineering process, with the intention of narrowing the engineering discipline and main activities to focus on the reduction and elimination of defects as well, and to suggest or alternative means to standardise the daily operational activities for better control, best results and best utilisation of the available competent resources and personnel.

1.3 BACKGROUND TO THE RESEARCH PROBLEM

F'SATI has been developing systems engineering products since 2012. It officially demonstrated its technical capability in this field in 2013 by launching its first of a kind nanosatellite project called ZACUBE-1 to into orbital space, which is four years old today and coping very well with the harsh space environment. The cubesat was designed and developed under the magnitude constraints limitations of 10x10x10 cubic centimetres with a mass of 1.2 kg. The organisation's intention was to design and develop the CubeSat within the specified time frame using the current available resources, and to outsource areas that were not possible within the research and innovation hub. Therefore with all the effort exerted to get this project done, possible quality costs were incurred during the development of ZACUBE-1. However, it could not be determined though measurement analysis to what extent the quality cost would have an impact to future development.

ZACUBE-1, also known as TshepisoSAT, is the first ever African CubeSat in space; its success has led to more confidence in the team, and as a result ZACUBE-2 is under development. F'SATI ventured into this great initiative with the intention of contributing to international space innovation and development body of knowledge initiatives; to deliver solutions for current space innovation challenges; and to educate and to transfer skills and knowledge from academics and experienced engineers to students. According to Toorian (2005) as cited in Jayarama and Gonzalez (2011:49) CubeSats were first established by a collaboration between the California Polytechnic State University, San Luis Obispo, and Stanford University's Space System Development Laboratory, with the aim of raising awareness of this field.

F'SATI in collaboration with African Space Innovation Centre (ASIC) is currently developing a nanosatellite on CPUT's Bellville campus for known specific space mission applications. Its quality mission is mainly to focus on framework design which entirely depends on hardware and selected materials which are known as commercial off-the-shelf (COTS), clean room temperature techniques (5 S), in-house manufactured products (printed circuit boards), and natural environmental application (space prediction conditions). The leadership has established a philosophy of continuous improvement and management together with an assembled team of engineers, which strives to improve the current innovation process by all possible means. However monitoring traceability performance in such initiatives seems to be hardly verifiable.

Part of the identified company's continuous improvement strategy is to develop a standardised operating procedure and to seek opportunities to industrialise the current innovation and development system for all engineering activities, for better quality and process monitoring, and quality controls. The main intention of the organization is to develop this engineering wing beyond the natural academic setting, in order for it to became an independent entity (university spinout private company), which will be taking ideas from the thrust of academics and students to increase and to improve its innovation and development capacity.

The innovation and development makes use of electronic and space components such as COTS components to develop nanosatellite product; COTS components offer significant quality regarding space mission conditions. Therefore it was noted from the underlying advancement improvement venture that more waste was created during the development of ZACUBE-1, in view of the failed parts evidenced in item quality appraisals. This exploration will help F'SATI to reduce waste and the level of fluctuation events with its current approach. This exploration looks at exploring different choices that could be conveyed to improve the current existing advancement and improvement process approach, with the goal of enhancing the development of ZACUBE-2.

1.4 STATEMENT OF THE RESEARCH PROBLEM

Cooper and Schindler (2006:96) contend that an exploration issue is a range which relates to an issue with the examination condition, and tends to frame the essential concentration of the exploration. Based on the previous background discussions in this research, the research problem for this study reads as follow: “Lack of continuous improvement evaluation within the nanosatellite innovation and development process leads to increased non-value added activities and to poor product quality".

1.5 RESEARCH QUESTION STATEMENT

The research question of this research reads as follow: “How can non-value added activities be eliminated and improved product quality be achieved through continuous improvement in the innovation of nanosatellite development”?

1.6 INVESTIGATIVE QUESTIONS

The investigative sub-questions are listed below:

- How can the implementation of continuous quality improvement reduce the cost of poor quality?
- What continuous quality improvement programmes are engaged to deliver defective-free products?
- How are lean principles implemented and practised to the gradual condensed development process cycle?
- What tracking and monitoring processes are applied to measure and analyse the current situation against the intended targets?
- What can be done to sustain continual quality improvement processes and low development costs?

1.7. Primary research objectives

The primary research objectives of the nanosatellite innovation and development process environment are tabled as follows:

- To address the effectiveness of key lean manufacturing principles that are in place.

- To determine whether current continuous quality improvement measures reduce various costs.
- To examine the effectiveness of the current used development process.
- To identify main reasons for failures of continuous quality improvement.
- To define and recommend an effective approach that can be utilised to sustain continuous quality improvement.

1.8 THE RESEARCH PROCESS

According to Mouton (2001:46-49), the examination procedure is the path in which an analyst settles on a choice in how to lead an exploration and the specialist ought to plainly express the devices to be utilised in directing a predetermined research subject. This exploration is conducted with regard to the nanosatellite innovation and development process set-up at the Cape Peninsula University of Technology (CPUT), in the French Institute (F'SATI) research hub. Therefore, for the effectiveness of this study,development engineers based at the design and development laboratories are expected to co-operate with the researcher during this process. However the researcher will critically select areas of interest that are critical to the research question and objectives. The researcher intends to evaluate the current continuous improvement process that is currently deployed in the innovation and development process within the research hub. The interaction between the researcher and the innovation and development team will be used as a learning approach for the researcher to critically observe the innovation and development process map.

Based on the nature of the innovation and development team, population size, and the maturity of the innovation and development process, value-adding results are required so that effective continuous improvement is attainable. For the purpose of effective and value-adding results, different research strategies will be utilised in an effort to assemble reliable and relevant data. The examination information will be gathered at the site utilizing different tools and techniques. Firstly, the data will be gathered through a continuous observation process. Here, the researcher will participate in selected development processes such as design review and product development feedback sessions, to gain further insight into the processes as well as to review certain previous organisational documents. The information gathered during the observation will be used to create a tool for further data collection processes, and to review and realign the initial research objectives. Secondly, the researcher will conduct group interviews (n=3) with relevant operational staff as tabled in the organogram (see Appendix I) and a questionnaire will be used. Lastly, an electronic survey questionnaire will also be used to collect data that could not be properly captured during the interview sessions. The high number of data collection methods is influenced by the intentions of the research, nature of the innovation and development team, maturity level within this innovation and development unit, as well as population size.

Following that the researcher will interpret and analyse the collected data from the interviews and questionnaires. The analysis and interpretation process will include determining the time spent on innovation processes, the effectiveness of the current personnel competence and resources, and effectiveness of the effort made by innovators with regard to all critical steps within the innovation development process map to reduce cost levels. Firstly, the research will determine whether the nanosatellite development process employs quality controls to monitor the capability and the reliability of the processes/product used throughout its development process cycle. Secondly, the researcher will determine and evaluate whether the F'SATI innovation and development of nanosatellite improvement process used is able to be measured or not, to gauge its effectiveness. Possible methods to be followed in conducting this research are discussed as follows, and the researcher will choose the most suitable method for the environment.

1.9 RESEARCH DESIGN AND METHODOLOGY

The area where the study was conducted was a disruptive environment. Here, the current trend is bound to be changed rapidly, depending on current customer specifications, which could be a mission objective or specific mission requirements. A disruptive innovation is one that out of the blue uproots a current design or customer stated specification requirements and the change is influenced by the client's requirements at that particular instance (Clayton, 1997:11). Therefore based on the nature of the research environment, innovation and development maturity process, population size and the researcher’s objectives in conducting this research, a mixed research design was chosen. Creswell (2009:3) notes that the research design process is a means and work guideline that includes arrangement of choices that are to be made to achieve certain objectives within an identified research environment. The mixed research approach was tested and deployed as best method in the hope that it would deliver best results that could possibly assist the team to improve its daily operational activities. Based on the nature of the research environment, two research methods, namely case study and action research are possibly appropriate; however the decision as to which method to use was determined by the research objectives. The two methodologies which are case study and action research are further discussed below and the best suitable method was selected for effective results.

The researcher requested the innovation and development team leadership to allow him to carry out a field observation in selected activities, in an effort to learn more about its processes so that best research method is elected. The leadership granted the researcher such an opportunity. The field observation process was used as a pilot study, so that important variables might be identified by the researcher. Of two poles of field observation, namely total observation and total participation, one was elected as the best approach. For effective results, the researcher needed to be independent of the innovation and development team to avoid biased results; to achieve such impartiality the researcher opted for the total field observation approach. Total observation occurs when the observer (researcher) assumes no particular role in the phenomenon being observed (Wimmer and Dominick, 1983:95).

The information collected during field observation helped the researcher to assemble questions that were relevant to the innovation and development team, and that were able to address the research objectives and for effective data collection. Mouton (2011:98) trusts that support of a scientist to an association's day-by-day movement would intend to enter a characteristic set-up or research facility to witness the genuine development operation that is set up. Throughout the field observation process, the researcher observed the innovation and development interaction of activities and interpersonal skills level with respect to innovation and development activities. For the duration of the field observation sessions the researcher made use of the privilege granted to later inquire interrogate for the sake of clarity, where clear-cut or high level or advanced technical information was presented by the innovation and development team.

One set of structured interview questions and thirty quantitative questionnaires were selected and arranged to allow ease of flow from participants view. The interviews questions were prepared in advance and subjected to expert review, which was more aligned to the innovation and development team and given to an expert in operational systems engineering for further review prior to being issued to participants. The participants were given five minutes to go through the interview questions before commencing of the interview session. However, for the sake of interviewee interest in understanding the investigator's intention, a research brief poster that described the research objectives and the research question was dispensed to participants two weeks before the interview date, so that participants could familiarise themselves with the researcher's intentions and possibly inquire where necessary before the interview date.

The content of the interview's questions were relevant to innovation and development activities of the nanosatellite and aligned to research objectives as well as to the research questions of the study in question.

1.9.1 Research Approach

The researcher chose one of three approaches, namely inductive, abductive and deductive research. Saunders, Lewis and Thornhic (2009:124) view the deductive approach as a scientific research principle which pays attention to the development of a theory that is subjected to rigorous examination. They observe that this approach is a dominant tool in the natural science research domain. The deductive research approach will force the researcher to set up the study prior to date collection and analysis phases of the research (Saunders *et al.* 2009:127)

An inductive approach is the principle that allow the interaction of a number of individual phenomena and try to find a common link to gauge any possible relationship at surface (Saunders *et al.*2009: 125-126).They hold the view that this approach allows the researcher to understand how processes interact to each other to reach the end of a product output or service provision. Therefore, based on the stated research objectives and researcher's intentions in conducting this study, the inductive approach was used. Creswell (2002), cited in Saunders et al. (2009: 127) argue that the inductive approach is suitable for an environment where literature is limited in defining a theoretical framework, and that is why it becomes relevant for this study; in this environment of nanosatellite innovation and development, not much has been done with respect to continuous improvement. The abductive approach is viewed as a process that assist the practitioner/researcher to gain new knowledge in a particular setting and is meant to cover both practical reasoning and scientific inquiry within the innovation and development team of choice (Lipscomb, 2012:245-246).

1.9.2 Case study approach

A further option is the case study approach. According to Bromely (1990:32), cited in Maree (2007:75), case study research is a systematic inquiry into an event or set of related events which aims to describe and explain the phenomenon of interest. According to Mouton (2001: 149), case study methods deploy qualitative strategies to acquire knowledge about something. The case study is viewed as particularly advantageous to a researcher whose intention is to identify the real problem in an order to define further research aimed at improving the research area (Simon (1969), cited by Wimmer and Dominick (1987:156).

A case study of an innovation and development team in its natural state allows knowledge from previous achievements or failures to be reviewed against the current set-up outputs. According to Maree (2007: 75-76), the case study research approach is aimed at gaining greater insight and understanding of environmental dynamics within the innovation and development team of choice, so that effective measures can be applied to further contain current challenges. It has the ability to examine all possible inputs and output in detail to identify possible gaps that require attention, as well as noting good practice. In research there are two types of case study to choose from and their distinction is provided below.

1.9.2.1 Single Case Design

A case study offers a multiperspective analysis in which the investigator prefers not only the opinion and perspective of one or two participants in a situation, but also the views of other relevant groups of performers and the interaction between them (Maree 2007:75). Gravitta and Forzano (2006:381) regard single case design as a method that probably make use of the results from single participants or subject to establish the existence of the cause and the effect of relationship. The aim of single subject research is to show that manipulation of one variance (the treatment) causes a change in a second variable (the participant's behavior) (Gravetter and Forzano, 2006:389).

1.9.2.2 Exploratory Single Case study

A case study is a study of single individual for the purpose of obtaining a description of a particular distinct (Gravetter and Forzano, 2006:378). According to Maree (2007:76), a key strength of the method is the deployment of different resources and relevant techniques in the information gathering process. The researcher was partly aware of the current innovation and development maturity systems levels, and some but not all of the existing challenges within the development process at CPUT F'SATI as he gained information during the field observation process. The researcher further engaged with the current team with the intention of exploring all areas with respect to the research topic, the main intention being to reveal best practice and possible areas of improvement for the better operational process.

1.9.3 Action Research

Action research is viewed as a form of inquiry that can be used or applied by practitioners/researchers in every work situation and walk of life to investigate and to evaluate process effectiveness (McNiff and Whitehead, 2011:7). Action research is known by its ability to allow a researcher to observe the process in action within the area of investigation so that possible troubling areas can be identified and first-hand attention be given to resolve such worrying sections without delay. Action research is also described as an orientation to knowledge creation that arises in the context of practice, and its nature requires researchers to work with the personnel and situation being studied to effect positive change (Huang, 2010:93). Action research can only be used under circumstances where the practitioners/researchers want to improve the current research operational set-up, extend known information and to influence other related areas; however it cannot be used when one wants to draw up a comparison or in demonstration of cause and possible effects (McNiff and Whitehead, 2011:7).

The purpose of this study is to look at the existing continuous improvement process approach and to assess its effectiveness with the intentions of processing weaknesses, and to display possible improvement strategies for the sake of performance improvement, and to measure possible waste created during innovation and development cycle of the nanosatellite production. The researcher investigated the development process and the current value streams by evaluating relevant sources, including listening to feedback in the form of total observation, conducting interviews with development engineers, operators and management of the systems engineering development section; studying of the internal documents, and studying weekly or monthly reports of pertaining to ZACUBE-1.

The focus will be directed on the development process to identify the effectiveness of the current continuous improvement process and to identify possible non-value added activities through a tracking and monitoring approach, and to view means to reduce or to eliminate any possible waste. Literature was reviewed with respect to case study research and action research approaches, and learned that both methods are viable, However on revisiting the research objectives, research questions, reasons behind conducting the research as well as possible effective ways to be used to collect data a decision was made. The researcher was convinced after several field observations of design briefing meetings which were regularly held that the action research method would allow insight into the selected topic, articulate process deficiencies, and provide suitable recommendations.

1.10 DATA COLLECTION AND DESIGN METHODOLOGY

Saunders, Lewis and Thornhill (2009:289) describes a participant's observation as a rule that permits a researcher to partake in the exercises of an association and accordingly turn into an individual from the gathering or group. However, field observation is viewed as useful data collection method for generating hypotheses or theories, it is more concerned with descriptions and explanations and presented in two forms, namely total observation and total participation (Wimmer and Dominick, 1983:95). This research made use of the field observation (total observation) methodology process approach. This methodology enables a researcher to become part of the innovation and development team without assuming any role in operation, but to observe and capture information for later use. Throughout the field observation procedure the researcher studied the innovation and development of a nanosatellite in passive role by merely watching systems engineers and listening to the production feedback sessions, and that information was used to compose data collection tools. Recorded data was collected in two forms, primary data and secondary data and is discussed in the following section.

1.10.1 Collection of primary data

The normal principle is that the data gathered by a researcher is one of a kind to the individual participants and their research environment experience. The primary data for this study is not available to anyone until it has been published by the researcher. A study that uses an overview to depict of a specific procedure or operation is known as a survey research design (Gravetter and Forzano, 2006:361). They furthermore explain that an objective of survey research design is to obtain an accurate picture of the individual being studied at that particular moment.

Primary data was collected by means of interview in this research. Saunders et al. (2009:318-319), citing Kahn and Cannell (1957), explains interviews as an intentional interactive dialog between at least two or more individuals or groups. Interviews assists the researcher to collect valid and reliable data that is relevant to the research question(s) and objective(s). In this research, the following types of interviews were conducted: are semi-structured interview, and group interviews (structured interview).

1.10.2 Collection of secondary data

The research environment behind the innovation and development of the nanosatellite under discussion has already made history in the development of this electronic equipment. ZACUBE-1 was completed in 2012, and the CubeSat was officially sent into space in 2013, therefore this accomplishment has made it possible for a researcher to collect secondary data (documented organisational knowledge) information. Saunders et al. (2009:256) note that secondary data takes two different forms, namely raw data and organizational documents.

The reported data considered for this examination includes written material and other material such as video accounts, pictures, illustrations, films and monitoring performance analysis results for ZACUBE-1 and the process of operational feedback. The information reviewed was expected to reveal the reality as well as balance of positive progression in innovation and development of a nanosatellite, as well as the required areas of improvement when properly aligned to the research objectives and research question.

1.11 DATA VALIDITY AND RELIABILITY

The collected data in this research was evaluated to gain confidence in the reality that is presented, and it was very important for the research to present a true reflection of what was really happening within the CPUT F'SATI nanosatellite innovation and development environment. Based on the nature of the innovation and development team and its periodic growth sensitivity, qualitative validity and reliability of the collected data was important and the qualitative validity method was deployed to authenticate the analysed collected data. Creswell (2009:190), citing from Gibbs (2007), defined qualitative validity as an instrument that is used by the researcher to check exactness of discoveries through use of important systems, such as data finding presentations and use of validity tools.

For this study a presentation of the research finding for both qualitative and quantitative results was carried out and the innovation and development team was expected to respond either positively or negatively and to acknowledge the sample presented. The research finding presentation slideshow and audio record was only available to the innovation and development team on request. Quantitative reliability was also used as the second tool in checking reliability of the collected quantitative data. Cronbach Alpha results, validity and reliability are further discussed below.

1.11.1 Validity

The validity of a research study is the level at which the researcher precisely gives input to the questions to which it was intended to respond (Gravetter and Forzano, 2006:156-157). They further state that validity is the quality or condition of being lawful. However, in the context of this research study 'validity is said to be the truth of the research or the accuracy of the results'. According to Gravetter and Forzano (2006:157), there are fundamentally two sorts of validity, which are interior legitimacy and outer legitimacy, which are discussed below.

1.11.2 Reliability

The term 'reliability' refers to the level or degree of consistency between at least two separate estimations (Gravetter and Forzano, 2006:84).The result was obtained from one institution, but from different departmental role-players. Therefore it was very difficult to obtain the same results from the different individuals. For the researcher to maintain and to increase reliability of the data collected, proper research planning was executed before the questionnaires and survey, structured interviews and analysis process was carried out.

It is noted that validity and reliability are tools that are used to evaluate the quality of measurement procedures and they are related to each other in that reliability is a prerequisite of validity (Gravetter and Forzano, 2006:85). The Cronbach Alpha was also used to assess the validity of quantitative results even though the sample was very small. Reynaldo and Santos (1999), define Cronbach Alpha as a device used to determine the internal consistency or average correlation of items in a survey instrument to gauge its reliability (refer to Appendix M: Cronbach Alpha Results). That helped the researcher to determine the reality in the data collected, so that value-adding findings and recommendations were presented to the innovation and development team at the end of the study.

1.12 ETHICS

The study was conducted in the CPUT F'SATI innovation and development laboratories operational set-up. The researcher is currently pursuing his Masters Degrees of Engineering in Quality and is employed as a quality management assessor of different engineering production, manufacturing and service provision process, areas which are governed by ISO 9001 principles. The researcher is continually learning quality techniques that are used in an engineering manufacturing, innovation and development set-up. Therefore, the author demonstrated his understanding and knowledge of quality techniques that he continued to apply and learn about in his day-to-day work activities. The researcher has the capability to conduct such a study and can potentially provide valid and reliable constructive feedback to the innovation and development team.

The research content does not intend by any means to cause harm to any participants involved in the interview process, completion of the research questionnaire or damage the reputation of the innovation and development team. The study is purely for academic purpose. The study, therefore, will not reveal names of participants or respondents, nor would it be interpreted in ways that would reveal the identity of any of the respondents, but it uses the term innovation and development team or CPUT F'SATI for easy reference and identity purpose. The research participants were coded-named according to their departmental role for easy reference and analysis.

All the data that was collected in this study includes thirty completed questionnaires, voice recordings of three group interviews and interview transcripts as well and one Powerpoint presentation of expect results that summarises data were maintained as necessary. The data collected was kept in its original version to avoid any data distortion of events or results that are misleading, and to be given to CPUT F'SATI Systems Engineering Research Innovation and Development department's relevant person once the project is completed.

1.13 RESEARCH ASSUMPTIONS

In order for a researcher to conduct research in this field, some assumptions have to be made to find a point of departure. The researcher had to assume that basic operational process, information and procedures were in place in the CPUT F'SATI innovation and development department. The researcher's assumption might not be true or the organization might not be aware of these, therefore the study was intended to verify this. For this study, the following assumptions were suggested.

- Structured organisational work instructions or procedures that fitted well with the type of operation were established and were effective in the set-up.
- The relevant organizational documented information (organisational knowledge) would always be available when required and would always be updated as needed.
- Human resource capacities matched the required activities to be carried out.

1.14 RESEARCH CONSTRAINTS

The researcher has a passion for continuous improvement and for that reason he chose a new area of research which was innovation and development of nanosatellite systems engineering. The researcher had other personal work commitment that might influence the proper execution of this project. The circumstantial gap in accordance with the research environment technical operational activities is a concern based on the complexity of a specific technical knowledge required by the researcher. The national student protest movement in higher education might have caused delays in completing this research in accordance with plans and arrangements.

These three major factors might have in a way limit the researcher's ability to conduct research in a normal way. However, the researcher was willing to manage his own personal challenges, while the technical knowledge gap in systems engineering and national student protests remains the major issues. In this research there were two inhibiting factors that are expected to surface; the limitations and delimitations and these factors are further elaborated below.

1.14.1 Limitations

The researcher is not an employee of CPUT F'SATI systems engineering. Therefore the scientific technical language barrier and little access to the day-to day team engagement time are anticipated to influence negatively the data collection process. The innovation and development terms/words used within the innovation and development team might have been strange to the researcher and create possible confusion; however provision to deal with this was provided through available organisational documented information. The distance between the researcher and site of the research would definitely play a part in limiting time for interacting and observation. The researcher was employed full time, and could only make use of annual leave to engage properly (to perform effective total observation) with the research site personnel; alternately, appointments after normal working hours with CPUT F'SATI personnel were arranged.

The CPUT F'SATI developed various types of electronic products and the researcher could not conduct continuous improvement evaluation on all other products or process approach. The focus area of this study was mainly in the innovation and development product or process approach from ZACUBE-1 to ZACUBE-2.Therefore the collected results could be used by the organization in other processes to improve its innovation and development procedures. The national students protest activities could contribute negatively in making data collection and analysis effectively for the research and that could prolong time frame set for completion of this study. Apart from the mentioned limitations, it has been noted that CPUT F'SATI does not have good records for the process approach used in developing ZACUBE-1, which might limit the researcher to secondary data collection principles.

1.14.2 Delimitation

Maree (2007:42) maintains that researcher delimitations should be clearly stated in research so that expectations can be really narrowed down to the focus area of concerned. The research was conducted in a research-based environment, where process industrialisation is really not an issue; the major focus within the nanosatellite development was to get the output as anticipated through input engagement. The focus of this research was the assessment of continuous improvement processes that were deployed during the development of nanosatellite ZACUBE-2 within the CPUT F'SATI therefore the study could assess other process development areas. However, the findings might still be used to improve those areas.

1.15 SIGNIFICANCE OF THE PROPOSED RESEARCH

The research findings are anticipated to be utilised by CPUT F'SATI systems engineering innovation and development to enhance daily operations through adoption of the relevant World Class Manufacturing (WCM) and Lean manufacturing principles that are outlined in this work. The adoption of quality continuous improvement in nanosatellite development will definitely improve and sustain the current good practise improvement principles. The motivation of this study was to establish possible means to evaluate current continuous improvement methods and to reduce internal development cost, so that a basis of innovation and development could established and referenced for future use. The anticipated significance is tabled as following:

- To view the importance of documentation in such environment, so that information referencing is always available at the point of use whenever it is required.
- To make innovation and development staff aware of product quality principles that can advance the standard of the work operations.
- To identify the need for an effective continuous improvement for nanosatellite innovation and development process; and lastly
- To make personnel aware of the waste created during the development process and to introduce waste reduction strategies to benefit the institution.

1.16 ANTICIPATED FINDINGS

The achievement of 21 November 2013 has been noted, when ZACUBE-1 was successfully launched and placed in orbit. Therefore, based on this achievement, together with noted innovation and development challenges, some key components are assumed to be in place within the research environment. The anticipated findings for this study are listed as follows:

- Non-existence of industrialised set-up innovation and development layout, which would cause deficiencies in personnel and resource capability performance.
- Lack of quality tools to monitor and evaluate product or process capability as well as reliability.
- The absence of quality waste reduction tools deployed within the innovation and development process approach.
- An ineffective process approach in maintaining innovation and development information for future reference.

1.17 CHAPTER AND CONTENT ANALYSIS

Chapter 1: This chapter provides a brief introduction and the background to the research. The research process is explained, followed by the formulation of the research problem, the research question and the study's supportive investigative questions. The research assumptions and constraints are listed, together with the overall research design and methodology.

Chapter 2: Here, a holistic perspective of the research environment is provided. This chapter provides background and holistic view of the CPUT F'SATI systems engineering research as innovation and development research unit.

Chapter 3: This literature review discusses the relevant research that has been conducted in related fields with respect to the research topic, namely the history of satellite systems engineering development from the 1950's till 2013 with regard to success and failure rates. The quality impact on design and development engineering firms is discussed. This review also includes concepts of quality in order to avoid loss in engineering manufacturing companies, such as Cost of Quality, Kaizen Philosophy, and Continual Improvement. The focus is, however, more on process or product development capability and the application of continuous quality improvement tools, which are used to eliminate waste.

Chapter 4: Data collection design and methodology are unpacked in this chapter. This includes data collected through questionnaires and interviewing participants at CPUT F'SATI in order to acquire the relevant information for analysis.

Chapter 5: This chapter examines the data via analysis and interpretation. The data is analysed and results are interpreted. The measurement scales used are also being explained in detail.

Chapter 6: This conclusion discusses the findings by revisiting the research problem, research hypothesis, investigative questions, research objectives, and research recommendations. The chapter concludes by tabling future research areas to be explored for the benefits of continual quality improvements in the research environment. The research objectives were all effectively addressed and the researcher firmly argues that there is a strong integrative link between the research results, the objectives, the conclusion, recommendations and future research areas.

CHAPTER 2: HOLISTIC OVERVIEW OF THE RESEARCH ENVIROMENT

This chapter provides an overview of the research environment. Firstly, an introduction to the research environment is provided. This introduction will be followed by a discussion regarding the nature of the environment and issues that create an opportunity for wastage, product or process quality imperfection within the innovation of nanosatellite. Lastly, the research unit which is the site of this study has been profiled to lay out out the history in this phenomenon of innovation and development, and the issues that are related to continuous improvement within the development are examined.

2.1 INTRODUCTION

The innovation and development of nanosatellite within the CPUT F'SATI involves a series of related activities; therefore the involved activities are classified as the manufacturing process in the context of this research. Levinson (2017:2) describes manufacturing as the process where information (input) is transformed into a product (output) that meets human needs or certain requirements in accordance with the specifications and results stipulated by the end user.

The intent of this study is to evaluate the effectiveness of the currently deployed continuous improvement practices within a nanosatellite innovation or manufacturing capability of CPUT F'SATI. The development of nanosatellites in this environment is carried out by engineers and student engineers under research and development circumstances and interested parties and product application requirements are considered to meet stated mission requirements. Here, the term human need is used interchangeably with the term customer. It could therefore be argued that the sustainability of quality together with its constant improvement in an innovation engineering development assists understanding of the standard of service or product being offered by the organization.

The Institution offers a service in nanosatellite development programme to customers who have a major interest in the space mission environment, and the service offered within the institution is heterogeneous, based on different nanosatellites that are developed for different space mission needs. The proposed dimensional requirements (specification) by the customer, determine the priority of development within the nanosatellite development. The institution offers or delivers a tangible product such as CubeSat and CanSats to its respective customers. The Cubesats and CanSats are visible product and it takes a lot of discipline and effort to get good results.

The term ‘product ‘in this research is defined as an output of an organization that can be produced for a customer, and transaction takes place between the two entities as an expression of product acceptance or delivery (ISO 9001, 2015:21).

2.2 DEVELOPMENT THROUGH NOVELTY

Foster (2013:213), elaborates that manufacturing institutions produce physical dimensions, such as height as well as specific density to the product being developed in accordance with the given customer specification. The companies that provide tangible and intangible services differ in their offerings, but still they have the common objective which is to satisfy the person with a buying power in accordance with specifications and meeting applicable statutory requirement through quality service provision.

Quality service is not only an imperative for competitiveness but also a sign of quality maturity within the innovation and development process used by the institution (Foster, 2013:211). The institution is assumed to be deploying an effective process approach with risk-based thinking strategy and nanosatellite development ranges from interior and frame structure housing for electronic delegate components. Here, Predictable and consistent results are achieved more effectively when activities are understood and managed in accordance with the set of interrelated processes that function as a coherent system (ISO 9001, 2015:6).

The National Aeronautics and Space Administration (NASA 2015) describes a cubesat as a very small satellite built to standard dimension (Units or ‘U’ from 1U, 2U, and 3U) of 10x10x11 cm and these geometric dimension may change based on the unit required.

The CubeSat concept was proposed by professor Twiggs at the university space symposium in 1999 (Takei et al., 2007:707-708). The South African Universities participating in nanosatellite development like Cape Peninsula University of Technology (CPUT), University of Stellenbosch (USB) and University of Pretoria are used as vehicles to educate or create awareness to students about space engineering, including mission conceptualisation, satellite design, fabrication, ground testing, feedback of the results, launch and operations as well space environment (Funase et al., 2007:708). The Cape Peninsula University of Technology is following in the footsteps of University of Tokyo which made history in June 2003 by successfully launching the first ever Cubesat in Space called XI-IV (Funase et al. 2007:708).

The development of this small satellite requires unending continuous improvement strategies to keep up with ever rapidly changing harsh space atmospheric conditions, mission applications; continuous improvement is expected to yield good results and to eliminate innovation and development waste within the core and supporting process involved. The primary research objectives of this study are mentioned in Chapter One in section 1.7 of this document. A description of a nanosatellite follows.

2.3 THE NATURE OF NANOSATELLITE PRODUCT AND ITS COMPONENTS

Nanosatellites are one of the smallest classes of satellites, ranging from dimensions of 1 to 10 kg, and this innovative concept has generated much interest achievement in the past decades. The nanosatellite is developed for specific mission objectives and therefore, design specification requirements become vital in order to achieve the intended mission objective. According to Funase et al. (2007:707) the nanosatellite is primarily used as a tool to educate university and college students, and it is most important for students to experience the whole innovation and development cycle of a space project so that their confidence and knowledge became strong in this field.

The dimensional requirements are limited to 0.1 to 1kg and nanosatellites ranges from 1 to 10 kg with trigonometric constraints. At the present moment, nanosatellites are developed and produced in square shapes of 10x10cm across the section. The main reason for the dimensional constraints is launching restrictions imposed by the satellite carrier, or deployment system (DS).The nanosatellite designs range across different unit sizes and at the current moment 3U is a trending range; its development is influenced by the requirements of new missions. The main focus is to develop more capable and advanced satellites that can deliver more accurate performance than previously developed. Academia has developed most satellites for different mission objectives. The nanosatellites serve the purpose, and are serving at different ranges of altitude depending on their stated mission objectives.

Nanosatellites under development undergo severe monitored evaluation processes such as vibration and radiation assessments to attain safety guarantee of performance in the space environment. Therefore some electronic components show enough strength to withstand launching condition, while some fail during development and launching phase. Therefore, a decision has to be taken to segregate such inferior components from the innovation and development line. When all components meet the expected performance requirements the satellite is then built, evaluated and launched into space as the secondary payload; it is launched as secondary payloads so that launch cost is reduced to a minimum. The selection of material normally takes place during the design and development process, where the selection of appropriate materials are agreed upon by the innovation and development engineers.

The decision to accept or to reject components is influenced by the design and development output results. Design and development are a set of interactive and interrelated activities that transform the stated expectation into more detailed requirements. Therefore COTS components and/or space-qualified materials are selected to participate in this innovation development. These latter components are known by their reliability and flight heritage reputation. During the launching process, the nanosatellite is placed on a missile. The current missile in use can only accommodate three CubeSats at the moment, which can only be packed in a series formation. Therefore, launching constraints contribute to the size of the CubeSat to be developed.

2. 3.1 The Nanosatellite development and its purpose

Nanosatellites are generally designed and developed for the different missions and design complexity is determined by mission requirements. Therefore, the development frame would require an integration of competency from personnel and capable facilities as well as the set of selected material to achieve the stated mission objectives. Competency in this context would mean the ability of an individual to successfully apply capabilities or knowledge and skills to achieve intended results. The combination of academic training, experience and on-the-job training within the team that is developing a nanosatellite would possiblly guarantee the output products with minimum defects. In design and development environment, a defect is known as an area of dissatisfaction which creates the possibility of failure for a product or service. For effective nanosatellite operation, defects are not acceptable at all, because defective product will not be able achieve stated mission requirements and could increase the cost of poor quality.

The primary function of the nanosatellite at CPUT F'SATI is to educate our younger generation and engineers about satellite development and to cultivate the interest of young people in this challenging and exciting career in South Africa and in Africa as a whole. The other main intention of developing nanosatellites is to introduce African innovation skills to the world in this area. The function of the nanosatellites developed at university level, especially at CPUT F'SATI, is to monitor environmental behavior. It can be used for rapid responses to disaster for asset tracking, where ships or vessels at sea are monitored for risk management purposes so that risk and opportunities can be anticipated ahead of a potential disaster. The nanosatellite is also developed to study the nature of sun-earth relationships, including turbulence in the existing ionosphere plasma. The functions of nanosatellite are not limited to the abovementioned, but the function of each nanosatellite will be determined by the objectives of the mission at hand.

The nature of developing nanosatellite at CPUT F'SATI is influenced by skills development. Here, young engineers shadow the experienced and learned systems and space researchers. These young engineers perform their task under the watchful eyes of experienced personnel, who give guidance and evaluate any potential risk that might occur during the innovation and development phase. The nanosatellite development programme from the institution of learning is used as the vehicle to transport the development skills from matured engineers to young engineers, so that young engineers grasp the idea of developing a bigger satellite for more advanced missions for future and that carries continuous improvement thinking. The major intention is to deploy principles of continuous improvement and strategies to enhance both the innovation development process and the performance capabilities of nanosatellite from small to a bigger scale and to develop as well as preserve this scarce skill.

The CPUT F'SATI nanosatellite development programme has a minimum time frame to develop one CubeSat. The time constraints provide an opportunity for the developers to learn project management skills, coupled with engineering development principles within a short space of time to possibly achieve immaculate results. According to Lim et al. (2015:158), the period spent in developing small-scale satellite has created a perfect relationship between the industry and academia and the most attractive part is the time spent on the capability to lower cost of development. Planet Labs, an American earth imaging private company based in San Francisco, CA, founded on December 29, 2010, has proven this as true, because in 2014 this company launched more than 93 Dove-type series of nanosatellite (Lim et al., 2015:158). Planet Lab development maturity has been noted from its output. The development team required only a minimum of two weeks to put together two Nanosatellites for a launch at Planet Lab (Lim et al., 2015:158). Planet Labs designs and manufactures Triple-CubeSat miniature satellites called Doves that are then delivered into orbit as passengers on other missions, for cost prevention reason. Therefore for this (CPUT F'SATI) team one saletellite is delivered within 24 – 36 months. The length of development is influenced by several factors, hence the researcher evaluates the effectiveness of applied continuous improvement.

The area or rather site of this research has made history already on the African soil with respect to development of nanosatellites when CPUT F'SATI on 21 November 2013 launched ZACUBE 1 into space. The CubeSat was then renamed TshepisaSAT, which means “Hope of our African soil”. This has inspired many young African engineers to get involved in such programmes.

CPUT F’SATI has followed on this achievement by building ZACUBE-2 which is three times bigger than ZACUBE-1. It was expected to be assembled by the beginning of September 2016, the expected date for Flight Readiness Review (FRR) was set for the end of December 2017,and later changed for 1May 2018 at an altitude of 550km and at an inclination angle of 98 degrees Celsius

The ZACUBE-2 consists of three units (3U which is 3 x bigger than ZACUBE-1). It was expected to be delivered in 18 months, but due to internal operational delay the project took longer than expected. Possible issues that affect the effectiveness of innovation and development of the nanosatellite have been noted in relation to good manufacturing practice since the inception of this innovation, and these alarming issues pose a risk for cost of quality. As mentioned these issues resulted in the manifestation of non-value added activities that increase the deficiencies in continuous improvement process of nanosatellite innovation and development activities. These issues further discussed below.

2.3.1.1 Material selection within innovation and development

Some of the materials used to develop and produce nanosatellite are scarce. The rare condition of the material is influenced by the structural composition. The selected material in this stream must have the ability to withstand application conditions and selection has to be done within the application of microsphere philosophy. Microsphere philosophy refers to the use of state of the art material and consideration of the known commercial-off-the-shelf components (COTS). Such type of material has vast potential for developing such spacecraft in a short period with high lifetime capabilities (Toronto Institute for Aerospace studies space flight Laboratory, 2011). COTS material are known as the flexible material that can be trusted when assembled with other components and there would be no problems during mission application,provided the assembling process is performed accordingly.The components’ lifecycle mismatch problem requires that design development engineers be cognisant of which parts are available and which part may be obsolete during the development run (Solomon, Sandborn, and Pecht,2000:707).The challenge within university or college development that influences the high rate of cost of quality is a lack of expertise within the development team. The nature of the academic environment in some areas within the development process is viewed as autonomous and therefore this affects continuous improvement processes. The nanosatellite development process requires individuals who possess the relevant skills to influence planned development processes to achieve a stated mission concept. The process approach would require certain skills that are not within the organizational development structure, because the development time frame may not be sufficient to equip every individual with the relevant skills for the project at hand.

The stated dimensional constraints of a nanosatellite are influenced by launching requirements; these constraints would therefore enforce outsourcing of services and components where in-house capability is limited. Therefore the outsourcing process was the best option to achieve that promised targets by CPUT F'SATI to be able to deliver quality results. However, even though outsourcing is regarded as best means to reduce cost by shortening innovation and development time and improve quality of a product, it still in some degree increase expenditure cost within the innovation and development tight budget.

In some cases, it became challenging for space mission development programmes to meet exactly the specified customer requirements, because the designed spacecraft would have challenges in orbit, where limited pointing accuracy become the issue.
The availability of local flight-qualified hardware to achieve quality objectives and the more reliable satellites that will potentially serve mission objectives with less challenging factors. The absence of flight-qualified hardware may cause a system to encounter obsolence problems prior to field life and often experience obsolence problems during its field life (Solomon, Sandbon and Pecht, 2000:707).

There are several issues that influence quality in this exciting career innovation development, but for the purposes of this study, the focus will be directed to activities that are taken to address risk and opportunities within the development process with regard to the effectiness of the continuous improvement process. Here, the interest is embedded within the possible actions that are taken by the innovation and development hub before accepting the responsibility of developing a nanosatellite and could be the issues from internal or external in considering the operational processes.

Secondly resources and performance of design and development will be monitored, as well as looking at the possibilities of retaining updated organisational documented information that is in line with innovation and development activities. Thirdly, quality control practices will be reviewed that are performed in external provided process, products and services. Lastly, the focus will be directed on the behavior of electronic space components during the design and development process of the nanosatellite.

2.4 RISKS AND OPPORTUNITIES WITHIN THE INNOVATION AND DEVELOPMENT PROCESS

The risk assessment in engineering design and development is a very crucial factor that cannot be ignored by any means. Understanding the nature of a risk is critical in making an informed decision that is appropriate to manage a process approach. According to Vatsa (2004:1), environment resilience in resisting the negative outcomes of these risky events is an indicative of its level of vulnerability. Thefore an organization needs to find a sustainable plan for risks and means to avoid a situation that forces the process to cope with unsolicited events. The classical conception views risk as the chance of injury, damage, or loss that can happen in a planned operational set-up. It can also be seen as the probability that a particular adverse event will occur during a stated period of time, or output from a separate challenge that can negatively influence planned arrangement otherwise (Vatsa, 2004:4).

According to Smallman (1996:12), little information has been collected that proves methodically what kind of organisation it is that takes or avoids risks, although much is known informally within development circles. According to Smallman (1996:13), (citing Ashby and Diacon (1994), the current economic and financial paradigm at that time wanted research to look at risk management rather than to be focused on development of an organization, political and in contextual models, so this means the risks were noted and realised but were once looked at in one sided.

This is evidence that risk-based thinking has been a burning issue since the inception of business development, but little was done to mitigates such risks for better operational changes. It is then necessary for the organization to anticipate a change and cut across boundaries within the value chain to gain support for that particular change (Rostopt and Aiello 1991), cited in Smallman (1996:13).The asignments of task within the organisation also determines the level at which operational risks can be managed. In an organization, certain individuals are given authority to control certain areas of the process, therefore power will definitely accrue to the few who are allotted to manage the cost and the risk associated with the process approach deployed (Smallman, 1996:13)

The competency of personnel or resources in managing risk became a very important factor; therefore managers with high-risk propensities are more likely to provide decisions at short notice in facilitating the progress in development process line. The organization needs to determine its relevant competencies required of a person doing work that affects the positive progression of a project, and this person's ability to apply knowledge and skills to achieve intended results should be evaluated. According to Tummala (1996:54), the person identified as competent to deal with risk management should be able to evaluate several decision alternatives based on the risk profile generated by using risk identification, risk measurement, and risk assessment phases and be able to choose most suitable course of action and be able to manage and control the identified risk.

The risk assessment practice reveals area of interest within the organizational process and the areas of concern in the context of this study are recognised as opportunities of improvement, and an effective approach in dealing with opportunities needs to be established. Certain risks are not easy to eliminate; the best way to deal with them is to accept and find way to control their interference within the organizational subprocess, and by doing so the organization practices or applies the proper risk management process (rpm) in pursuit of eliminating possible nonconformity or major risk severity. Risk, as mentioned above, creates different levels of opportunity within the organization, discovers opportunities, and risks mandate the business to look for better alternative ways of doing business, but not far from the perceived business initiated plan. The organization may have highly skilled personnel to work in the production and innovation process to deliver product or a service, but due to the lack of driven quality leadership in product or process, all that potential might not be effective as perceived by the process owner.

Foster (2013:113) views leadership as a process that mandates an individual to influence a particular group to move towards the attainment of organizational superordinate goals in pursuit of human needs. The role of leadership is to enforce stability in proper application of principle for a specific process approach in pursuit of organizational improvement. According to Vatsa (2004:8), risk is known as the loss in the probability of occurrence of a specific potential hazard in a given area over a period of time, and by controlling risk one increases opportunities for producing high-quality products or services within the probability dimension of the stated requirements.

2.5 MONITORING AND MEASURING

The process approach used by CPUT F'SATI requires an effective monitoring and measurement process so that the process owner envisions its capability to deliver the perceived or expected results. The monitoring of a process performance is crucial because this exercise helps to make problema visible, assists in detecting potential problems prior to their existence, and subsequently enforces the process owner to eliminate or rectify abnormal behavior in a particular area. Das et al. (2015:785) believe that process monitoring schemes have evolved around two different strategies, namely, model-based methods and information-based methods and these two need to be considered in an innovation and development environment set-up based on their proven track capability.

The organization appoints a monitoring process approach that best suits its operational environment on the basis of requirements of the product or process being looked at. ISO 9001 (2015:7) notes that the organization shall determine and provide the resources needed to ensure that valid and reliable results are achieved for innovation and development activities, so that a workable and systematic model is determined. Das et al. (2015:718, citing Chen and Tsou (2003), Iserman (2005), Luan et al. (2005), and Luan and Zhao (2008) view model-based strategy as an approach that relies on explicit mathematical formulations to ensure the process of an organisation. The data-based strategy relies on process history data for building a statistical or data-mining model which is subsequently employed to monitori the concerned area within a process or product being developed.

The model-based monitoring process is usually a plethora of data that is drawn during the regular development production process and analysed with the aid of relevant statistical or data mining methods. In view of the process or product capability and its effectiveness through the monitoring process approach, the data-based strategy is considered the preferred choice (Nijhuis et al. 1999; Simoglou et al., 2000; Saavedra and Cordova, 2011, cited in Das et al., 2015:719). The reason for the selection of the database strategy is the fact that it is able to provide reasonable information and clear analysis of which area of concern to prioritise.

In this study, because of the nature of the research environment, both monitoring and measuring strategies were deployed. The intention was to present the actual process performance in an effort to point out good practise as well as to reveal areas of improvement that require urgent attention, so that direct continuous improvement might be applied.

2.6 THE CONTROLS OVER OUTSOURCED ACTIVITIES

The CPUT F'SATI team needs to establish resources needed to produce the required product within the set timeframes. The current available resources could possible hinder the progress in an engineering development environment based on capability. Engineers and scientists who invent new technologies often lack the resources to turn their ideas into viable ventures that can realise a business opportunity (Theyel, Theyel, and Garnsey, 2012:101). Within F'SATI, some work is outsourced, depending on the available resource capability. The outsourced work might show some inconsistency in quality if the service provider does not adhere to the specifications provided. Therefore it has become a principal rule to set and establish a level of control for outsourced activities so that service providers consistently provide defect-free products.

According to ISO 9001 (2015:13), the accountability of quality relies on the organization that is being supplied with the project to make sure that the external provider delivers a service or product that conforms to stated requirements. For F'SATI to maintain quality in services or activities that are performed by an external provider, critical quality control gates have to be established and the external provider has to agree to terms before accepting the responsibility. The reason for controlling this process is to unite the two parties to further the common goal of quality improvement for the benefits of the customer and the organisation that provides services or products (Lin, 1990:35). This study conducted an industry-specific comparison between Japanese and American industries and demonstrated that the use if quality control gates established superior quality information systems (Lin, 1999:35).

During the development process within F'SATI, specific sub-processes are viewed as crucial, to the extent that the available resources fail to participate in execution of these processes. Therefore the organizational process leadership makes a decision to outsourced them to a service provider with a verifiable track record in performing such tasks. According to Eldridge et al. (1992:66), process management is a well-known and extensive concept and is integrated into chosen primary business models as an essential part of achieving organisational brilliance in product or service delivery.

An organization is also obliged to determine and apply explicit criteria for evaluation, selection, and monitoring of the process or service that offered by an external provider. The organization need to find a way to re-evaluate the ability of the service provider in consistently providing high-quality work as stipulated in the customer specifications and that needs to be properly communuicated with the service provider before accepting the responsibility. The organization need to establish the relevant types of control to be deployed, which are then employed by the organization in order to eliminate causes of variability (Lin, 1999:32).

2.7 THE BEHAVIOUR OF ELECTRONIC COMPONENTS DURING APPLICATION

The context in which all organizations work today is characterised by accelerated change, globalization of markets and the emergence of knowledge as a tertiary resource (ISO 9001, 2015: 1). The selection of relevant component is influenced by a number of factors, to which the nominated components may be subjected to. Therefore customer satisfaction or output expectation demand extends beyond the organization’s stated day-to-day objectives, and that influences the component selection process.

The main reason behind this high rate of expectation is influenced by the fact that clients or customers become more knowledgeable and tend to set requirements higher than the thinking of an organisation. This demand then has a ripple effect amongst the interested parties; as the parties become interested they also become influential in making decisions within the operational set-up. According to Solomon (2000:1), electronic components that are selected to partake in the development of nanosatellites have their lifespan set for operation in space, and the lifespan is decided on the life cycle of the product being developed and its applications, considering the interested parties set performance parameters.

Therefore it becomes more important to understand the application environment of the designed product to cater for component life cycles, because an obsolete component will not be able to perform to expectation as its operational life is stretched. Thus the application of any component to this environment needs to be considered periodically and adhered to. The space mission components are developed to suit the mission and when the time for a mission to expires, that particular product failure to progress will be accepted. In some cases, the nanosatellite is employed beyond its designed lifespan which mean that the building components are uprated. Uprating is the process of using a component of a particular product in certain condition beyond its expected designed lifespan (Humphrey et al., 2000: 595).

The component might encounter environmental factors such as extremely harsh temperatures which are higher than the manufacturer’s rated values (Solomon et al., 2000:2). Therefore the application of risk-based thinking is appropriate to practice in such an environment so that preventative measures can be carried out prior to component deployment. Electronic components are usually deployed in different environments; evaluation of their performance prior to deployment becomes a critical element.

The space-qualifying components may sometimes call for more intensive considerations such as radiation hardness assessment capability due to the effect of neutrons and functional redundancy and heat dissipation that emerge due to some principles of engineering design as well as through application considerations. The mission can only be achieved if the satellite is designed and assembled with components that can cope with application conditions. Therefore it is very important to understand the operational life cycle of its components as well as its duration of performance in application in order to set up operational parameters to avoid possible components uprating.

2.8 SUMMARY

In this chapter, the holistic perspective in the research environment was provided. The research environment was discussed in detail together with some of the areas that need to be addressed. The nature of nanosatellites as a product, the function of the nanosatellite, issues that affect quality in the development process, the possible risk and opportunities within the development process, measuring and monitoring, and controls of external provided process were also discussed. And lastly, the behavior of electronic components was examined.

CHAPTER 3: LITERATURE REVIEW

3.1 INTRODUCTION

In this review, literature categories pertaining to this research are examined, such as journal articles, books, organisational knowledge (documented information) and internet sources. Innovation and development are processes that involve a set of activities and sub-departmental operations in the organization being researched. Given this complexity, it is important that all these activities are carried out accordingly, and that the plan to facilitate them is approved to be reliable and efficient to deliver expected results.

The innovation and technological growth curve can be traced back as early as the transition of the First Industrial Revolution between 1750 and 1850 (Vries, 2008). As from this era, continuous improvement activities were applied to improve the existing engineering artefacts with the intention to better product efficiency performance and appearance. The existed technology during the First Industrial Revolution triggered the engineer's interest, like Guglielmo Marconi and Endeavour Morse to realise their dream of creating a worldwide communication system in an effort to solve some of the communication challenges of that time (Regal, 2005).Through many discoveries made during that era to enhanced human kind needs, Alexander Graham Bell and Thomas Watson in 1871 discovered that a sound from one side to another can be experienced through use of wire string suspended in liquid solution, that detection was viewed as the birth of a telephone (Regal, 2005, Puleo, 2011).

The continuous improvement vehicle from the First Industrial Revolution steadily moved to the Second industrial Revolution (1870 – 1914) and 36 years later from the Second industrial Revolution, Bell Telephone Laboratories engineer Dr John R. Pierce assessed the viability and cost that would be needed to build and keep a satellite inspace and positive results were published in the 1950s (Pierce, 1990).

In 1957 six years after the release of the results, Sputnik 1, was successfully launched by the Soviet Union. On the 4th January 1958, Sputnik 1 mission came to termination (Tate 2012). The success of Sputnik 1 triggered a space race. Several studies were conducted to identify the possible cause of the failure and information gathered was used to advance the development of satellite throughout the world. As the century progressed smaller countries were involved through academic technological transition and failures were still experienced, which raised questions around the effectiveness of applied quality continuous improvement within the innovation and development fields. Therefore, the primary research objective of this study is to measure the current continuous improvement process effectiveness of the innovation and development process at F'SATI.

Satellite evolution since 1950 is reviewed, as a CubeSat evolution. The following matters are also discussed: introduction of satellite systems to Africa; nanosatellite quality output against production targets; the success and challenges as well as lessons learned from the very first artificial satellite up to the status quo; The Cost of Poor Quality (CoPQ) with respect to prevention, appraisal and failure costs; Total Quality Management (TQM) with respect to quality improvement, such as Deming cycle and its application; Six Sigma principles with Define, Measure, Analyze, Improve, and Control. (DMAIC) and Design for Six Sigma (DFSS) and RADAR Matrix; process improvement and quality analysis tools.

The quality tools such as Process Block Diagram, Cause-and-Effect, Pareto Charts and Scatter plot diagram are further discussed, as are the role of Kaizen principles in manufacturing; the benefits of using a continuous improvement process; and lean principles in managing innovation and development flow with respect to quality output.

3.2 SATELLITE EVOLUTION SINCE 1950

The idea of eyes in the sky was initiated in the early 1950s, four years after the work of John R. Pierce, a communication engineer at Bell Telephone (Pierce, 1990). The United State of America and Soviet Union in 1955 publicly announced that the first man-made satellite would be launched towards 1957 (NASA, 1955). Tate (2012) noted that the motivation for this particular year was to commemorate the International Geophysical Year. The announcements triggered a sense of competition in countries with scientific capabilities to compete at this level. The race became part of the Cold War.

The scientific race between the United State of America and Union of Soviet Socialist Republics was motivated by research results that was possible to launch an object into orbit around the Earth (Tate, 2012). The competing countries brought appropriate planning and well-balanced risk assessments to the development of their satellites.

During the innovation, design, and development of the first elementary satellite, Soviet Union planning was not strategic and the risks associated with development were not all addressed. As result, their first project, Object-D, with a mass of 1.400kg was put on hold after it was noted that it was going to go past the launch date (Tate, 2012). It is the duty and responsibility of the innovation and developing organization to plan activities to be carried out and assess potential risks involved and again to assign appropriate countermeasure in dealing with anticipated risks (ISO 9001, 2015: 5).

The Soviet Union acknowledged the shortfalls of their initial planning and revised their scope by developing a much smaller elementary satellite with a mass of 83.6 kg which was launched on 4 October 1957; the satellite was named Sputnik 1 (Pelton, 2010:25). Its mission was to place a radio transmitter into orbit around the earth and the 4th January 1958, Sputnik mission came to termination (Jobbours et al.,2015). Sputnik 1 transmitted radio signals in the form of beep sounds for 22 days, which were heard throughout the world (Tate, 2012).

The success and the failure of Sputnik1 led to much scientific introspection by the Americans from 1955 -1961. It was found that the Soviet Union was producing two to three times as many scientists per year compared to the United States (Kaiser, 2006:1238-1239). The study results accelerated the space race between the two superpowers, and other developed countries followed in their footsteps.

The development of satellites progressed and more satellites were launched successfully. At the time of writing the report the latest satellite, M3MSAT was launched in 2016 from Canada to monitor maritime traffic and communication in Canadian waters (Canada Space Agency, 2013). Satellite innovation and development hasn’t been a smooth ride for all the countries involved; lessons were learned and better innovation development strategies were initiated.

As interest and the demand increased throughout the world, institutions of learning with scientific and technological faculties were became vehicle to transfer skills form experienced engineers to students, hence the introduction of nanosatellite or CubeSats.

Africa was officially introduced to this domain of scientific innovation as early as the early dawn of satellite development, on 23 February 1999 South Africa launch a micro-satellite, namely SANSAT, with a mass of 64 kg, developed by a South African postgraduate student (SANSAT, 2003).

3.3 EVOLUTION OF CubeSats AS VEHICLES TO TRANSFER TECHNICAL CAPABILITIES

Space scientists and engineers worked in collaboration to develop large and sophisticated spacecraft that required a budget that only large government-backed institutions could afford. The CubeSat concept was proposed in early 1999 by Jordi Puig-Suari of Polytechnic State University and Bob Twiggs of Stanford University to enable science graduates to invent, design, build, and assess operational capabilities of the elementary satellite within set timeframes and financial constraints (Funase et al., 2016:59).

The increasing interest in nanosatellites created increased demand to manufacture of space-qualified components. In order for a component supply industry to cope with the demand, COTS technology and miniaturised components were developed to feed the CubeSat industry (Poghosyan and Golker, 2016:59). As prescribed by Puig-Suari and Twiggs, CubeSat parameters were created under the constraint dimensions of Poly Picosatellite Orbital Deployer (CO-POD) the Cubesat carrier that is used during the launching process activities (Swartwout, 2013:214).

CubeSats are classified according to sizes (weight and mass) and assigned mission capabilities. The first and the smallest range of CubeSats was the 1U-CubeSat with dimensions of 10x10x10 cm and with a maximum mass of 1.33 kg (Bouwmeester and Gou, 2010:855). The motivation was to create standard specifications for vehicle producers and to adopt common deployment systems, independently of the CubeSat manufacturer (Poghosyan and Golker, 2016: 60). The smallest satellite size was categorised as the Fenito satellite with a mass of <100 g (Konecny, 2004). Satellite classification is presented in accordance with mass and cost in the following table

Table 3.1: Satellite classification based on mass and possible cost (Rycroft and Crosby, 2002:2; Konecny, 2004)

Class	Mass (kg or g)	Cost (US Million Dollars)
Larger Satellites	>1000 kg	> 140
Small Satellites	500 – 1000 kg	50 - 140
Mini- Satellites	100 -500 kg	10 - 30
Micro- Satellites	10 -100 kg	3 - 6
Nano Satellites	1 – 10 kg	0.3 – 1.5
Pico Satellites	<1kg	< 0.3
Fenito Satellites	< 100 g kg	< 0.3

The complete standard parameters for CubeSats are 1U, 2U and 3U dimensions (Selva and Krejci, 2012:55). The success and challenges in the development of 1U - 3U units has triggered further continuous improvement initiatives in building 6U, 12U and 27U allowing much greater CubeSat capabilities (Herneir et al., 2011:2).
The first successful nanosatellite was built by the University of Tokyo Intelligent Space Systems Laboratory (ISL) and launched on 30 June 2003 on a Russian Rocket (Peng et al., 2016:1; Swartwout, 2013:214).

After this successful launch of the CubeSat, this scientific knowledge was spread to many different institutions of higher learning with aerospace programmes,which took the lead (Peng et al.2016:1).Nanosatellites were placed in orbit and continuous evaluation was carried out to assess performance capabilities against expected outputs.Lessons learned were used as input for future development of 1U – 3U nanosatellites.

3.4 INTRODUCTION OF SATELLITE SYSTEMS TO AFRICA

African was actively involved in space exploration as early as the beginning of the Space Age in the 1950’s. Throughout the African continent, at presenst only a few countries show interest in the innovation and development of artificial nanosatellites in university programmes.

The six African countries that are involved in artificial satellite development, extension of quality outputs against development targets, success and challenges faced by developers, and the scientific environment are discussed below.

3.4.1 South Africa in scientific satellite development

Africa formally introduced itself to space scientific innovation and development of satellite activities on 23 February 1999, through SANSAT, a University of Stellenbosch microsatellite with a mass of 64 kg, launched on a Russian missile (SANSAT, 2003). The African satellite served the mission it was intended for, and lasted till 19 January 2001 (SANSAT 2001).

On 17 September 2009, the second round of South African innovation was an 81 kg microsatellite ZASA002, which was later given the indigenous name of SumbandileSAT which literally mean "lead the way" (Martine, 2012). The space mission assigned for SumbandileSAT was to observe disaster management, oil spills and to track fires;, however, it gave in to Solar Storms in June 2011 after two years from the deployment date (Martine, 2012).

The Cape Peninsula University of Technology in partnership with the French Institute of South Africa and government institutions such as South African National Space Agency (SANSA) embarked on the development of a 1. 2 kg nanosatellite ZACUBE-1, later called TshepisoSAT, which means “promise”. The ZACUBE-1 nanosatellite was 100 times smaller than Sputnik 1 . ZACUBE-1 was launched on 21 November 2013 by means of a Russian vehicle (SANSA 2013).

TshepisaSAT is armed with a high frequency beacon transmitter used to perform weather research and to monitor grassland fires (SANSA, 2013). The ZACUBE-1 nanosatellite is attending to the mission it was intended to, and consistently communicates with the ground station since its launch date and it was over four years old at the time of writing (F'SATI, 2018).

The success of ZACUBE-1 gained Southern Africa international visibility and recognition to have launched for having operated the first nanosatellite developed on the African continent (De Villiers and van Zyl, 2018).

The data collected as well as experience picked through the innovation and development of TshepisoSAT was then used in the development of the second CPUT F'SATI nanosatellite, ZACUBE-2, with dimensions of 10 x 10 x 30 in centimetres, with an approximate mass of 4kg (De Villiers and van Zyl, 2018). The ZACUBE-2 mission capabilities are far more advanced than TshepisoSAT, based on its ability to track vessels and fire detection capabilities. The nanosatellite is expected to be integrated in project Marine Domain Awareness (MDA) which is aimed at supporting international maritime communication established by Phakisa (Space in Africa, 2018).

3.4.2 Ghana in scientific satellite development

Ghana has also shown interest in satellite development. The first Ghanain nanosatellite, 1U with dimensions of 10x10x10 cubic centimetres and a mass of 1 kg named GhanaSat-1 was designed, developed assembled and tested by three Ghananian students at All Nation University and was successfully launched on 3 June 2017 (BBC News, 2017).

The GhanaSat-1 was built to monitor the Ghananian coastal area. Its secondary mission was to measure the effect of radiation in space, and to facilitate technological capacity building within the country (BBC News, 2017). The successful launch of GhanSat-1 contributed to strengthening the Sub-Saharan African contribution to this noble scientific innovation and development through learning institutions.

3.4.3 Nigeria in scientific satellite development

The country's wealth plays a major role in the growth and the development of its economy. Nigeria is one amongst few countries in Africa such as Angola, Algeria, Egypt and Libya that have natural oil wells, therefore effective monitoring and control of such resources is a major priority. Nigeria before 2005 used to produce between 2.1 and 2.6 million barrel of oil, but that output rate has dropped due to security problems connected to a violent militant group (Capenter, 2015).

The country launched NigerianSat-1 with a mass of 90.1 kg in 2003 and this achievement was followed by the NigerianSat-X with a mass of 87 kg on 17 August 2011. It had two primary missions, which are to provide service to the Nigerian National Space Research and Development Agency (NASRDA) and disaster monitoring constellation with earth observation imaging capability primarily to be used for resource management and mapping of Nigerian territory (Baker, 2012).

NigerianSat-X was designed and built to monitor the country's geographical area and crop status, observe unrest, and monitor government election processes. Amongst its objectives was to build and capacitate students with cutting edge technological skill sets (La, 2012).

3.4.4 Angola in scientific satellite development

The first satellite built for Angola was named AngolaSat-1 with a mass of 1.550 kg and launched on 26 December 2017 (William, 2017). The mission of this satellite was to provide assistance to Angola's ministry of telecommunication and information technology in facilitating space communication (NASA, 2017). The AngoSat-1 gave in to space harsh conditions just after four months from the date of launch, which points to the Immaturity of innovation and development capabilities (Henry, 2017). The failures of satellite either on innovation and development, during the launch process or in the space contribute heavily to reducing the confidence of developing countries in this innovation and technological field.

3.4.5 Algeria in scientific satellite development

Algeria established the Algerian Space Agency (ASAL) in 2002. Algeria like other technologically developing countries, and in an effort to manage high cost, has embarked on scientific skills capacity building, making use of postgraduate engineering student to develop the small satellites with an aid of experience engineers. A small satellite called AlSat Nano was successfully developed and launched on 26 September 2016 with the help of United Kingdom Space Agency (La, 2017).

The Alsat Nano project was a successful project in facilitating capacity building. The performance output of the AlSat Nano has been monitored since its space deployment and it is reported that AlSat Nano is performing very well since the launch date and is achieving its mission as well as showcasing the United Kingdom’s scientific technical capabilities (La, 2017).

3.4.6 Egypt in scientific satellite development

The Egyptians are known for their technological contribution in the building of a Lighthouse of Alexandria slightly before the 1950s, the development of Mediterranean maritime technology and from this reference, we can easily say that technology and innovation was always part of the country even before 1950. The first Egyptian earth observation satellite named EgyptSat-1 with a mass of 165 kg was built with an aid of Yuzhnoye State Design Office located in Dnipro, Ukraine, and launched on 17 April 2007 (William 2017). The satellite survived for 3 years after the launch date, but lost communication on 23 October 2010. The failure was suspected to be caused by malfunctioning flight control systems (Saleh, Mohammed, and Rashwan, 2010).

This was not the very first satellite built and launched in Egypt; NileSAT-101 with a mass of 1, 7 kg was launched on 28 April 1998 and was officially deactivated on February 2013. NileSAT-102 was launched on 17 August 2000 with a mass of 1,8 kg. The failure of EgyptSat-1 after three years of operation from the launch date revealed the maturity level of the country’s technical capabilities in this scientific environment and effective measures were put in place. As a result, EgyptSat-2 with a mass of 1050kg was then developed and finally launched on 16 April 2014, and survived until 14 April 2015, approximately 12 months (Space News and Beyond, 2018).

The Egyptians also developed CubeSats through the academic system. EgyCubeSat -1 with a mass of 1kg was developed and expected to be launched in 2017 (Egypt-independent, 2015). Until now there has been no news reporting the launch of EgyCubeSat.

3.5 SATELLITE DEVELOPMENT QUALITY OUTPUT AGAINST PRODUCTION TARGETS

The innovation and development of satellites has never been an easy road to travel. The United State of America and Soviet Union (Eastern Bloc country) started this scientific race, experienced different challenges and those challenges contributed to the quality integrity of built satellites and therefore continuous improvements were outlined. The category of satellite is usually determined by its mission, and its specified geometric parameters. Satellite that are between the mass ranges of 1kg – 10 kg are identified as Nanosatellites and their mission capabilities are limited (Rycroft and Crosby, 2002:2).

The number of satellite that are successfully launched and actually achieve their mission, compared with the number of satellites built is red flag if one has to look at the cost of quality involved. The following sections tabled challenges and successes by satellite developers since 1957 until the era of university Cubesats.

3.5.1 The success and challenges of the first ever developed artificial satellites

The project Object-D was initially started early in 1957 and during its execution, some further analysis was done and results showed that it was impossible to complete in the same year 1957 as publically announced (Tate, 2012). Alternatives means were put in place and a new sets of project parameters, product size, and other related development issues were established and a microsatellite called Sputnik 1 with a mass of 83.6kg was developed and successfully launched on the 4th October 1957 (Tate, 2012).

The first American designed and developed nanosatellite in 1957 was named Vanguard Test Vehicle -3 (Vanguard TV-3) with a mass of 1.5 kg smaller than Sputnik 1 and was officially launched on 6 December 1957. The launch of Vanguard TV-3 was not successful, because the rocket that carried the TV-3 experienced technical challenges during preparation for take-off and eventually fell down on the launch pad and exploded (Green and Lomask, 1970). The failure of the rocket was analysed and results showed that the lower fuel tank could not withstand the pressure released by the rocket during the launching process and all the effort contributed to cost of quality (Deffree, 2007).

The postponed Soviet Union project Object-D was then recalled after the successful launch of Sputnik 1, while the Americans made use of the lesson learned in the failure of Vanguard TV-3 to develop the second satellite. The second developed American microsatellite Explorer 1 with a mass of 13.97kg was successfully launched on 31 January 1958 (Green and Lomask, 1970).

To compare the quality against quantities of output with respect to the early satellites, one needs to look at the mission application timeframe of each satellite, time taken to develop, a reason behind the development and other related influential issues.

Sputnik 1 withstood harsh space conditions approximately for four months and on On 4 January 1958, Sputnik 1 mission came to termination, while Sputnik 2 was launched on 03 November 1957 and stopped working on 14 April 1958. This mission was different to the first one, because the satellite transported a live dog (Zak, 2017). However, Explorer 1 survived for 3 months and 23 days (Green and Lomask, 1970).

It was clear that quality between the two countries was not the focus area during the race, the intentions were to compete on quantity delivery basis, while the cost involved in the development process approach was not a high priority. What mattered most at that time was the space race.

3.5.2 Positive effects drawn by Sputnik 1 and Explorer 1 in satellite innovation and development growth

After the breakthrough of Sputnik1 and Explorer 1, the interest in satellites spread all over the world and since early in the 1980s, universities around the world have been involved in this field. The first satellite breakthrough from the university regime was made by the University of Surrey in 1981, when a microsatellite named UoSAT-1 with a mass of 52 kg was launched into space on 6 October 1981. Its mission was to investigate and demonstrate the feasibility of the design, fabrication and launch of a scientific satellite at an affordable low cost without compromising quality of the product (Konecny, 2004).

The UoSAT-1 attended to its assigned mission, even though after seven months from the date of the launch the satellite lost contact and the problem was then resolved after six months (Konecny, 2004). The satellite UoSAT-1 continued a good eight years in the space performing its mission and communicating, and was lost on 13 October 1989 (AMSAT-UK : 2013). As a result of this success, universities around the world showed started developing more satellites, Between 1980 and 1999 about 238 mini-satellites and 249 microsatellites have been developed and successfully launched all over the world (Konecny, 2004). These developments triggered continuous improvement innovation thinking in the satellite development communities, and the CubeSat was then born in 2003; the University of Tokyo placed the very first CubeSat called CubeSat-XI with a mass of 1kg in orbit on the 30th June 2003 using a Russian delivery system (Swartwout, 2013:214). From the inception of the CubeSats until 2012, a total of 112 Cubesate had been launched and conducted their missions successfully (Swartwout, 2013:214) Between 2013 and 2015, 320 were launched (Pang et al., 2016:2).

The existence of Cubesate has made space more accessible and this new size has allowed small developing countries to participate and to conduct a variety of missions (Asundi and Fitz-Coy, 2013:1). With CubeSat development and design for different missions, the industry has grown dramatically over the past years. Between 1998 till 18 April 2018, a total of 930 nanosatellites and 857 CubeSats were launched; 589 Nanosatellites are still in orbit and 86 are nomre attending to the mission assigned and some have been destroyed (Kulu, 2018). CubeSat success rapidly spread within academia by facilitating and strengthening students' space scientific skills and capabilities, the technology to assess suitability of components, and Commercial to provide and maintained and advanced telecommunication application (Pang et al. 2016:1; NASA, 2015).

This growth in university satellite production clearly shows that there is a need for a proper alignment of activities with respect to reducing failure rates with respect to manufacturing capability, nanosatellite launch as well as product performance outputs.

Asundi and Fitz-Coy (2013:1) maintained that among many factors that hinder the success rate of satellite development is the lack of a systems engineering management approach within development and innovation circles.

Initial development and innovation of satellites was carried out by rich countries that could afford durable components. The components used to produce nanosatellite were subjected to performance assessments to thoroughly check durability and ability to withstand both launching and space conditions. The introduction of developing countries to this scientific field was done through university-aligned space-related programmes; state-of-the-art COTS components were also used because of their space heritage properties and affordability (Langer and Bouwmeester, 2016).

In an effort to invent and design quality outputs, a clear conventional systems engineering approach had to be established in an effort to minimise level of defects that could contribute to internal as well as possible external failures, with the intention of improving daily operational activities and provide clear operational directions (Bouwmeester, 2016; Asundi and Fitz-Coy, 2013:1). The establishment of conventional system engineering management plans has to allow for the technical maturity of the team involved and also create opportunities for clear benchmarking in order to fully capacitate developers.

The use commercial off-the-shelf components did not do away with a components durability assessment process that is used to validate component fitness for space applications; instead it has made component selection easy. Researchers need to outline possible continuous improvement tools that have been and are tried tested and are known to add value in order to eliminate waste and to improve the operations to current working practise.Therfore, the following section is reviewed to assess the level at which CPUT F'SATI applies continuous improvement on its daily activities.

3.6 COST OF POOR QUALITY (CoPQ)

In the context of manufacturing, the approach taken to deliver a quality output is important as evaluating the manufacturing specification, because the approach needs to deliver a defect-free product in an effort to eliminate the cost that can be incurred due to product poor quality. Cheah, Shahbudina, and Taib (2010:405) defined CoPQ as the sum total of expenditures incurred to ensure that attainment of the desired quality level in a product being developed is achieved, and as well as the expenses incurred due to failure to meet the desired customer quality level. However, according to Campanella (1999), cited in Cheah et al. (2010:406) Cost of Quality is characterised as the cost difference between the actual cost of a product that would accrue if there was no possibility of substandard services during its manufacturing or development processes, such as the failure of the product or defect in its innovation and development process stages.

The Cost of Quality is also termed Preventive Appraisal Failure Cost (PAF)Foster 2013). The PAF is described as the means of conformance to the stated requirements, while non-conformance refers to the failure to do things right the first time (Cheah et al., 2010:407). Bamford and Land (2006:266) view PAF in the split of percentage representative formation with its contribution in quality, where P=5 per cent, A=28 per cent and F=67 per cent.

Dahlgaard and Dahlgaard-Park (2006:267), define quality cost as the cost which would disappear if no imperfections were created and Cost of Poor Quality (COPQ) as the sum of all cost that would fade if there were no quality challenges within the innovation and development of Nanosatellites. Unfortunately, with the current set-up of innovation and development at F'SATI, the institution tends to experience a remarkable value of cost of quality. Hence the effectiveness of the current continuous improvement needs to be evaluated for its efficacy. PAF methodology is further discussed below.

3.6.1 Prevention Cost

The Systems Management Approach that is adopted by nanosatellite manufacturing capability is supposed to limit cost incurred during development and allow opportunity for further continuous improvement. Feigenbaum (1991) described Prevention Cost as the expenses incurred to prevent defects and non-conformities from occurring either in the innovation and development or in manufacturing set-up. Good quality work environments within innovation and development practice tends to yield products with high-quality futures (Kanitvittaya and Suksai, 2008). Kotler, Bowen and Makens (1996:362) are of the view that companies with better quality services earn a higher financial return than companies that innovate and develop inferior quality products.

Therefore, developing quality products may also reduce and/or prevent the rate of incidents with respect to employee injuries, because an uncontrolled environment becomes hazardous to its operators (Kanitvittaya and Suksai, 2008). In achieving continuous process or product improvement, all employees should embark on interventions that will benefit the organization to move forward with less expenditure and a high return on investment in quality output. To have an effective prevention process one should be able to plan and execute innovations and development activities according to planned arrangements.

3.6.2 Appraisal Cost

The appraisal stage does not only focus on making sure that the innovation and development System Engineering process delivers a quality product, but also that the process deployed is reliable enough to create expected outputs. Therefore process reliability needs to be deployed to build quality into a system or in a product. NASA/SP (2007-6101:44), defines reliability as the probability that a device, product, or system will not fail for a given period of time under the stated manufacturer-specified operating condition until it delivers the expected results. The reliability of the process or product determines the cost-effectiveness of the employed system in consuming company resources effectively in pursuit of delivering best practices and results.

Here, a company's quality service should encompass quality dimensions, such as client empathy (Martin and Frasier, 2002:477). This will allow the client or customer to understand the importance of their investment in the company they engage with and stable relationships will be established. Martin and Frasier (2002: 477-478) further elaborate that empathy is the degree of care, and an uncompromised individualised attention being offered which is in line with service that the developing and innovation organisation's staff provides to its space and innovation customers. The innovation and development process owner should be able to produce nanosatellites that are able to cope with the known and predicable harsh space conditions.

According to NASA/SP (2007-6101:44), every space mission has a unique stated set of environmental requirements, therefore it is critical to study both internal and external environment for each nanosatellite built at Cape Peninsula University of Technology (CPUT) F'SATI Systems Engineering. These conditions include acceleration, vibration, shock, static loads, material contamination, and acoustic, thermal, and radiation effects. Understanding these factors will help an organization to focus on building quality into a product, taking into consideration the expected environmental application risks and opportunities involved.

3.6.3 Failure Cost

Failure cost is viewed as the cost incurred when a company fails to meet customer requirements based on product or service performance level (Foster 2013: 188). The failure cost is expanded into two formations, which are internal and external failure. Internal failure costs are known as inferior product defects detected or happened within the company premises possible during innovation and development or launching phase of the product, before delivery to a customer, such as failure of satellite rocket during the launch, satellite components failing during vibration or radiation testing; this is termed in-process failure in delivering to set requirements (Foster, 2013:118). Nanosatellites that are sent to space but still fail to accomplish their entire mission are contributing to external failure.

Foster (2013:118) further defines external failure cost as mainly influenced by rejected goods, such as recall from the counter, and warranty claims. Within the nanosatellite development environment, the Cost of Quality for such internal and external failures could be due to various factors and it might not be possible to recall a launched nanosatellite due the to high level of cost involved. The best solution for failed mission would for nanosatellite developer to rebuild and resend a new CubeSat to complete the failed mission, but that solution will not come without significant costs.

The PAF model has been recognised by Campanella (1999), cited in Cheah et al. (2010), Foster (1996) and Gryna (1988) as an optimal quality model. It is built on the innovation and development company premise that when resources are spent on prevention and appraisal activities, quality will then improve, with a resulting decrease in failure cost. Tools such as the Failure Mode Effect Analysis (FMEA) may be employed to strengthen and to assess a product's quality. Failure mode effects analysis can therefore be employed to facilitate the PAF paradigm, especially when avoiding failure cost (Foster, 2013:201). According to Foster (2013:201), FMEA is a quality improvement tool used by a product development company and it delivers benefits such as product safety, and enhanced quality, performance and reliability.

3.7 TOTAL QUALITY MANAGEMENT (TQM)

Karkoszka and Honorowcz (2009:179) hold that continuous improvement of process and product is the responsibility of all members of an organization because teamwork is the fundamental guideline of Total Quality Management (TQM). Therefore the developing team needs to identify suitable components in order to build satellites that can withstand space conditions and in the current development phase, commercial off-the-shelf is an option. Commercial off-the-shelf material (COTS) is proven to be reliable for use in space engineering; this is only possible when the adopted nanosatellite system designed is appropriately aligned with the set requirements (Nakasuka et al. 2010:1099).

In building nanosatellites, the systems engineering process need to include quality process that is able to meet customer requirements. According to Gryna (2001:4), the customer is anyone who is affected by product or process; customers are divided into two categories, internal and external customers.Managing quality is the process of identifying and administering the activities needed to achieve the quality objective of the process and provide solutions where specifications are compromised (Gryna.2001:11). The employee's participation is highly recommended in achieving quality outputs through process development and if all employees are involved in assessing positive and negative opportunities within the development environment, then Total Quality Management is achieved.

Slobodan (2011:173) views continuous improvement as a process that stimulates and involves workers and medium rank managers in the decision-making process in order to streamline task alignment based on their competency. Gryna (2001:14) defined TQM as the system of managerial, statistical, and technological concepts and techniques that is normally used to achieve quality objectives throughout involvement of all stake holders that are affected.

Sadikoglu and Olcay (2014:1) define TQM as a firm-wide management philosophy of continually improving the quality of product/service/process by focusing on customer needs through consideration of the available skills, capacity resources and expectations to enhance satisfaction in client and firm performance. The continuous improvement of processes and product, as well as the responsibility all workers for quality, are fundamental guidelines of TQM philosophy. This philosophy is engaged to increase productivity without a concurrent decrease in quality, and the concept applied is the Deming cycle or PDCA cycle to achieve such objectives (Karkoszka and Honorowicz. 2009:197).

3.7.1 Deming Cycle (PDCA-Cycle)

Quality output improvement does not natural happen in the innovation and development set-up; therefore to attain positive change different set of strategic methodologies that are approved to yield good results to such process are really needed to be considered. Deming cycle known as the Plan, Do, Check, and Act cycle (PDCA) is one methodology among many, which can be used to monitor the existing process performance of the nanosatellite innovation and development for improvement purpose. The Deming cycle, characterise the repeatability of actions; it is aimed at the achievement of further improvements for the benefits of management systems process approach (Karkoszka and Honorowicz. 2009:197-198). The effect of Deming's cycle in the nanosatellite system engineering process would be to assist in facilitation, identification of purpose, defining of the execution method, measuring the process capability through monitoring, test validity and lastly to integrate the lessons learned during the development for better results (Clements 2011:18).

Sokovic, Pavletic and Pipan (2010: 476) view the PDCA cycle as a well-known fundamental concept of continuous improvement that is applicable in every spectrum of the business operation. The cycle is an integral part of process management and is created as a dynamic model because one complete cycle is evidence of one complete step of improvement of the innovation and development process or product (Sokovic, Jovanovic and Vujovic, 2009: 01). Titu, Oprean and Grecu (2010), view PDCA as a method of quality improvement that can be deployed in daily process activities in order to obtain a competitive advantage and to raise overall business performance. PDCA-cycle priority is to standardise the process and prevent the reoccurrence of process/product nonconformities within the innovation and development environment.

3.7.1.1 PDCA-cycle in application

According to Sokovic (2010: 478) PDCA cycle makes problems visible. It enables two types of corrective measures to deal with visible problems, which are temporal and permanent. Karkoszka and Honorowicz (2009:197) believed that the Deming–cycle has the ability to influence the philosophy of productivity to increase without compromising the quality of a product being developed. The PDCA-cycle in its application consists of four quadrants, and each quadrant represents the most important phase of the application in a process (ISO 9001, 2008). According to Sokovic et al. (2010:478), the PDCA-cycle third quadrant (act) is the most prominent feature of this quality improvement methodology. The act phase influences further improvement innovation and development activities. The PDCA-cycle and Kaizen – which means “improvement for better” – can be integrated with each other to achieve better results. PDCA is known as Plan-Do-Check and Act. The Kaizen philosophy is discussed further in this study.

3.8 THE SIX SIGMA

The Six Sigma (6 sigma) approach is defined as a collection of managerial and statistical concepts and techniques that focus on reducing variation in an established innovation and development process and preventing deficiencies in a product being developed (Gryna et al., 2007:67). They define variation as the condition where no two items that were produced in different set times frames will be perfectly equivalent to each other. The Six Sigma approach is viewed as a management philosophy that focuses on eliminating possible mistakes, waste and reworking during the innovation and development process (Kabir, Boby and Lutfi, 2013:1056).

Innovation and development requires an approach that is able to monitor and manage the development process of nanosatellite so that effectiveness and maintainability are attained within the space innovation and development environment. Kabir et al. (2013:1056) interpreted Six Sigma as a methodology that gives discipline, structure, and foundation for concrete decision making, based on statistical sampling deployed by the organization. Levin, Ramsey and Smidt (2001:04) describe a statistical process as a way of thinking through awareness and it gives an understanding that variation does exist and the only thing that can be done is to find a way to manage and control its existence.

According to Ramamoorthy (2003:3), Six Sigma was once applied or practiced up to its maximum delivery by Fredrick W. Taylor in Principles of Scientific Management in 1909, when he used this principle to break down systems into subsystems with the aim of increasing manufacturing process efficiency. Blanchard and Fabrycky (2011:17) define a system as a set of interrelated components (subsystem) that function together in the direction of some common objectives or purposes to satisfy the customer's stated requirement. The former elaborates that the situation of a system may change over time in only certain ways and that might influence the behavior of that particular innovation.

Every system whether it is manufacturing or service systems is made up of different elements or components, and these can be broken down into smaller constituents, from which principle subsystems emerge (Blanchard et al. 2011:18-19). The Six Sigma principle does not only focus on the system process, it also incorporates human resources capabilities. The Sigma principle management philosophy has potential to combine personnel competence, resource capabilities and knowledge, together with an adopted innovation and development process in moving products out of the development line (Kabir 2013:1056). The longer an item is in the process of development or innovation and the more it is moved about, the greater the ultimate cost of that particular product (Vendan and Sakthidhasan, 2010:579).

The Six Sigma principle was once used by Henry Ford to manage the automotive production process line; Ford dwelled on four principles which were “Continuous flow, interchangeable parts, the division of workforce, and reduction of wasted effort”. The effort was taken to retain and improve the existing customer base, and to attract new customers; the chief purpose still to to maintain customers’ buying power with regard to the product being developed (Ramamoorthy et al. 2003). The principle is viewed as a methodology that seeks to improve the quality of a process output, and this is done through identification and removing of the cause and effect (errors) and minimising the variability in a manufacturing process (Deolia, Verma and Bajapai, 2015:1045).

The Six Sigma is an organization-wide approach used to postulate exactly how organizations managers set-up and achieve objectives of a certain mission (Sokovic 2009:04). The Sigma principles demonstrate how breakthrough improvements tied to significant bottom line results can be achieved in an organizational process (Keller 2005). Juran (1996), cited in Gryna (2007:19-21), described breakthrough improvement as a means to achieve a change in business performance from historical process performance. Gryna (2007:21) emphasizes that the change does not just happen; it requires a systematic change process focused on a project-by-project to achieve breakthroughs.DeFeo and Barnard (2003), cited in Gryna (2007:21), identified six types of breakthrough as prerequisites for achieving and sustaining improvement in an organizational performance, namely leadership, organisation, current performance, management, adaptability and culture.

Six Sigma is prescribed as an improvement process that is suitable for existing process, which is DMAIC, an acronym that stands for define–measure–analyse–improve–control) (Sokovic et al., 2009:4-5).The process improvement which is deployed for a non-existing process is DMADV, an acronym that stands for define–measure-analyse–design–and–verify, and IDOV, identify–design–optimise-and–validate) which are further described below (Sokovic et al. 2010:418).

3.8.1 DMAIC Methodology

Continuous improvement in innovation and development activities clearly happens when process performance is monitored and results are captured for analysis. DMAIC methodology becomes the best approach to deploy. DMAIC methodology is an improvement methodology which monitors the flow of an existing process with maintenance strategies entrenched within the process to improve innovation and development performance delivery (Gryna, 2007:21).

The methodology can facilitate the appropriate and effective utilization of quality tools and Six Sigma projects (Matathil et al., 2012:53). Kabir et al. (2013:1057) argues that deliverables for a given steps must be completed prior to a formal gate review approval, and the step review should occur sequentially within the development process. Sokovic et al. (2010:480) define DMAIC as a methodology that sets improvement through organised phases, namely to define, measure, analyse, improve and control the process capability.

Blanchard et al. (2011:126) view functional capability as a means to display a perspective of the system to accomplish its intended mission and objectives that are set by the innovation and development manufacturing capabilities.Sokovic (2010:481) believe that if one cannot define the process, then it is impossible to measure its performance output. Measuring performance reliability would need a set of capable and relevant quality tools; the following are common quality tools that are entrenched within DMAIC process quality improvement that could still be used to measure innovation and development activities (Sokovic 2009:05).

3.8.2 Design for Six Sigma (DFSS) Methodology

Design For Six Sigma is viewed as a systematic and structured approach to innovation and product development or process design that focuses on problem prevention (Sokovic 2010:481). Davenport (1993) cited in Ball (1998:342) describes a process as a structured, measured set of activities that are designed to yield required product within a specified sets of parameters for an individual client. The DFSS or DMADV approach is centred on designing and development of a new product and service as compared to Six Sigma, which is primarily a process improvement methodology

(Gryna 2007:21). Design for Six Sigma as a methodology focusses on creating new development or modified designs that are capable of significantly higher levels of performance (Gryna 2007:148).

DFSS is a fundamental verification which performs differently than Six Sigma, and it promotes the holistic approach of re-engineering rather than a technique to complement Six Sigma (Sokovic et al. 2010:481). Foster (2004:512) defines re-engineering as a method of creating quick, fundamental changes to a company's organization and existing processes. DMADV or IDOV the former explains as Define, Measure, Analyse, Design, Verify, while IDOV is Identity, Design, Optimise And Validate. DeFeo, Joseph, Barnard and William (2005) describes DMADV as a DFSS (Design for Six Sigma) and it considers five phases in facilitating continuous improvement which is DMADV.

3.8.3 RADAR Matrix

In controlling cost in a company, certain measurement with a track record of success needs to be deployed. According to Tavana, Yazdi, Shire and Rappaport (2011:645), the EFQM excellence model is a practical benchmarking tool that helps the organization to measure its progress position in excellence to the product it franchised with. The EFQM Excellence Model allows process owners and operators to understand the cause and effect relationships between what their organization does and the results it achieves for it intended use. Hence the study looks at the continuous improvement process performance in the delivery of quality product and error free outputs, and here the value of the RADAR Matrix is also relevant. Sokovic et al. (2010: 479) explain Results, Approach, Deploy, Assess and Refine as an instrument to raise awareness of the innovation and developing team. The RADAR Metrix methodology is a structured approach to interrogate the existing process approach of an organization.

According to Sokovic et al. (2010:479), the RADAR Matrix is used to estimate organizational performance effectiveness and it opens opportunities for integration with the European Foundation for Quality Management (EFQM) model. EFQM is a tool used to streamline business process governance, to support and improve its enabler and results obtained during the development process (Favaretti et al.

2015:157). Tavana et al. (2011:644) describe EFQM as a practical benchmarking tools that may help the organisation to measure its performance evolution with respect to its products under development. Favaretti et al. (2015:156) describe the EFQM model as a tool that provides guidance for an integrated management system. Based on the nature of the tool it is possible to craft robust assessment in attaining the degree of excellence in any organization that uses it.

Vogt (2001) cited in Tavana (2011:646) notes that the EFQM model is widely used in Germany hospital laboratories to achieve continuous improvement of service quality, and at the same time to reduce cost. According to Sahoo and Jena (2012:299), citing European Foundation for Quality Management (2010), EFQM was initially used in 1999 as a framework for evaluating and improving organizational performance, in order to achieve sustainable advantage.

The synergy of RADAR Matrix with the Deming cycle can be found in perusing improvement of an organizational process performance through an innovation and development elective approach (Sokovic et al. 2010:480). The benchmarking process between the two continuous improvement instruments is possible due to their interrelated operations. Gryna (2001:105) defines “benchmark” as a point of reference by which performance of a process is judged or measured for quality. Benchmarking is the sharing of information between operational divisions so that both can improve their processes (Foster 2013:64). If a process cannot be measured, then it becomes a challenge both to define its performance and to improve it. Therefore it becomes important to have tools to measure reliability and proficiency of an organizational process against its set performance targets.

3.9 QUALITY PROCESS IMPROVEMENT

Quality process improvement in the context of this study entails analysing an innovation and development process approach to identify problem areas and to plan actions to deal with them. When problem areas are identified, effective tools or measures are then selected and aligned to deal with such concerns.

The literature provides and offered a variety of tools and techniques to support improvement processes, but the strategy in moving from one stage to another of successful implementation of these tools can be disjointed in many cases due the organisational structure (Mugglestone et al. 2007:19). For this research, according to the research questions and objectives, the following strategic tools are anticipated to work in shifting the research design innovation and development environment from one point to another. In many instances quality improvement is achieved by proper planning. For this study it is predicted that the following product or process quality principle improvement tools can contribute to improving innovation and development output results.

3.9.1 Process analysis and tools

The organization must define a strategic way for meeting and exceeding the stated innovation and development specifications requirements with respect to the process it enterprises with (Nwabueze 2012:578). The process approach and steps used to define and exceeding expectations depend on the nature of systems application and the background, as well as the internal team capacity competence level (Blanchard et al. 2011:47).

The process analysis tools are used to measure output against the predictable input, and the output should demonstrate the expected quality. Quality assurance of a product usually implies two practices, namely performance quality and exit quality; the innovation and development team needs to fulfil these requirements as required by its customers (Foster, 2013:183). The goal of using process analysis is to improve the quality of a product or process to maintain the principle of innovation and development quality and to win customers.

Blanchard et al. (2011:47) argue that an innovative idea, need or evolving need has potential to generate new system requirements within the current development structure, therefore analysis and measurement become important. Tinaiker et al. (1994), cited in Nwabueze (2012:578) believe that process improvement through re-engineering should encompass the restructuring of organizations to attain major enhancement of the selected process approach.

Devenpont (1993), cited in Ball (1993:342) view process as a structured and measured set of activities that are composed to deliver a specified output for a particular client or market in accordance with the stated requirements. The process is then again seen as the set of activities that require good management skills to meet required standards. Ball (1993:342) argues that to attain improvement factors that improve quality of outpots, possible variation should be monitored by the process owners for easy management. Curtis et al. (1992), cited in Ball (1993:342), argues that complexity within the process needs to be diminished by deploying relevant quality analysis tools. Quality analysis tools make problem areas within the process visible, therefore allowing corrective measures to be taken.

3.9.2 Quality Analysis Tools

For analysis to be effectively undertaken, the organizational process model needs to be understood by its process operators. The nanosatellite development process approach and interaction of activities need to be transparent. Kabir et al. (2013:1058) suggest that creating a structure for operation systems clarifies the best spatial allocation to optimise production facilities. They note further that layout plays an important role in creating strong information sharing between teams involved in the process. It is very important in the analysis phase to demonstrate terms and variables as it helps to monitor causes and effects (Wilson 1993:36). The best process analysis tools relevant to this study are discussed below.

3.9.2.1 Process Block Diagram

In order to define a process diagram, understanding the problem or process before collecting data is the most imperative study of variables (Levine et al. 2011:45). Levine at al. (2011:45) further note that process flow diagrams are extensively used as roadmapa for locating and solving challenges and improving the quality of a product or process.

According to Kabir (2013:1058), the block diagram demonstrates the steps involved in a process to determine the complexity of a product or process and the extent of vertical or horizontal incorporation in the organization. Rath (2008:188) observes that process flow diagrams is the simplest and most flexible analysis approach. The block diagram allows the application of a systematic systems-level top-down or bottom-up approach dues the nature of its presentation.

3.9.2.2 Cause-and-effect diagram (Fishbone diagram)

According to Levin (2009:49), the cause-and-effect diagram was developed by Karu Ishikawa to demonstrate the link between an effect and set of possible causes, and for this reason, is known as the Ishikawa diagram. The diagram allows a systematic arrangement of ideas, and so identifies factors that contribute to nonconforming outputs of a service or product. The diagram helps the process owner to decrease production risks which contribute to increased costs of quality. Foster (2013:302) views production risk as the probability that a product will be rejected on inspection due to defects.

The Ishikawa diagram assists an organizational process to move from a lower to higher performance level of production by means of brainstorming strategy sessions to solve quality challenges (Foster, 2013:274). Kabir (2013:302) states that this diagram is often used as an input to design of process for quality control. It demonstrates both noise and control variables and output variables within the development system approach. The noise variable refers to a situation that is out of control of the organizational management, while a control variable can be managed by organizational management because it is built into the organisation process flows (Foster 2013:384).

3.9.2.3 Control Charts

Process management practice reflects an organizational agreement to enhance the reliability and control of performance, and at the same time search for better methods than existing processes (Sahoo and Jena, 2012:265). Gryna, Chua and DeFeo (2007:87) define control charts as powerful diagnostic quality tools, with two procecess control limits,and these can eliminate inconsistency within the organizational process. Foster (2004:288) notes that control charts are deployed to determine whether an

established process is able to deliver or produce a product or service with consistent measurable properties as requested by customer.
Control charts have two sets of limits, which are the Lower Control Limits (LCL) and Upper Control Limits (UCL). Gryna (2007:671) concludes that these limits are used to capture variation; therefore when variation exceeds the set control limits, it signals the interference of a “specific or special cause”. Gryna defines a special cause as a situation in a process or product that can yield excessive variation which will increase the level of cost.

Nwabueze (2012:581) contends that reduction of operating cost is the key to competitive advantage attained through process efficiency, and that is done through process streamlining to shorten the activity performed. Foster (2004:351) postulates four central requirements when using process control charts, which are generic processes for chart implementation, fundamentals of interpretation, process charts required for diverse circumstances, and computation of limits for different types of process charts. The process is reliable and effective if it involves common causes because common causes present stable and predictable results.

3.9.2.4 Pareto Diagram

Ball (1998:342) observes that process complexity requires process modelling by means of simulations that can visualise operational interactions with respect to a product under development in order to produce maximum efficiency in its capacity. Pareto analysis is a quality performance measurement tool that uses the 80/20 percent rule. This rule is named after Vilfredo Pareto (1848-1923) an economist in Italy who believed that a small percentage of known defects can cause a number of things to go wrong in a process (Foster 2013:60). Pareto analysis is used to manage the quality of process performance through the ranking of process data principles.

The data is set out in descending order, from the highest frequency of occurrence to the lowest frequency, with the sum of frequency equated to 100% percent (Fotopoulos and Kafetzopoulos, 2011:582). Citing Cravener et al. (1993), the former describe the 80/20 rule as follows: 80% of defects result from 20% of the possible causes.

Radson and Boyd (1999), cited in Fotopoulos et al. (2011:582) note that most effort in management must be directed to improvement of the most frequent quality challenges so that areas of are arrested within systems engineering. The systems engineering approach is an application of scientific and engineering effort to define an operational need in termes of systems capability parameters through the use of an iterative process approach (Blanchard et al. 2011:31). Pareto analysis tools are frequently used to determine maintenance priorities within the process by ranking failures of equipment or process approach stages according to their degree of importance or cost (Fotopoulos et al. 2011:585).

The Pareto method is also categorised as one of the elements in Statistical Process Control (SPC) that can assist an organization to manage process challenges with clear visualization of activities performed. Foster (2007:10) is of the view that SPC is concerned with observing process capability and its stability. He argues that if a process is efficient it will consistently produce products that meet specification and it will not exhibit random or common variation. Pareto analysis can also be applied in a number of environments, and it is regarded as a useful tool to identify which problem to tackle first in the process based on the percentage rate allocated to the problem identified.

3.9.2.5 Scatter Plot

Defining a problem within the innovation and development set-up is often the most challenging part of the process, especially if it is urgent to proceed with the development (Blanchard and Fabrycky 2011:71). To distinguish the difference between two variables in a process development, a scatter plot diagram is the best quality tool to deploy. Gryna et al. (2007:619) believe that if one wants to study the relationship between two variables in an established process approach, scatter diagrams are the best option.

The former note further that this process control acts as a regression analysis tool within set parameters. The process represents relationships amongst the set of interrelated steps within the innovation and development process. The relationship with the process stages exists in two forms, which are positive (strong) and negative (weak) and it may be simpler or more complex depending on process behavior at that particular instance (Magar and Shinde, 2014:369). The optimum operating condition is identified by this chart to determine the importance of variance in influencing the variance within process performance (Gryna et al. 2007:619-620).

3.10 KAIZEN

The Kaizen principle is derived from a Japanese management philosoph that focus on prediction for future challenges, creation of quality vision, building quality into the process and building a foundation of common knowledge for better operational activities (Wilson, 2013). Kaizen is regarded as the implementation of continuous improvement that offers a low investment cost run-out which enables production to take place at lowest possible costs and with the utmost emphasis on quality of the product or service being offered (Bessant et al. 1993:214). Kaizen is a philosophy of never-ending improvement and is devoted to the improvement of output, process efficiency, quality of a product, and in general, of company performance. Karkoszka and Honorowcz (2009:179) describe Kaizen as a kind of thinking and management system, and it is a philosophy used not only in the management field but also in the everyday life in countries such as Japan.

According to Titus, Oprean, and Grecu (2010), Kaizen philosophy makes a major contribution to the reinforcement of relationships within the operational process between employees and managers, since the achievement of company objectives is the result of the combined efforts of each employee. Kabir (2013:1059) view the word Kaizen as the effort of continuous improvement; it comes from the Japanese word “kia”, which simply means change or to correct, and “zen”, meaning good.

Karkoszka and Honorowicz (2009:198) comment that Kaizen philosophy is far from ideal, as it places strain on the process owners, work in return for relatively low salaries, and it does not promise improved social conditions to the majority of employees that practise it. However it delivers good returns over time for the sakeofgrowth. In this type of improvement strategy, employees are allowed to come up with creative ways to solve their own departmental challenges on regular basis (Kabir et al. 2013:1059). According to Prosic (2011:173), Kaizen means ‘small incremental or continuous improvement’ and is a philosophy that focuses on the innovation and development process and on the results of the process approach.

Imai (1998), cited in Prosic (2011:173), views Kaizen as a way in which work is humanised, with potential to eliminate unnecessary hard work, both mental and physical. The Kaizen principles of continuous improvement has no stringently defined constraints and tools; the organisation may choose the easy way to apply this process while considering the output expected (Karkoszka et al. 2009:199).

3.10.1 Principles of Kaizen

Kaizen philosophy helps an organization to maintain the accepted process approach to an existing situation or condition to facilitate standardization. According to Prosic (2011:174), the philosophy continuously identifies even the best product with the highest degree of quality and opens further opportunities to improve. Further improvement is facilitated through quality circles and group consensus structure. Prosic notes that Kaizen’s purpose is to maintain a higher standard, but the term ‘standard’ does not necessary mean rigid, unchangeable and absolutely in the context of continuous improvement. If the standard is interpreted as rigid, that wouldmean Kaizen principle is impossible to be practiced in such particular setting.

Karkoszka et al. (2009:198) openly agree that, Kaizen has a basis that is constituted by the 5S concept. The 5S concept is the principle of setting excellent customs and personnel acceptable behaviour within development and innovation operations. The 5S principles are viewed as techniques that allows the improvement of efficiency and output while ensuring a pleasant organizational climate (Titu, Opreana and Grecu, 2010:01). The 5S system is used to improve the quality and safety of the process or product within the established development environment. The 5S system is noted as one of the improvement principle that has a capability of making the problem visible within the innovation and development operations.

The 5S is an acronym represesnting five words, which present the concept of good maintenance within the innovation and development setting, and are described as follows (Titu et al. 2010:2, Karkoszka, 2009:198-199, Kabir 2013:1059).

- Seiri: sorting – making the difference between necessary and useless things, giving up the useless ones (preparation of workplace)
- Seiton: ordering/arrangement – the ordering of all the items after Seiri (tidiness in the workplace)
- Seiso: cleanness (cleaning) order in the workplace allowing an increase of safety. The control of tools and the building of quality into a process or product.
- Seiketsu: standardization – reminding employees about their duties in the respect of care in resource utilization.
- Shitsuke: sustain/self-control, adaptation of employees to the principles accepted by the organization, a process that allows elimination of non-added value customs.

Lim, Pervaiz, Ahmed and Zair (1999:307) argue that facilitating 5S in an organizational innovation and development process approach be driven by 4M elements, which are Method, Men, Machine and Material that are available at the point of operations.

3.11 LEAN AS PROCESS

The visibility of what is about to happen and what has already happened in innovation and development environment is viewed as the most important factor, because it give a clear indication of what has been achieved and also the sequence of the planned activities. Value stream mapping is a process used to identify value-added and non-value added activities within an innovation and development process approach (Belokar, Kharb and Kumar, 2012:233). The lean process entails reflection on what actually happens so that opportunities for improvement can be identified, and is often used to improve process cycle times because of its detailed instruction (Belokar et al. 2012:230). Gryna et al. (2007:398) contend that the value stream improvement journey typically starts with training of the team to capacitate them in the lean key concept. Once the team is technically capacitated, they will gain the required confidence to perform their job functions, and will be more motivated than before.

JIT is the core idea of lean manufacturing and it minimises stock waste and resources, which means that the company purchases materials and produce and distributes products when required (Gryna et al. 2007). This leads to the production of small, continuous batches of products to assist production to run smoothly and efficiently. Fullerton, Cheryl and McWatters (2000:83-84) are of the view that JIT encompasses more than just inventory control and material flow. It places attention on delivering the needed quality and quantity of material at the right place and in time with the innovation and development process set-up.

3.11.1 The Lean principles

According to Alves, Dinis-Carvalho and Sousa (2012:220), the lean thinking principle is implemented within the organization innovation and development process to reduce/eliminate waste (Muda, in Japanese). They describe waste as everything that does not directly add value to an organizational process/product, from the perspective of client specification and need. Womack and Jones (1996:6), cited in Dahlgaard and Dahlgaard-Park 2006:268) understand lean as a principle for reducing waste and building enterprise exactly the same as the well-known quality improvement process used by Motorola between 1983 and 1989 to improve their development process.

Gryna et al. (2007:388-390) propose seven lean principles for waste reduction which are described in section 3.7.2. Dinis-Carvalho and Sousa (2012:220) suggest five lean principles that should be deployed to do away with waste within the company development process.

3.11.2 Lean manufacturing eight wastes

According to Foster (2013) waste is anything that does not add value to the process or end product. In lean manufacturing, there are eight categories of waste that should be monitored. Shingo (1992), cited in Lim, Pervaiz, Ahmed and Zair 1999:304), tackles the issue of waste from a practitioner’s perspective and elaborates the following seven classes:

- Overproduction: Berlec*,T & M. Starbek*,M. (2014) hold that overproduction has an ability to confine employees to deplete the operational team’s capacity to detect defects as soon as they appear in the process.
- Waiting (time on hand): Ramachandran1,G.M * & S. Neelakrishnan2.S (2017) argues that reducing waiting time tends to assist the manufacturing company to produce an effective number of items and to meet set targets; people or machines are kept idling.
- Inventory (Work In Progress): an organization needs to ensure that their supply levels and work in progress inventories are reasonably manageable and the JIT principle needs to applied across the spectrum.
- Transportation (Conveyance): Ramachandran1,G.M * & S. Neelakrishnan2.S (2017) argues that more damage to the product is caused by double handling and unnecessary movement, therefore the manner in which product is handled needs to be controlled.
- Over-processing: Berlec*,T & M. Starbek*,M. (2014) argue that waste is generated in production and development, when providing higher quality products than required. They note that ‘’work” is performed to make up excess time rather than spend it waiting.
- Motion: Zhou and Zhau (2011) hold that if development and innovation motion is controlled, the employees will benefit as well as manufacturing ergonomics. The motion challenge contributes to non-conformance and adds no value to a maturity of a product or process.
- Defects: According to Zhou and Zhau (2011), defects are viewed as an opportunity for improvement and has the potential to a bring team together in pursuit of finding a solution to the problem at hand.
- Workforce: According to Liker, (2009), cited in Halen and Gerok (2014), employees’ competence and skills should be utilised in the correct manner. In other words, if workers skills are not utilised in accordance with pertinent competence, that would mean the organisation underutilises the skills and resources that are available.

3.11.3 Lean tools for waste reduction

The JIT concept is more based on efficiency in the sense that it forces the manufacturing or development company to only purchase the required quantity of components, and it also influences the supplier to supply the correct batch of quantity at the correct time at the place of work in order to manage process set-up time (Kilpatrick 2003:21). Singh and Khanduja (2010:100) citing (Hurly, 2000) note that set-up time reduction is a technique that was applied in 1987 to Mazda moulding presses in the automotive industry and successfully delivered 57% percent set-up time reduction. The following lean tools are mostly applied in the nature of design and development engineering environment in pursuit of continuous improvement efforts.

- Kanban is known as an orderly flow of material; the use of kanban cards is used to indicate material order points, demonstrate the amount of material required, specify the point of use of that particular material, and lastly indicate the point of delivery. (Lim; Pervaiz; Ahmed and Zair, 1999:308). They view kanban as a tool for visual control that works by presenting numerical information confirmed in the form of physical information through a card.
- Zero defect supports the company to prevent loss in rebuilding and reprocessing stages that prevent a faulty product; and it also encourages all operations to deliver a defect free product because it allows the second operator to inspect the previous operators work into his/her workstation (Fisher 1999:265).
- Single Minute Exchange (smd): Singh and Khanduja (2010:99) are of the view that lack of standardization procedures for set-up allows each person to do the set-up in their own way – undermining the cost of quality, JIT and quantity of a product.
- The 5S: this is the system of organizing the workplace environment; it is regarded as one of the simple lean tools to implement to any innovation and development set-up (Lim, Pervaiz, Ahmed and Zair 1999:306-307).
- Concurrent engineering: this employs a cross-functional team approach to develop and produce new products to market; it can reduce time to market by 50%; time to market is one of the most valuable tools for capturing information and it maintains the share to the market (Kilpatrick 2003:3-5).

3.12 THE POSSIBLE BENEFITS OF CONTINUOUS IMPROVEMENT

Wang (2008) argues that quality improvement starts with a diagnosis of a noted process deficiency in the innovation and development processes, and once the problem is scrutinised, cause and effects are identified, and an effective remedial solution is formulated to facilitate positive progression. The improvements in a nanosatellite engineering system innovation and development process would highlight the kinds of activities that still require careful attention, so that the JIT principle is applied as necessary to such identified areas.

The continuous improvement process uses JIT to enable an engineering development operation to strategise the available facility layout, product design, team and resource competency, production planning and scheduling, and the flow of material and supply chain aspects for efficient execution of activities (Lim, Pervaiz, Ahmed and Zair, 1999:308).

3.12.1 Continuous quality improvement in nanosatellite development

According to Cole (1992), cited in Foster (2013:396), the need for employee participation is a key element in managing a changing organization in order to survive the complex world of product development. Foster (2013:396) defines the term team as “a finite number of individuals who are united in common purpose”. Dinis-Carvalho and Sousa (2012:223), view continuous improvement as a means of being permanently dissatisfied with the status quo in order to identify challenges and deploy relevant preventative/corrective measures within the process approach. Nakasuka et al. (2010:1099) state that university students take part in teams in space exploration innovation by building nanosatellites to learn principles of building big satellites as part of continuus improvement on skills development; this is regarded as knowledge-building in order to strengthen existing passion, innovation capabilities, skills and confidence. Nakasuka et al. (2010:1100) elaborate that in advancing continuous improvement in this disruptive innovation, international cooperation in collaboration (benchmarking) with medium scale, well-established companies is motivated by an ongoing search for an opportunities to produce and launch satellite by university students.

Continuous improvement creates opportunities for increasing efficiency of innovation and development of nanosatellites; the nanosatellite developed increases its performance and delivers better results during mission execution. An innovation and development process will enable progress from one platform to another in a reasonably short period of time only if is monitored and controlled (Foster 2013:425). The organizational learning and knowledge have to be considered as one of the main building blocks where a quality culture is practiced.

Culture is referred to as the norm and belief that leads to decision-making patterns and actions in an organization that aspire to grow and improve (Thomasson and Wallin, 2013). In some cases, product development companies have cultures that are conducive to quality improvement; the quality improvement process should be flexible enough to be altered to suit any urgent positive change within product development, and statistical process control can be used to manage that change. The role of statistical process control in continuous improvement is to engineer the existing process with regard to mistake elimination, so that mistakes may be immediately detected and rectified before creating more con-conforming stages within the process approach (Fisher, 1999:264)

3.13 SUMMARY

In this chapter a literature review was inducted mainly on the concept of continuous improvement and its benefit; the literature on the history and inception of satellites as early as 1957 till the birth of sniversity satellite innovation and development is discussed; and the first ever university Cubesat to be launched and its introduction on the African continent is also briefly discussed. Kaizen philosophy and its benefits in the process improvement pattern, lean principles best practice and the effects of cost of quality to the engineering development process was elaborated. The key factors that affect continuous improvement of quality in the engineering manufacturing environment were discussed, and research objectives together with the research topic and the research problem were considered.

In Chapter 4, the approach to data collection is explained and the target population is defined. The measurement scales to be used in the survey, and the survey design, is also further explained.

CHAPTER 4: METHODOLOGY AND DATA COLLECTION

4.1 INTRODUCTION

This chapter discusses the methodology and data collection methods that are applied to this study. Following the introduction, the research design is discussed. Next, the sampling methods, and the research instrument and data collection are examined. The target audience, measurement scale, survey design and respondent brief are then disclosed. The final section of this chapter's discussion focuses on the validation of the study's survey. The chapter concludes with all the main points regarding research methodology and data collection.

Research methodology deals with the science of methods, where core principles for conducting quality research and learning to make a sound judgment about the methods are made (Neuman, 2011:2). There are two types of research methodology, namely, quantitative and qualitative. In this study, mixed research methodology of the previously mentioned methodologies has been used.

The researcher's objective is to peruse the F'SATI unit at CPUT with intentions to view the advancement of the nanosatellite innovation and development process, through continuous improvement assessments. Neuman (2011:2) emphasises that "research methodology and methods are closely linked and interdependent of each other". The methods define what to do, where specific strategies and procedures for implementing research design, including sampling, data collection, data analysis and interpretation of the findings are applied.

For this study, the research method is the collection of data by means of a questionnaire, document review, and group interviews. Following this, the collected data is analysed and the conclusion is drawn. The collected data speaks to quality principle methodologies, innovation and development, process effectiveness, internal capacity building in resources and personnel, and the means to sustain the current good working innovation and development process approach. The data has been collected from French South African Institute of Technology Satellite Systems Engineering at Cape Peninsula University of Technology, South Africa.

4.2 RESEARCH DESIGN

As stated earlier, for this study qualitative research methodology was applied. The most common sources of data collection in qualitative research are interviews, observations, and reviews of documented information. Therefore, for this research, participant observations, individual semi-structured interviews, structured group interviews and questionnaires were used to gather relevant information.

An action research model was used as a secondary method to collect information that cannot be easily obtained through a set of semi-structured interviews. Action research is an interactive inquiry process, whereby people share knowledge based on set objectives through the utilization of highly selected data concerning the research intentions (Huang, 2010**:** 95).Therefore, for this study, various employees were engaged in short interactive discussions where they were expected to explain their job function and their involvement in the innovation and development process of the nanosatellite.

The discussion included the participation of the innovation and development team directors, operational managers, chief engineers, development engineers and mission engineer (selected population)

4.3 SAMPLING METHODS

Emory and Cooper (1995) define two methods of survey sampling, namely the convenience sample, whereby a predetermined number of components, smaller than the chosen population from the innovation and development team, are chosen (typically randomly) in such a manner as to accurately represent without bias the total population. The census approach, here the point of departure, was influenced by the research objectives; therefore an attempt was made to survey every element within the innovation and development team population. Therefore this research is conducted through the use of the census approach.

The researcher's intentions were to focus on key players of the nanosatellite innovation and development process so that the key research objectives would be realised. The census approach was used as most applicable when the total population is sufficiently small, and there is a strong measure of diversity amongst the population element. The active and interactive participants of this innovation and development team were ten employees (see Appendix I: Organogram**).** For this research, the employees' opinions were gathered to prove or disprove the anticipated perceptions about certain issues pertaining to the innovation and development team.

These opinions were gathered by means of document review (documented information), group interviews, (see Appendix H: Qualitative Questionnaire) and quantitative questionnaire (see Appendix F: Quantitative Questionnaire). The use of different data collection methods (census approach) was influenced by the population scale and by the nature of the innovation and development team.

Emory and Cooper (1995), view the census approach as an aspect that exploits every section of the innovation and development team so that clear perceptions regarding the research objectives are achieved and value-added results are obtained.

4.4 RESEARCH INSTRUMENT AND DATA COLLECTION

In this study, data was collected by means of a document review, an objective short interview, and through use of a quantitative questionnaire. The researcher participated in the weekly project design briefings sessions. Here, the key role players reported their progress and challenges experienced in the tasks assigned to them in the previous week. The researcher used an unstructured interview or interactive discussions with the role players to obtain clarity on quality issues raised.

Data reliability was assessed to assure the integrity of the process. The statistical process approach and expert judgment was used to validate the result obtained from the research study. The information collected was compared to the research objectives as well as to the anticipated objectives of the study, and recommendations were made based on the findings.

4.5 TARGET POPULATION

According to Collis and Hussey (2003:157) population is any precisely defined set of people within the research environment, group or assortment of items which is under consideration for a purpose. For this survey, ten employees, collectively selected as an active team in the innovation and development of the nanosatellite, were nominated.

The researcher had the privilege of gaining knowledge of the core and support processes of the innovation and development group prior to defining the research topic, objectives, research questions, and both qualitative and quantitative questionnaire survey tools. In addition, the researcher was taken through the innovation and development process approach by the chief engineer for a better understanding of the environment. It was at that juncture that the researcher conducted informal interviews with development engineers and system engineers who were involved in the ZACUBE-1 project, and now are currently involved in the ZACUBE 2 innovation and development process. The target population for this study was the leadership of business and technical spheres, and innovation and development personnel including technical and operations, (see Appendix **I:** Organogram).

The researcher emailed the leadership of the nanosatellite innovation and development systems engineering team, requesting permission to collect data, (see Appendix C: Request for Data Collection). A meeting for this purpose was set and the research objectives and intentions were tabled in the meeting. After an understanding was reached, permission was granted to the researcher to proceed (see Appendix D: F'SATI CPUT Permission Letter). The interview questionnaire was formulated, and checked for correctness. The researcher conducted the interviews with the sample personnel, and thereafter, an electronic quantitative questionnaire was sent to the participants, (see Appendix F:, Quantitative Questionnaire)**.**

The participants were given two weeks to complete the questionnaire. However, the time frame set for completion of the interview did not turn out as planned and delays were caused by some of the issues elucidated in section 1.14 RESEARCH

CONSTRAINTS of this study**.** The participants actually took more than two to three weeks to complete an electronic questionnaire and that negatively influenced progress. However, the questionnaire was finally completed successfully by the participants.

4.6 MEASUREMENT SCALE

The measurement scale adopted for the quantitative survey questionnaire was a Lickert scale. The Lickert scale is a set of questions or statements that are drawn up in sequence and the respondents are then ask to mark the option that best reflect their opinions (Bishop and Herron 2015). The main reason for choosing the Lickert scale was its ability to increase the scope in data collection process and for ease of use. The Lickert scale tool has potential to glean data in support of the research problem in a question (Bishop and Herron 2015). The advantages of using the Lickert scale are:

- Easy and quick to construct.
- The Lickert scale is probably more reliable than the Thurson scale; it provides a greater volume of data.
- The Lickert scale can still be treated as an interval scale.
- It allows the researcher to be able probe questions based on research objectives in sequential order.

Remenyi et al. (1995) state that an interval scale facilitates meaningful statistics when calculating means, standard deviation, and Pearson correlation coefficients. An additional amount of data can be generated by other means, such as rated response and numeric scales. This scale collected information that supported the previously collected qualitative data.

4.7 SURVEY DESIGN

The researcher considered the maturity of the innovation and development team with regard to the product being developed, studied their progressive growth and learnt about the future aspirations, and formulated the topic based on the current status but taking into considering the future plans for research survey development purposes.

According to Collis and Hussey (2003), a research survey should be designed in agreement with the following stages:

- First stage: identifying the research topic and objective.
- Second stage: investigate people’s knowledge based on the topic of interest.
- Third stage: information areas should be identified as well as associated objectives within the departmental surroundings.
- Fourth stage: using information gathered from stage two, factual evaluation against the set objectives is carried out.
- Fifth stage: use the results from stage four to restructure the research objectives for purposes of standardisation.
- Sixth stage: the survey or questionnaire need to be composed.
- Seventh stage: revise the questionnaire or surveys to see the fitness for purpose, and if fitness for purpose cannot be discovered, realign them to attain the anticipated results.
- The eighth stage: compose and produce the final version of the survey or questionnaire.
- Ninth stage: systemise the questionnaire according to the suggested rating scale and distribute it.

In all questionnaires compiled, biased questions or statements have been omitted, as the researcher is aware of the implication of providing a biased questionnaire.

4.8 RESPONDENT BRIEF

The researcher from the onset clearly outlined the project timelines and research intentions to the F’SATI team, and mutual agreement between the three teams (engineers, project manager and top management) was reached. The researcher informed the participants that the first method of collecting data would be one-on-one and group interviews and later an electronic quantitative questionnaire would be distributed as the secondary methods. Finally, a document review would be conducted.

The research participants engaged with the researcher with respect to the research topic, objectives and research questions. It was the innovation and development team norm to have a weekly meeting, and in these sessions brainstorming, design review feedback and progress reports were tabled by the operational leaders, and were opened for further scrutiny. The researcher listened to output presentations made and sought clarity where possible, remaining neutral in his comments or statements, so that research participant felt free to comment further.

The research participants were all promised a project research poster, at least one week prior to the interview date, so that they may have an overview of the research project, (see Appendix B : Research Poster). The top management was sent an email requesting a suitable interview date and the date was confirmed and scheduled. The researcher once again made participants aware of confidentiality and ethical consent was completed prior data collection process. After the completion of interviews, participants were sent a formal letter requesting their participation for the second round of data collection process, containing a link to an electronic questionnaire (see Appendix E: Request Letter for Quantitative Questionnaire).

4.9 THE VALIDATION OF SURVEY QUESTIONNAIRE AND INTERVIEWS

A questionnaire was developed in alignment with the primary research objectives presented in Section 1.7. The intentions were to uncover hidden waste and process deficiencies,and to assess the effectiveness level of the team under study. Thequestionnaire was composed in a format that would ensure a higher degree of validity. The thirty completed questionnaires were mediated by Inqwise software andanalysed and results were made available on request for F'SATI's top management only.

For the interview, seven main questions, with two to three sub-questions each were composed (see Appendix H: Interview Questions). During the interview process, participants were given ten minutes to go through the questions before being questioned and possibly questioned for clarity. The responses were recorded and later transcribed for analysis. A voice recorder was used to capture the interviews, which were made available on request to the team leadership once the research was submitted for an examination.The researcher employed descriptive andinferential statistics to analyse the collected data from the participants,and that process is described in Chapter 5 of this document.

4.10 SUMMARY

The research methodology and methods were introduced. Next, the research sampling method was outlined. The research instruments and data collection process was explained. This was followed by a discussion regarding the target audience, measurement scale, survey design and the respondents brief delivered during a design briefing meeting. Lastly, the validation of the survey was discussed.

CHAPTER 5: DATA ANALYSIS AND INTERPRETATION OF RESULTS

This section of the study focuses on data analysis and the interpretation of the results. The chapter begins with a brief introduction. This is followed by the method of analysis (quantitative and qualitative), the sample group, and a brief description of the respondents, interpretation and analysis of data collected. Analysis of the quantitative data is followed by interpretation of qualitative data.

5.1 INTRODUCTION

Data collection is defined by Carpi and Egger (2003) as "the universal recording of information", while De Vos (2002:399) defines data analysis as "the process of bringing imperative structure and meaning to the mass of collected information or knowledge." The researcher therefore aimed to create structure and meaning from the systematically recorded information.

The electronic survey questionnaire that was completed by by F'SATI and ASIC team was revisited, analysed and findings were interpreted hence the analysis of the quantitative online survey results is reflected below and further discussed. The analysis was taken further through synthesis to reflect the study purpose and its relative significance. The following research questions guided the analysis:

- How can the implementation of continuous quality improvement reduce the cost of poor quality?
- What continuous quality improvement programmes are engaged to deliver defect-free product?
- How is the lean principle implemented and practiced in the development process cycle?
- What tracking and monitoring processes are applied to measure and analyse current practice against the intended targets?
- What can be done to sustain both continual quality improvement and low development cost?

The above research questions were derived from the primary research objectives and therefore both research questions and objectives were integrated for better results; hence the qualitative and quantitative research questionnaires were designed for easy capturing of the participant's perceptions about the current process approach. The latter is viewed as the application of current process together with identified process approach and interactions of the present process to deliver desired outcomes (ISO 9001, 2008: V).Therefore all-inclusive final results and recommendations were presented to the innovation and development team so that an internal process capability post-mortem could be carried out to improve current practices.

Based on the nature of the research environment and methods used to collect information, a decision was made with regards to data analysis presentation. The data was analysed and presented in two forms, which were quantitative (descriptive analysis) and qualitative (interpretative analysis)**.** The research findings and recommendations are contained in chapter six. The descriptive and inferential statistics are used to test the study hypothesis; the methods of analysis are described below.

5.2 METHOD OF ANALYSIS

This section deals with a descriptive analysis of the completed survey questionnaire and interpretive analysis of the one-on-one group interviews. Data was collected through means of primary data (online survey questionnaire and group interviews) and through secondary data (review of documented information). The documented information is viewed as an organizational knowledge and this knowledge can be used and shared amongst teams to achieve the stated organisational objectives (ISO 9001, 2015: 7). The responses to the questions obtained from the questionnaire and interviews are described below.

For a proper data presentation for data, validation has to be carried out. Data validation is the process of ensuring that a programme operates on clean, correct and useful data (Di Zio et al., 2016). The following three phases were used in analysing data.

- Cleaning, organising and coding the information that was collected, namely the data preparation phase.
- Describing the information that was collected (descriptive statistics and Interpretation): and
- Testing the hypothesis.

On completion of the analysis, the researcher recognised gaps and noted good practices. The analysed information will be handed over to F'SATI once the thesis has been marked and results are issued. The researcher is convinced that some if not most of the finding could be used to assist F'SATI to take more risk-based decisions with respect to innovation challenges, and to complement current innovation practices.

5.2.1 DATA FORMATTING

The online survey data was derived from the questionnaire feedback, which was coded and captured on a database developed using SPSS Statistics 24 software. The questionnaire responses were captured twice on a system and then the two datasets were compared to reduce capture errors. Once the database was developed and rules were applied that set boundaries for the different variables, and this is described in 5.4.1 Section A (Descriptive Analysis). A Likert scale was used and responses were codified as follows:

- "Strongly Disagree (SDA)" is coded as 1;
- "Disagree (DA)" is coded as 2;
- "Undecided (UD)" is coded as 3;
- "Agree (A)" is coded as 4; and
- "Strongly Agree (SA)" is coded as 5

The qualitative data was coded in accordance with the research questionnaire statements key words and were referenced as major and minor themes. Further details are explained in section 5.6 B: Qualitative Data Analysis.

5.2.2 RESPONDENT RATE AND SAMPLE

The innovation and development team population varies on a yearly basis. Therefore, in order for the researcher to achieve the stated research objectives, a well thought through risk-based thinking approach had to be taken. The participants for this study were carefully selected from various departments, taking into consideration the research questions. The areas of interest in accordance with the research topic were organisational leadership, operations management, technical staff including mission engineers, product engineers, and development engineers (see Appendix I: Organogram). The reason for such a careful selection approach was to make sure that the research question were properly addressed and participating individuals would get an opportunity to learn more about the value of quality in their routine activities, and provide meaningful information to F'SATI.

Therefore ten full-time employees who were fully involved in innovation and development activities were selected to participate in the study. The first data collection method deployed was qualitative approach and lastly, quantitative approach, here 100% participation in completing the Inqwise online questionnaire and in the interviews was noted.

The interview questionnaire was designed to answer all research questions in accordance with the research objectives are concerned. Therefore it was impossible to gather such information that addresses all five research questions with one set of questions using the one-on-one interview, so alternative means were established to gather further information.

Based on the nature of the innovation and development process and its complexity with respect to continuous improvement, the researcher conducted group interviews. For this approach, the population was divided into three groups, which were coded according to their departmental roles.

5.2.3 A BRIEF DESCRIPTION OF RESPONDENT

In total, all of the ten respondents completed the online questionnaire and all three group participated in an interview sessions. The innovation and development team population status as well as outlined research objectives forced the researcher to consider biographic information only during the interviews session, but not for the purpose of analysis.

The biographic information included involvement of the innovation and development team. Knowing the involvement of the personnel helped the researcher to understand individual responsibilities. It was observed that there was top management (leadership), operational management, and the majority of the group, product and development engineers.

A descriptive and interpretative approach was deployed to analyse collected information and for the use of the innovation and development team. The following information describes the way in which respondent's perceived statements and questions stated or probed to them during the investigation phase of this study.

5.3 QUESTIONNAIRE STATEMENT DESCRIPTION

In Table 5.1 below, questionnaire statements are shown, with each variable name and the different sections of the questionnaire. Here, the questionnaire statements are divided into five sections according to the research objectives, namely firstly, to address the effectiveness of key lean manufacturing principles that are in place. Secondly, to determine whether current continuous quality improvement reduces various costs. Thirdly, to examine the effectiveness of the current development process. Fourthly, to identify main reasons that cause continual quality improvement to fail. Lastly, to define and recommend an effective approach that can be utilised to sustain continual quality improvement. It is crucial for the reader or innovation and development team to note that these variables are based on the current innovation and development process approach as well as on the available sample selected, in considering the research objectives of this study. The following table 5.1 presents the questionnaire and variable statements used.

Table 5.1 Questionnaire statements and variable names

VARIABLE NAME	QUESTION/STATEMENT
Objective One: To address the effectiveness of key lean manufacturing principles that is in place.	
Q1	Different components are produced in different stages.
Q2	Components and people move between workstations efficiently
Q3	Working areas are clean and organised
Q4	Sometimes a product is delivered to the wrong point
Q5	Formal development layout is established
Objective Two: To determine whether current continual quality improvement reduces various cost	
Q6	Supplier provides standard parameters for our work operation?
Q7	Procument policy is flexible?
Q8	Risk-based thinking is performed during planning?
Q9	Project scopes are always clear?
Q10	Some activities are outsourced?
Objective Three: To examine the effectiveness of the current development process	
Q11	The quality of work is monitored in every stage?
Q12	Design reviews are both formal and informal?
Q13	Products failed during testing process are downgraded?
Q14	Level of defect is recorded and measured?
Q15	Parts are evaluated prior their employment?
Q16	Previous projects documents are always available when needed?
Q17	Complaint are recorded and resolved immediately?
Q18	Project tracking and monitoring process is practised?
Q19	Customer property is preserved as required?
Q20	Targets are set to improve the existing development process?
Objective Four: To identify main reasons that cause continual quality improvement to fail	
Q21	People always have work to do?
Q22	Supplier evaluation is performed prior to business engagements?
Q23	Product testing is performed on all products and components?
Q24	The supplier evaluation process is too long?
Q25	Testing stations are capably of testing components?
Q26	Controls for outsourced activities are established?
Objective Five: To define and recommend an effective approach that can be utilised to sustain continual quality improvement	
Q27	Information is documented at all stages during operations?
Q28	Logbooks are used to record the machine usage?
Q29	All involved personnel have access to documented information?
Q30	Space qualified components are used for production?

5.4 DESCRIPTIVE STATISTICS FOR EACH VARIABLE OF THE SURVEY AS PER THE QUESTIONNARE.

The collected questionnaire data are listed in Annexure F: Descriptive Statistics and further interpreted and described in Figures 5.1_to 5.30, with each Likert scaling aligned to the number of respondents per statement. The quantitative data responses are presented in Table 5.2. The data is presented according to respondent frequency, percentage, valid percentage and cumulative percentage as displayed in the graphical presentations. Respondent's opinions based on valid percentage, verification was made to check if there were or were not controls in the process, and literature was revisited to support the presented findings.

Table 5.2: The Likert scale data presentation.

Likert Coding	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5
0-1 SDA	5	9	11	4	3
1- 2 DA	4	4	7	4	1
2 - 3 UD	13	11	30	14	14
3 - 4 A	**14**	**18**	**29**	**23**	**14**
4-5 SA	**14**	**9**	**24**	**15**	**6**
Total response	**50**	**51**	**101**	**60**	**38**
Ten participants answering 30 research questions each equate to 300 responses					

5.4.1 SECTION A: DESCRIPTIVE STATISTICS (Quantitative Analysis)

The research participants were informed about the research topic, clarification questions were asked by the research participants during an organised official research briefing session, as well as about the main research objectives and later a written request was sent for their participation in research interviews and to complete an online questionnaire (see Appendices E and G).

The researcher further elaborated the intent of the research project to the participants by attaching a research poster, which explained the possible value that could be added by the study to nanosatellite innovation and development capabilities (see Appendix B).

The researcher initially attended the design review and project report briefing sessions, in order to understand the level of thinking within the group, to capture areas of progressive improvement, and to test the first draft of the survey questionnaire. Secondly, the researcher wanted to gain the participants' trust and influence them to support the objective of wanting to improve, and lastly, to emotionally prepare the participants, so that they were eager to participate and complete the provided research questionnaire without any fear; and to gain a true reflection of what was really going on within the innovation and development team.

The researcher decided to start with quantitative data analysis and later tackle qualitative data for reasons of ease of flow and reporting. The questionnaire statements were coded as presented in Table 5.3. Descriptive statistics with standard deviation, mean, maximum and minimum in a thirty (30) research statement are presented in table 5.3.

Table 5.3 Descriptive statistics – minimum, maximum, mean and standard deviation.

CODED - STATEMENT	N	Minimum	Maximum	Mean	Std. Deviation
Process layout	10	1.00	5.00	4.2000	1.22927
Controls in outsourced	10	1.00	5.00	4.2000	1.22927
Formal and informal	10	1.00	5.00	4.2000	1.22927
Product testing	10	1.00	5.00	4.0000	1.15470
Evaluation	10	3.00	5.00	4.0000	.81650
Clear directives	10	3.00	5.00	4.0000	.81650
Providers Evaluation	10	2.00	5.00	3.9000	.99443
Previous project	10	1.00	5.00	3.9000	1.28668
Different components	10	2.00	5.00	3.9000	.99443
Procurement policy	10	1.00	5.00	3.8000	1.22927
Record machine usage	10	3.00	5.00	3.8000	.78881
Resolved immediately	10	2.00	5.00	3.7000	.82327
Recorded and measured	10	3.00	5.00	3.7000	.82327
Work is monitored	10	1.00	5.00	3.7000	1.49443
Standard parameters	10	2.00	5.00	3.6000	.84327
Space qualified	10	1.00	5.00	3.6000	1.17379
Testing station	10	2.00	5.00	3.6000	.96609
Outsourced activities	10	1.00	5.00	3.6000	1.17379
Project tracking	10	2.00	5.00	3.5000	.97183
Delivered wrong point	10	2.00	5.00	3.5000	.97183
Information documented	10	1.00	5.00	3.4000	1.17379

Evaluation performed	10	2.00	5.00	3.4000	.84327
Moves between stations	10	1.00	5.00	3.4000	1.17379
Clean and organised	10	1.00	5.00	3.4000	1.34990
Access to information	10	1.00	5.00	3.1000	.99443
Have work	10	1.00	5.00	3.0000	1.33333
Improve existing	10	1.00	5.00	2.9000	1.44914
Preserved as required	10	1.00	4.00	2.6000	1.26491
Testing process	10	1.00	4.00	2.5000	1.08012
Risk based thinking	10	1.00	4.00	1.6000	.96609
Valid N (list wise)	10				

5.5 SECTION A: UNIVARIATE GRAPHS OF THE QUANTITATIVE APPROACH

The questionnaire for this research was developed before the group interviews, based on observations and literature reviewed, and considering research objectives outlined in chapter one of this study. However, after completion of the first phase of the group interviews, some statements were altered in order to raise questions that were not clearly answered during the interviews.

The following are the univariate graphs that illustrate the respondents' feedback in percentage format; the summary of the feedback given by the participants, obviously supported by literature where possible, is tabled below. The percentage analysis was carried out in descending or ascending order, arranged from "strongly agree" to "strongly disagree"

5.5.1 Objective One: To address the effectiveness of key lean manufacturing principles that is in place.

Figure 5.1: Different components are produced in different stations

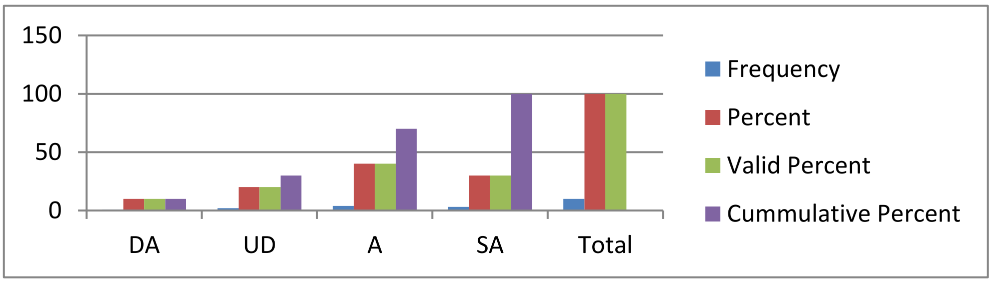

Figure 5.1 above reveals that 70% of the population is in agreement that components process control is carried out in defferent workstations.However, 30% of the population confirms that this system wasn't introduced to them, or they are not equipped as to how the components get developed to make up an object. Therefore, continuous improvement control with respect to processes involved is required. The 70 % participant feedback is in agreement with Siva (2012:84) who argues that principle of continuous improvement is commonly identified within development processes specifically with practices in manufacturing, such as process control.

Figure 5.2: Components and people move between workstations
efficiently.

Figure 5.2 reveals that 50% of the entire population is in disagreement about the efficience movement of components or personnel during development. Therefore, the over-the wall-syndrome is found not well managed as far as this perception is concerned.

Over the wall-syndrome refers to challenges that arise when different types of engineers work in totally different departments in the same organization (Foster, 2013:196). This can be addressed by an information session to inform the entire team about the movement of people and components.

Figure 5.3: Working areas are clean and organised

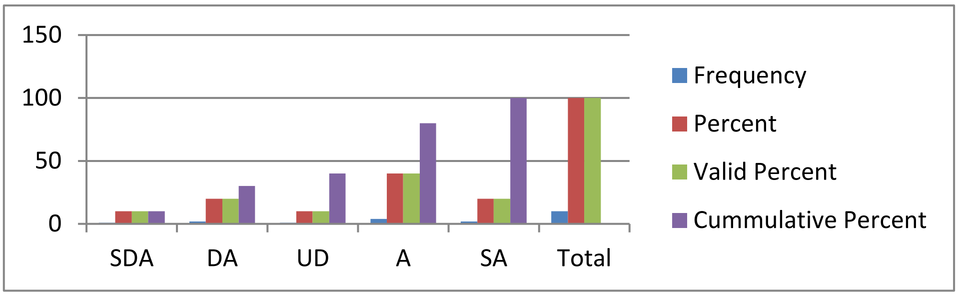

Figure 5.3 reveals that 80% of the entire population agrees that housekeeping is well maintained, the clean environment reveals an opportunity to produce an uncontaminated product of high quality. The response shift in this question shows that only 20% percent of the population that is not sure if the work environment is clean and organised.

The majority of the participants agree that lean production is deployed, which is defined as a system with a focus on optimizing current process through a philosophy of continual improvement (Foster,2013:92). Therefore, the team should devise means of informing the whole team so that they support effective continuous improvement further.

Figure 5.4: Sometimes a product quotation and components are lost through procurement system.

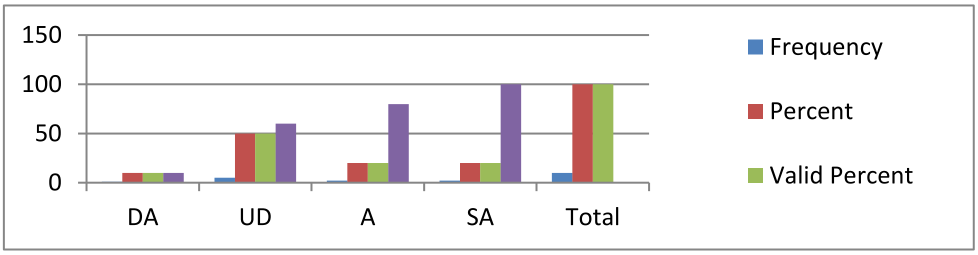

Figure 5.4 reveals that 50% of the sample is undecided that a core process such as procurement systems is so inefficiency, or is absence of controls that quotations and products are lost through it, and that could causes a developmental delay.
A core process is one that is central to the organization and its internal customers, which is the procurement process in this instance (Foster, 2013:451). The minority

percentage 10% does not agree, while 40% agree with the sentiment, therefore awareness of how one should place and follow up an order is highly recommended for the entire team.

Figure 5.5: Formal development layout is established.

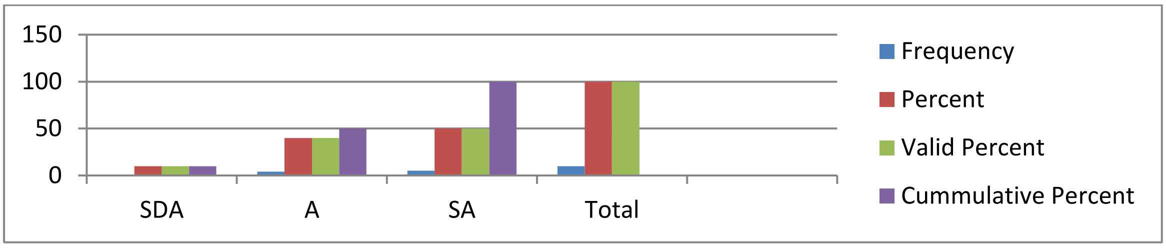

Figure 5.5 show that 90% of the participants agree that layout is established with the intention to reduce possible cost and to improve development process , and it is percieved that cost-benefit analysis is considered during planning.

Cost benefit analysis is deployed to determine efficacy of proposed continual development improvement within an innovation and development structure (Foster, 2013: 451). Only 10% of the population did not agree strongly with the sentiment, which indicates that there is still room for improvement in this regard.

5.5.2 Objective Two: To determine whether current continual improvement reduces various waste.

Figure 5.6 Supplier provides standard parameters for our work operations.

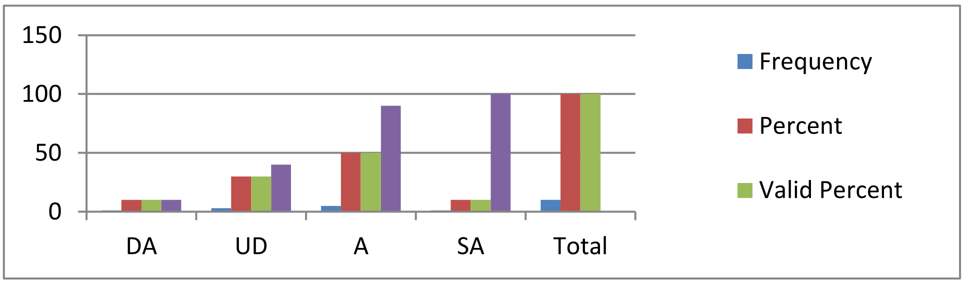

Figure 5.6 reveals that 30% of the population is not aware of suppliers being able to provide standard parameters, while 60% of the target group agrees that suppliers are able to provide the standard parameters of components, and this demonstrates that a well-established supplier alliance is in place and the current suppliers are able to attend to requisitions.

A supplier alliance is an established business relationship between the supplier and customer that enforces a high degree of linkage interdependence and this process is inspired by a lean purchasing approach (Foster 2013: 254).

However, in some cases, components supplied needed to be reworked in order to reach the expected performance reliability and durability for application purposes. The organization will need to share the challenge (reworking of components) with all team members so that everyone is informed about this challenge and team contribution in arresting these issues will then form part of continuous improvement.

Figure 5.7: Our procument policy is flexible

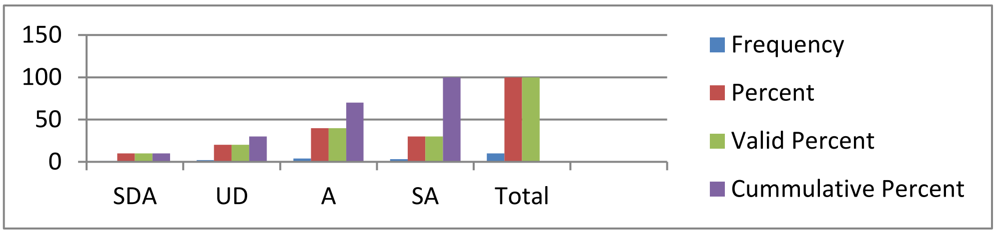

Figure 5.7 shows that 70% agree that the procurement system really assists in making sure that the development environment meets the expected targets, even though a series of control gates needed to be considered at the planning phase in order for a team to deliver within the stipulated dates. It is evident that procurement policy caters for purchasing system activities.

Gryna (2007:357) views these activities as the specification of requirements, selection of suppliers and supply chain management, which focuses on the ultimate goal of meeting stated requirements.

Figure 5.8: Risk-based thinking is performed during planning.

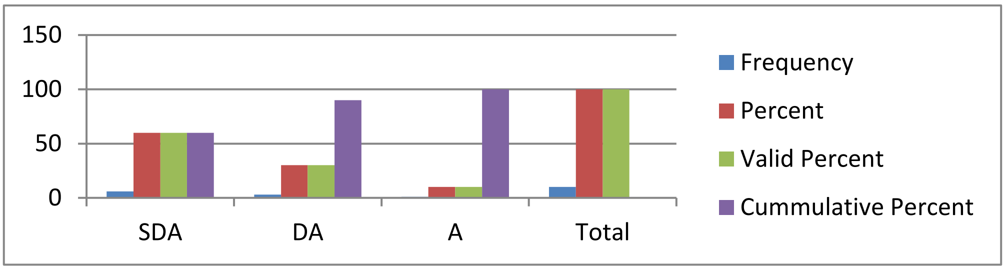

Figure 5.8 shows that 60% agree that risk-based thinking is not taken as one of the major principles within the development environment. This sentiment creates an opportunity for defects or failure of planned activities.

Risk-based thinking is an approach that enables the planning team to determine factors that could cause deviation from the planned arrangement and if considered can motivate a culture of introducing mitigating factors to deal with it when it plays out (ISO 9001-2015: 5).

Risk base thinking is used to reduce in-process control responsibility. Process control involves observing actual performance, comparing it with a standard and being forced to take actions if the observed performance is significantly different from the agreed standard (Gryna et al. 2007:171). Only 10% that agrees that risk is considered, and this could be the leadership group. Therefore more awareness is required to inform every member of the importance of a risk-based thinking approach and the need for analysis in such an environment.

Figure 5.9: Projects scopes are always clear

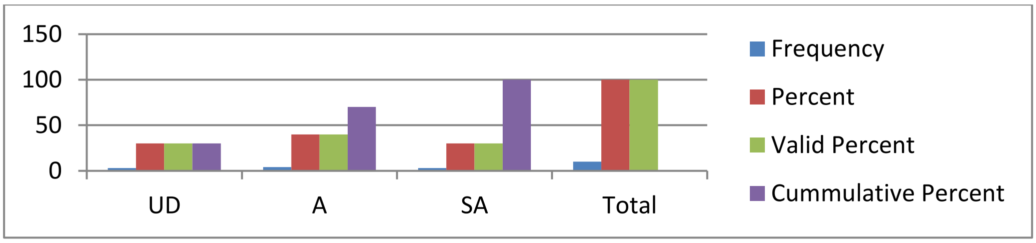

Figure 5.9 that 70% agree that project scope is always clear to the entire team. However, 30% of the population were undecided. Project scope refers to customer

specifications and customer product parameters that need to be verified prior to engaging.

The development team needs to ensure that those customer parameters are determined, confirmed and are met with the aim of enhancing customer satisfaction as agreed upon the project hand-over stage (ISO 9001, 2008:4). For effective development, project scope should be outlined to all participating team members, so that all inputs are properly verified before the project is undertaken.

Figure 5.10: Some activities are given to skilled external providers

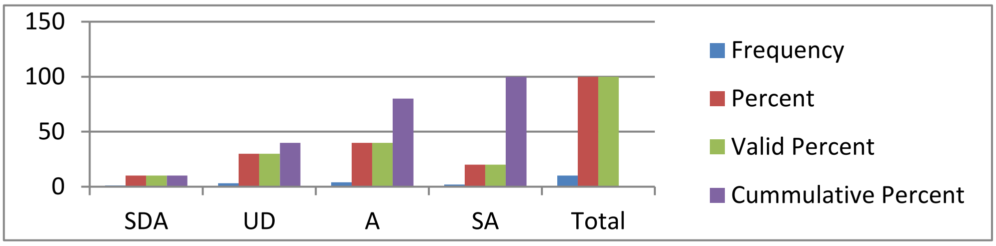

Figure 5.10 shows that more advanced development activities (production and some of performance or compliant assessments) are outsourced.

Gryna et al. (2007: 361) view the outsourcing process as subcontracting arrangement made with or to an external supplier, or a part of an activity that is currently conducted in-house by an external provider, with the intention of speeding up the process or reducing cycle times in an attempt of improve the quality of a product. An organisation should build relevant capacity and do away with the outsourcing of activities, in order to save money and time.

5.5.3 Objective Three: To examine the effectiveness of the current development process

Figure 5.11 The quality of work is monitored at every stage.

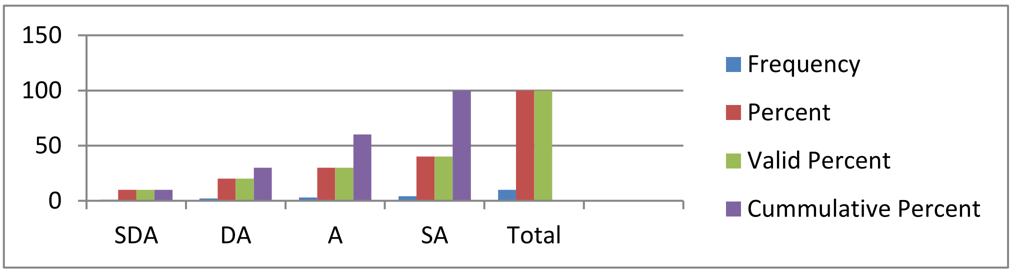

Figure 5.11 shows that 70% agree that the necessary quality controls are deployed. The quality of work is monitored from component stage to assembly and product performance stage, to avoid internal and external failure costs.

Internal failure is viewed as the cost of deficiencies that are discovered before delivery, while external failure is viewed as failure detected after the customer receives the products (Gryna et al. 2007:31). The monitoring of work at every stage helps to reduce the 'lose to society syndrome', which is defined according to Taguchi as the situation where the agreed product dimension varies from its target magnitude (Foster 2013:382).

Figure 5.12: Design reviews are carried out both formal and informal.

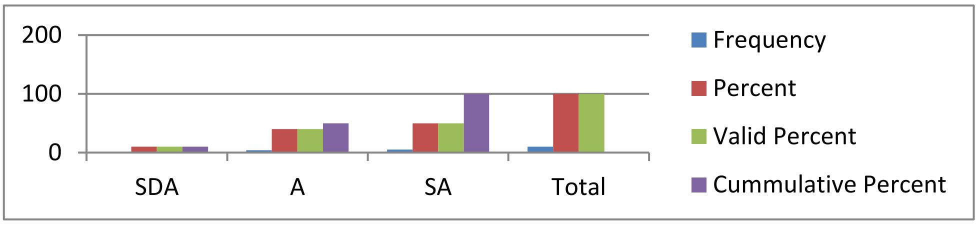

Figure 5.12 shows that 90% agree that design reviews are carried out both formally and informally in order to track progress and to avoid the process of inspecting the end product output.

Design review is the process of checking accuracy of a product being developed to view any possible interference, and interference checking is defined as the process of examining the design (product under development) to see if different components in a product occupy the same agreed space (Foster, 2013: 193).

Figure 5.13: Components that failed during testing process are downgraded for different use.

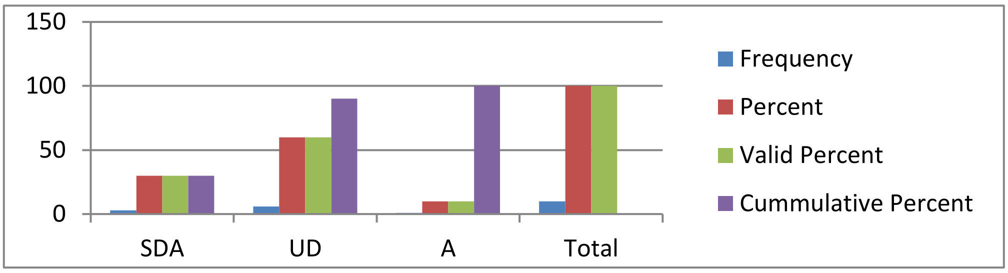

Figure 5.13 shows that 10% agree that components that fail during testing or assessment are downgraded and used later for different purposes, while it is not clear how the innovation and development team deals with completely failed components. 60% of the population were undecided and 30% disagreed.

The organisation needs to ensure that outputs that do not conform to their stated requirements are identified, segregated, and the cause of the problem is investigated and controlled to prevent unintended use or delivery to the customer or to the next working station for further processing (ISO 9001, 2015:16). The development team needs to pay attention to this area so that cost of quality is reduced.

Figure 5.14: Level of defect is recorded and measured.

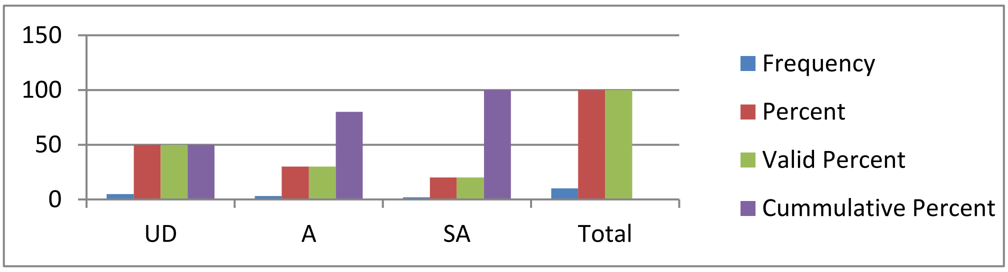

Figure 5.14 shows that half of the population 50% agrees that defects are recorded and analysed while none disagree and 50% is undecided about this practice.

The development team needs to analyse and evaluate data and information arising from the monitoring and measurement process and use the results to assess the degree of satisfaction in the innovation and development capabilities (ISO 9001, 2015:17). Analysis of failed products helps identify the root cause, in order to comprehend the problem, to avoid reoccurrence, and to evaluate financial losses, so that effective controls are established.

Figure 5.15: Components are subjected to evaluation before their use.

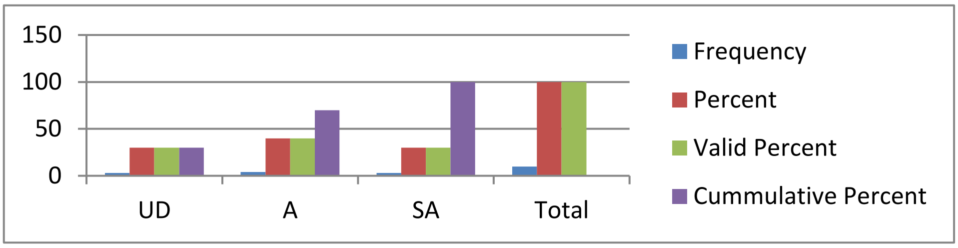

Figure 5.15 demonstrate that 70% agree that building components are subjected to engineering evaluation prior to their application, while the 30% of the population remains undecided about this function.

Engineering evaluation may depend on different tests such as heat transfer, vibration test, material stress calculations, and radiation resistance to determine the dynamic behavior of an identified component properties before being used (Foster, 2013:193). This evaluation helps the development team to gain confidence in product performance and its durability during its deployment.

Figure 5.16: Previous projects documents are always available when needed.

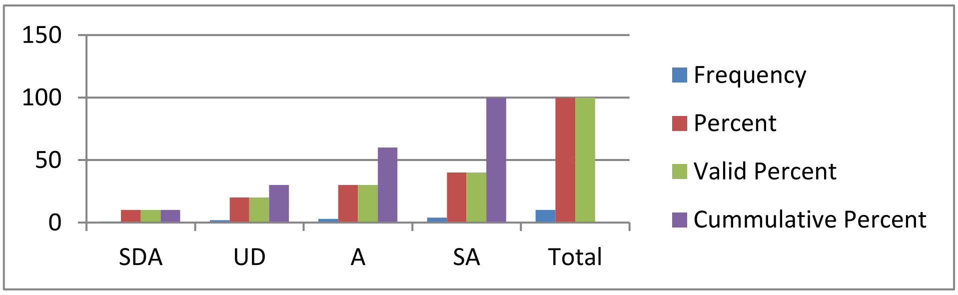

Figure 5.16 shows that 70% agree that information of the previous project is retrievable and can be used as a point of reference for current and future projects.

It is regarded as a systems engineer's responsibility to develop many of the project documents, including the System Engineering Management Plan (SEMP), requirements/specification documents, verification and validation documents, certification packages and other technical documentation, and this information need to be available (NASA/SP,2007: 3).

The need for record keeping arises and a proper system for this important function is essential.

Figure 5.17: Complaints are recorded and resolved immediately

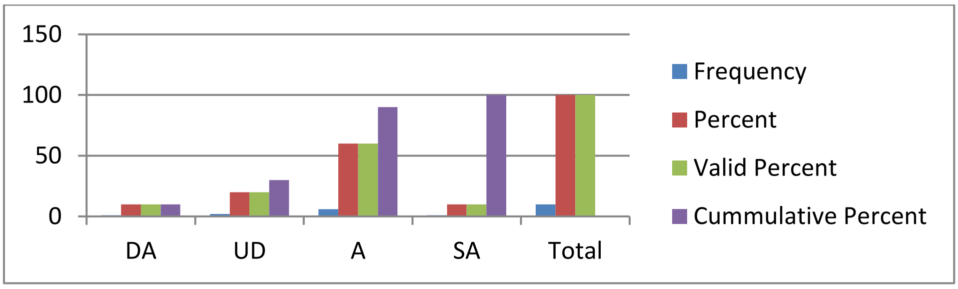

Figure 5.17's show that 70% believe that complaint and concerns are well taken careof, to the satisfaction of the concerned individual, while 30% does not support this view. The organization needs to determine and implement effective means of communicating. Complaints can be described as an internal customer complaint. The complaint or concern should be taken as an opportunity for improvement because a complaint or concern reveals how an individual feels or views things, and negative feeling has a ripple effect on how one performs.

Figure 5.18: Project tracking and monitoring process is practiced

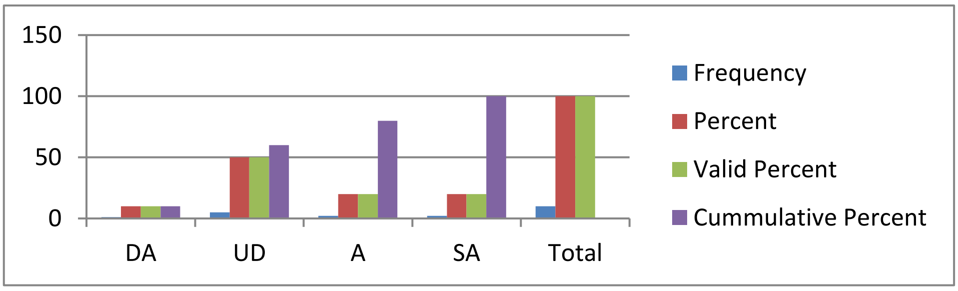

Figure 5.18 shows that 40% agree that project tracking and monitoring is practiced, while 50% is undecided. The picture painted suggests that tracking and monitoring is carried out to a certain degree and is not effective.

Progress of a project needs to be monitored to view its continuity so that process and product design improvement is captured and evaluated to improve the quality of an output. Six Sigma assessments are based on good data collected, and measurement system analysis (MSA), is a technique to ensure that the measurement system yields high-quality data. It is based on collected data design scorecards created to track design evolution (Gryna 2007:149).

Figure 5.19 Customer property is preserved as required

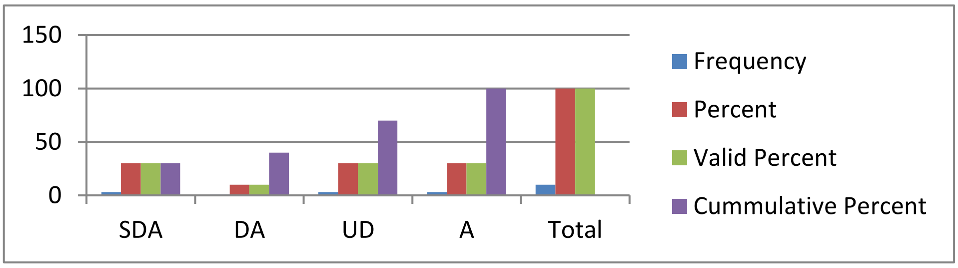

Figure 5.19 shows that 40% disagree that property of a customer is preserved, while 30% agree that customer property is well preserved, and 30% are undecided. The results demonstrate that customer property is not well looked after. It is a duty and the responsibility of the innovation and development team to exercise extra care to a property or information that belongs to a customer or external service provider, while it is under the organization’s control or being working on it or used (ISO 9001-2015:15).

Figure 5.20: Targets are set to improve the existing development process.

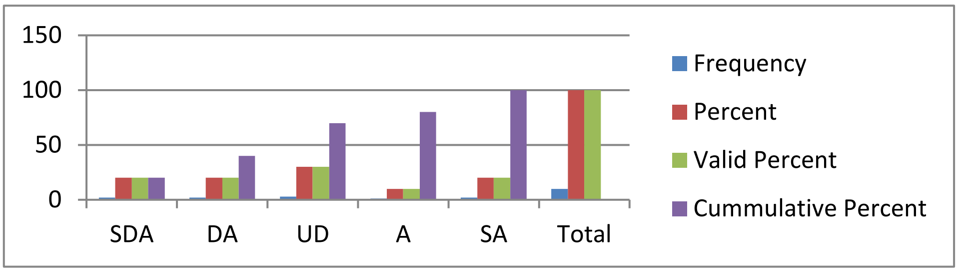

Figure 5.20 shows that 40% believe that set targets are not effectively communicated to the entire team, and that leaves the majority of people working without knowing how urgent the project at hand is, and how much time should be invested in that particular activity. Known the activity development timeframe is very important because it makes people focus on the main objective and prioritise activities appropriately.

The target or goal is viewed as the desired results to be achieved by certain group or individuals within a specified time frame as influenced by set objectives (Gryna et al., 2007:250). The daily or weekly innovation and development operational target need to be established at relevant functions and levels, and to be communicated and documented for future reference and for easy traceability when required (ISO 9001, 2015:5).

5.5.4 Objective Four: To identify main reasons that cause continual quality improvement to fail.

Figure 5.21: Work is always available.

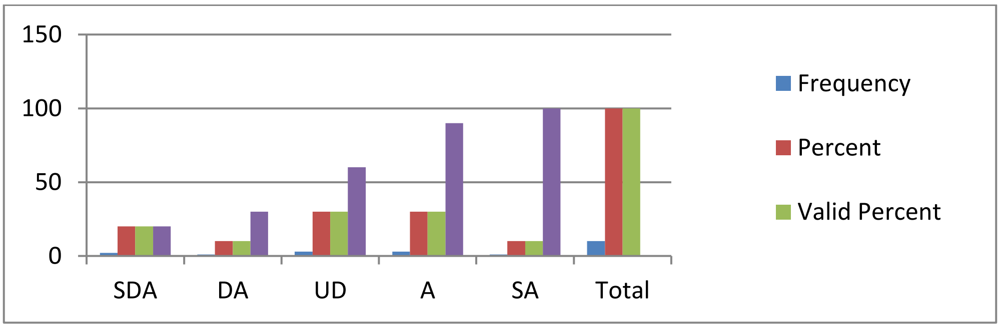

Figure 5.21: the 40% result reveals that activities within the innovation and development environment are not always planned ahead very well, and people or personnel sometimes wait longer than necessary for an activity to come up, and as the result find themselves doing any available work. This demonstrates the level at which innovation and development planning is executed with respect to daily or weekly activities.

Proper alignment of activities needs to be established so that people know in advance as far as a week or month ahead of upcoming work. leadership needs to take responsibility in making sure that activities are planned and resources relevant for such activities are provided for ease of execution.

Figure 5.22: Supplier evaluation is performed prior to business engagements

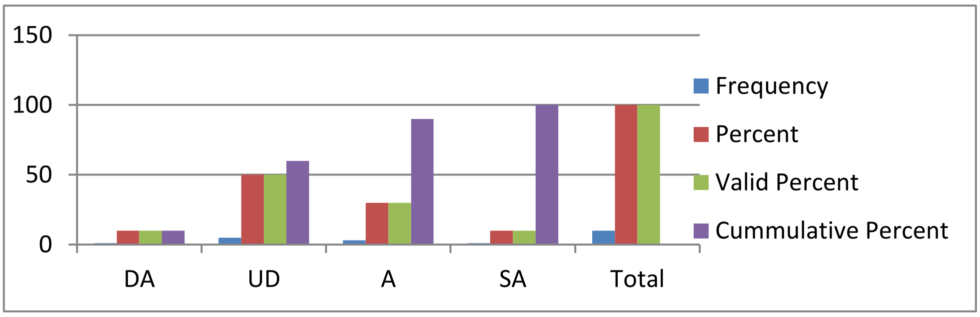

Figure 5.22 reveals that only 40% of the participant agree that supplier evaluation is carried out to make sure that the selected suppliers are capable of providing the required products/components or service of requested parameters and to control quality variation, where one item might be supplied by different suppliers. However, 50% of the sample is unaware of such activity. Supplier evaluation is viewed as tool or process that is used to differentiate and discriminate through performance evaluation between more than one supplier that is willing and capable of providing a service requested (Foster, 2013:246).

On many occasions, supplier evaluation is carried out on deliver;, here product certificates of compliance or laboratory results are accepted together with a product as a means certifying conformance. Hence it is the responsibility of an organisation to select suppliers based on their ability to supply a requested product with set specifications and parameters (ISO 9001, 2015:10).

Figure 5.23. Product testing is performed on all products and components

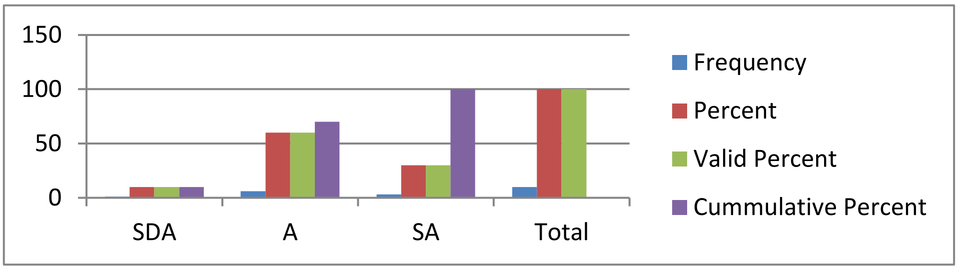

Figure 5.23. shows that 90% agree that performance appraisal of products is carried out on the premises and records of such activities are kept. The engineering product reliability testing process is carried out to give confidence to product guarantees during applications.

Engineering product reliability is viewed as a technique to be used in defining areas of improvement in the product being developed within innovation operations so that proper performance level outputs are certain before release (Gryna et al., 2007:335)

Figure 5.24: Supplier evaluation is time-consuming

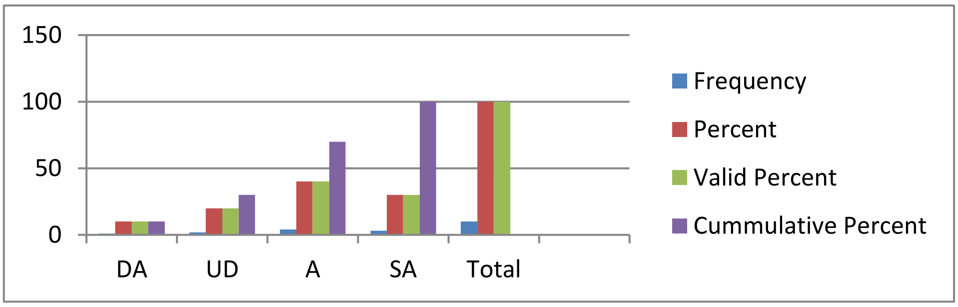

Figure 5.24 reveals that 70% agree that the supplier evaluation process consumes a lot of time and that it causes a delay in the development process,while 20% disagree with the statement. The main reason to perform supplier evaluation is to increase the pull of suppliers and to do away with sole supplier relationships, and to haveassurance of excellent service from suppliers whenever needed.

Many companies perform lengthy inspections before engaging suppliers and that involves longer visits and assessment of these assessments/programmes. It is viewed as supplier certification or qualification programmes if the focus is entirely on supplier delivery potential evaluation (Foster, 2013:246).

Figure 5.25: Fully equipped testing stations are used for product evaluation

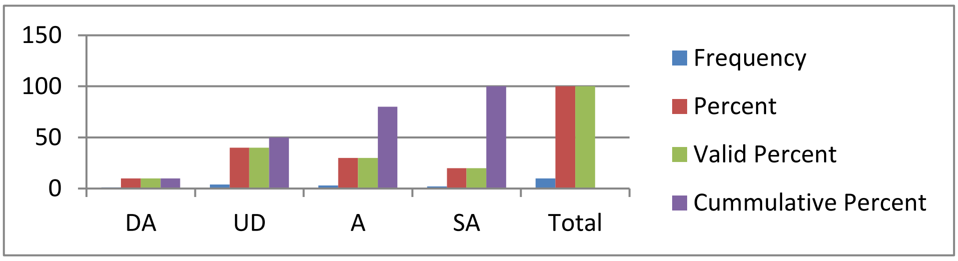

Figure 5.25 reveals that 50% of the participants agree that relevant resources such as fully equipped testing workstations have been provided by leadership (upper management), and resources provided are capable of conducting the required assessment on space components that are used to developed a nanosatellite.

The organization’s upper management is viewed as the key role player in providing relevant resources for all key operational activities, so that necessary equipment is available (Gryna, 2007:219). However, the 40% undecided response gives an indication that somewhere in the system there is percentage of personnel who disagree that testing equipment performance capabilities takes place.

Figure 5.26: Controls for outsourced activities are established

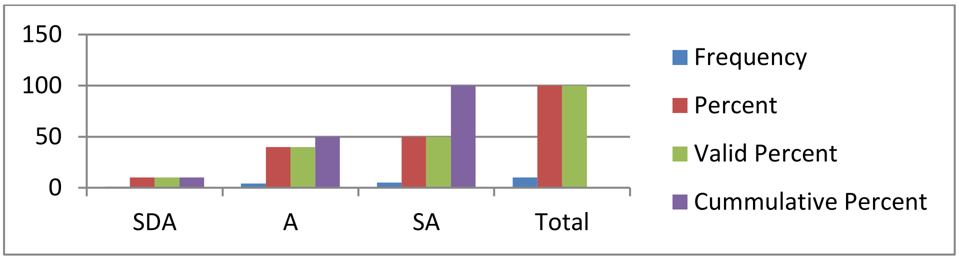

Figure 5.26 reveals that 90% agree that the innovation and development team takes full control with respect to quality of outsourced production activities. The organization needs to determine the control to be applied to externally provided processes or products and to take into consideration the potential impact of the externally provided processes or services on an innovation and development process (ISO 9001, 2015:13).

This helps the team to assess if the product complies/does not, with the set requirements. The organization being supplied must know its suppliers and work closely with to enhance supplier's performance through development and partnering and if this is present, the supplied organisation will have proper control over service or product being offered and quality inferior products won't be delivered to its premises (Foster, 2013:104)

5.5.5 Objective Five: To define and recommend an effective approach that can be utilised to sustain continual quality improvement.

Figure 5.27: Documented information is accessible to all personnel

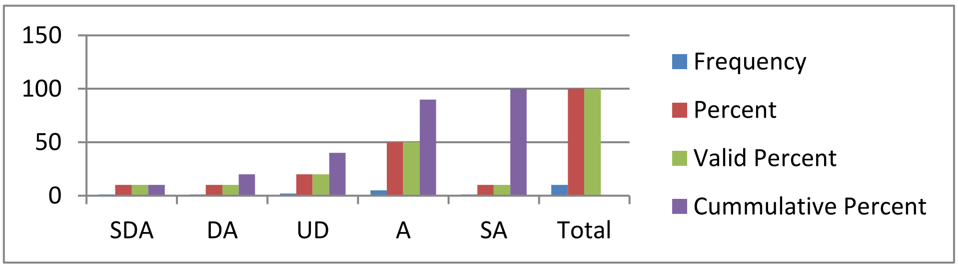

Figure 5.27: the results validate by 60% that documented information is accessible to some team members to a certain extent. The organization should make information related to innovation and development activities available to all participating individual.

Access to technical innovation and development information is one of the best tools that nanosatellite developers should have and be able to access effectively. The information revolution needs to be effectively deployed within the environment. When information is disseminated accordingly to teams it becomes easy to plan and control activities that were unthinkable a few decades ago (Gryna 2007 et al, 2007:12). However, highly classified and sensitive information should not be mistaken with design and development project history that needs to be accessible.

Figure 5.28: Logbooks are used to record machine usage

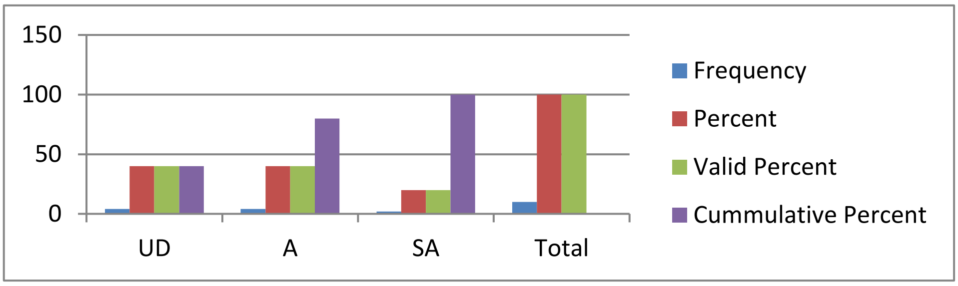

Figure 5.28: the 60% results reveal that sometimes logbooks are used to record machine/equipment usage. Machine usage should be recorded so that due mantainance is carried out whenever required to keep accuracy and performance levels to acceptable operational parameters. The use of uncalibrated machines may result in nonconforming outputs; therefore equipment use and maintainability needs to be monitored.

Maintainability is defined as the ability of an item or process to be retained or restored to an accepted range of performance; it is usually carried out using an approved procedure by a competent person (NASA/SP 2007:65).

Figure 5.29: Information is documented at all stages during operations

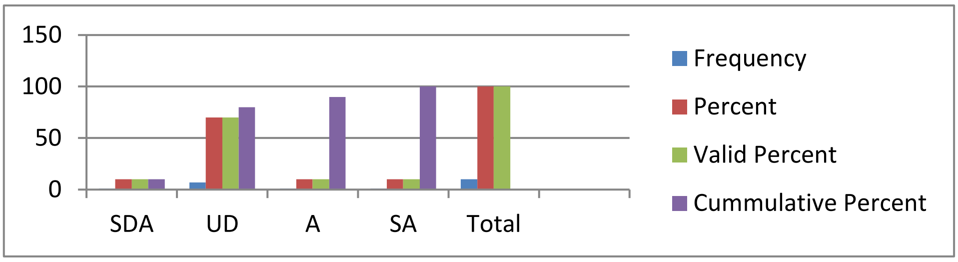

Figure 5.29: the results reveal by 70% that documentation is not consistently practiced. The recording and documenting of information would help an organization to to have a point of reference when something happens in future. The works orders or job cards may be used to register steps to follow or complete.

Figure 5.30: Space-qualified components are used for production

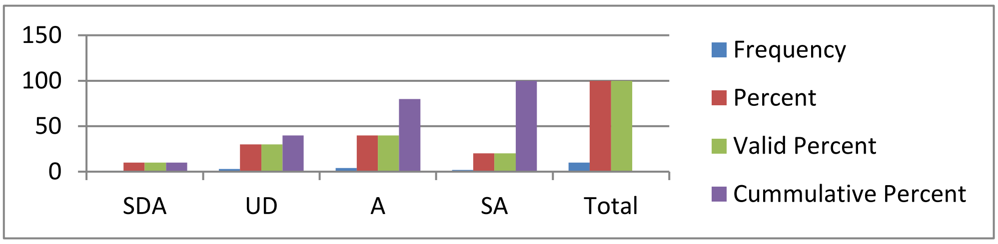

Figure 5.30: the results reveal by 60% that space qualified components are used to some degree to develop the nanosatellite. The reason for using such components is to operate effectively in space. A product applied on the ground could fail in space. A space heritage review (component evaluation) is carried out to qualify the application of the component to be space conditions (NASA/SP, 2007:76). However, 30% regard the activity as not being implemented, and awareness of this important factor is required.

5.5.6 Quantitative Reliability Testing

The quantitative information looked into or for inward consistence earlier being broke down to ensure that it speak to the real snap of the examination condition (see

Annexure H: Cronbach's Alpha Results). Here a dependability test was used by means of Cronbach's alpha and unwavering quality is seen as a degree to which quantitative results are predictable after some time and exact reorientation of the whole thought about gathering for a specific report (Golafshani, 2003:598). The Cronbach's alpha result validated to 0.5 that the collected data was reliable. The value for reliability is determine by the maturity of the innovation and development team as well as the volume of the participants and therefore, for this particular study an alpha value of 0.5 is considered as reliable.

5.6 SECTION A: QUALITATIVE DATA PRESENTATION AND ANALYSIS

5.6.1 INTRODUCTION

The study used interviews as an initial means of collecting data and also to gather fact-based information in verbal discussion. The research was carried in the nanosatellite innovation and development centre; here innovation and production complement or feed each other. Therefore, it is important to distinguish the difference between the two processes so that an understanding of the innovation and development team is drawn for the attention of the reader.

Production is the creation of output to stated specifications through utilization of inputs such as personnel experience, skills and fit for purpose resources such as equipment, machinery and material (Kotler et al. 2006). However, innovation is often viewed as the better application of personnel skills and competence to derive a better performing product with improved presentation or arrival (Maranville, 1992).

The research environment is typically governed and controlled by the influence of these process approaches. Therefore, for the researcher to be able to collect data effectively, a decision to conduct group interviews was taken. The nanosatellite population was divided into three groups, considering their individual departmental roles and responsibilities. The participant's roles and responsibilities were assigned and clearly outlined in the organogram.

To ensure confidentiality, the participants' departmental identity were coded as D1, D2, and D3. The researcher attended design briefing meeting sessions, academic talks and departmental seminars to gain more knowledge of the research environment. The main reason for such attendance, the researcher wanted to understand the research environment and afford the participants an opportunity to know him better and allow participants to ask as many questions as they could before the second phase of data collection (quantitative survey) was conducted; indeed questions were asked and the team showed interest in the second round of data collection.

The research objectives were used as the basis to create the survey interview. Here, six main open-ended questions and its eighteen sub-questions were created, which made twenty-four officially registered interviews questions. However, a number of unregistered interrogations were probed during the interview sessions to clarify ambiguous responses.Positive responses were captured from the research participants.

5.6.1.2 **Presentation of Qualitative Results and Analysis**

Interviews, were conducted on three different occasions, in different locations; interviews with engineers were held in Stellenbosch, and with operational management and top management were held in Bellville; that was influenced by the availability of the participants and constraints mentioned in chapter one of this documents (see section 1.14 RESEARCH CONSTRAINTS). The participants were sent a letter requesting a convenient date for their respective interview dates and the participants chose different days in different venues and an agreement between the two parties was drawn.

The interviews were carried out in a noise-free environment (in noise-controlled boardrooms on three different occasions). One set of questions was used for the interviews throughout qualitative data collection. A focus group interview was used, namely a group of individual who are assembled for a question-and-answer session, usually from six to nine participants (Latif and Dilshad, 2013 :192, citing Denscombe, 2007:115). This method was selected as the most suitable approach to explore attitudes, perceptions, feelings and ideas of the participants.

During the interview process, questions were asked anyone from the group was free to respond. The researcher made use of a Samsung J3/6-2016 cellphone to capture voice interaction between the researcher and the interviewees. The audio-visual data was later transcribed so that it could be easily analysed.

The voice / video clip is available on request for the top management only as far as confidentiality is concerned. The transcripts were sorted into main–themes and subthemes for ease of analysis. These are discussed below and supported by literature where necessary.

5.6.1.3 **Themes and Participants**

The transcribed information was streamlined into thirteen main themes, with each had two to three subthemes which equated to a total number of 33 subthemes. The themes were derived from the research objectives, the answers provided by interviewee and the research questions. Therefore 46 themes in total were traversed and supported by the relevant literature where possible. Table 5.4 presents the main themes as well as their respective subthemes.

Table 5.4: The Main Themes and Sub-themes.

Main – Themes	Sub - Themes
A. Main involvement	Participants description provided
1. Continuous improvement	Lean Cost Reduction Relevant Experience Compatibility Material
2. Production Planning	Customer Expectations Life Development Cost Involvement
3. Process Flexibility	Lean Time Current Policy Responsive Environment
4. Components Segregation	Non-conforming outputs Documentation
5. Information Control	Development Process Effective Communication
6. Product Acceptance	Conformance Test Process Constance
7. Process Examination	Design Reviews Identification Engineering Approach
8. Information Preservation	Established Document System Engineering Plan
9. Lean Effectiveness	Product Handling Discipline Specific Movement of people or components.
10. Personnel Competence	Outsourced Skills Capacity vs Capability
11. Process Evaluation	Procedural System Supplier Evaluation Acceptance Criteria
12. Monitor and Measure	Qualification Test Management Tools
13. Process Sustainability	Test Results Certified Environment

5.6.4 Status of the participants' responses and theme analysis.

In an attempt to ensure that all respondents were from CPUT F'SATI, a question related to their main roles and responsibilities was asked and the following was learned.

Table 5.6.2 Main involvement

The participants were all from F'SATI and in order to determine each participant's main responsibility and authority as well as their direct involvement, a question related to such a fact-finding drive was asked during to the interview sessions. Table 5.5 presents the fact-based evidence in quantitative format

Table 5.5 Main involvement

Question: Tell me about your main involvement in this environment?	
Theme	Interview findings
Main involvement	70% of the population were involved in innovation activities, design and development, product performance evaluation, product handling, and development and outsourcing of space-qualified components. 20% managed operations with respect to development activities, including the execution of procurement, while 10% oversaw the complete operation, and hoped to spin out the innovation hub as a business enterprise in the near future.

The responses gave a thorough indication that responsibilities and authority were assigned to each individual and were understood. They also reveal that leadership ensured that relevant roles, responsibilities, and authority for different personnel were assigned according to individual competence, and were communicated throughout the entire organisation (ISO9001, 2015:4).

5.6.4.1 Theme 1: Continuous Improvement

In order for any organization to move from one point of aspiration to another, relevant tools to facilitate such move are required. Continuous improvement is viewed as the best tool for positive change. Continuous improvement functions typically request increased levels of employee involvement and often attempts to empower the entire team to participate willingly for the benefit of the operations (McLean and Antony, 2013:373). The following table presents the participants' views with respect to the research objective in question.

In an attempt to establish the views of the respondents with respect to the application of lean-cost reduction principles, the following question and sub-themes were developed from the participants' feedback.

Table 5.6.: Lean cost reduction, relevant experience and compatible material.

Theme Question: Tell me about the different techniques that are used to reduce cost and waste within the nanosatellite development process.	
Subthemes	**Interview Findings**
Lean-Cost Reduction	Operations personnel and engineers stated that different quotes are compared, and approved suppliers are used. The components are subjected to evaluation prior being assembled. Tasks are allocated to individual's whose competence is known. However, leadership felt that a high cost is incurred based on poor human capacity competency level.
Relevant experience	Engineers stated that development activities are distributed to personnel with the right competence. However, operations personnel felt that certain regulations need to be considered and leadership consistently maintains that the majority of the entire team is still inexperienced, therefore level of expenditure is high based on that.
Compatible Material	The Eighty percent of Engineers and leadership are of the opinion that space qualified components (off-the-shelf's components or space heritage components - COTS) are used for development activities. The operations management referred answers to Engineers.

The following quotations are provided as evidence of the participants responses to the objective in question and participants are coded as mentioned above.

D1 the establishment of different quotes from different approved (recognised) suppliers, selection of best price for quality components, consideration of suppliers lead time against the project deadlines, distribution of manpower in relevant departments, ordering of required components for the project at hand and provision of storage for the defective (components that fail during testing process) to be used in similar project as secondary component.

D2 - first of all we are public funded, we have to follow certain regulations in terms of procurement - we need to compare the various costs of options and way that with a suitable of the project [asic] or service that we are pursuing. The Cape Peninsula University guides us to that process.

D3 - The human capacity is our biggest cost, in any way to make that more effectively is to make the learning experience more effectively in innovation environment, but we have a long way... the nanosatellite community is an open community, we share information. So on component base engineers will tell you more about the best practices in terms of which components to use. We tend to use off-the-shelf components, there are more robust ones than others and so initial when we start a project we look at the material to reduce cost and we look at the critical ones that has heritage in space. I think that is a good line of research to assess off-the-shelf components for radiation hardness and we don't have all the answers. We use the skills to determine what works before and what did not work. We use experience more than anything that can be utilised.

Summary of findings based on the exact quotations is provided as follows

Lean-cost reduction: The operations personnel and engineer samples believed that lean principles are applied to reduce and control possible cost within this innovation technological investment. Cost control is viewed as a key issue in major investment project initiatives (Olsson, 2015:84). The operations personnel believe that less experienced personnel contribute to increasing the level of cost and waste. Waste in the context of lean principles includes all activities and production of non-conforming output that does not add value to a product or service as it viewed from the customer perspective (Wickramasinghe and Wickramasinghe, 2017:532).

Relevant experience: The engineers believed that responsibilities are assigned to knowledgeable and experienced employees and personnel knowledge is acknowledged at all times. Personnel knowledge is recognized as a corporate asset and, like any corporate asset, it should be managed and used accordingly (Bogdanowics and Bailey, 2002:126). Operations personnel maintained that regulations governed the processes, so everything happened under procedural requirements and under controlled conditions; the leadership remained assertive that the majority of the team is inexperienced, therefore a portion of waste is certainly created during innovation and development activities.

Compatible Material: Engineers and leadership are of the opinion that space compatible components or off-the-shelf components are used during innovation and development process. The off-the-shelf components are regarded as hardware or software that has the ability to withstand the harsh space conditions (NASA/SP, 2007:76).

Conclusion: It seems that a well-established development process approach is in place. However, the employees' level of competence and their experience remain the burning issue that requires attention for the innovation and development team, so that the level of cost of quality is maintained at minimum level.

5.6.4.2 Theme 2: Production Planning

Production planning remains a crucial element in the innovation and development environment,as it helps in allocation of responsibilitie to relevant individual personnel considering technical competence level of sequence.Innovation production planning should be initiated at the beginning of the project generation phase for the project at hand, so that available resources or competences are deployed accordingly (NASA/SP, 2007:79).

Pproduction planning helps the organization to select the most relevant and effective process approach, which will assist in ease of process management. A process approach has the ability to control innovation and development interdependencies among the processes of the system (ISO 9001, 2015: VII)

In an attempt to establish the views of the respondents with respect to production planning, the following question and sub-themes were developed from the participants' feedback.

Table 5.7: Customer Expectations, Life Development, and Cost Involvement.

Theme Question: Tell me about the process followed to begin any new space-related project:	
Subthemes	**Interview Findings**
Customer Expectations	The engineers and operations staff stated that customer needs are evaluated and properly discussed before committing to deliver an expeted reults, to achieve a satisfactory agreement. leadership felt that the space environment should not be clustered with things that might not add value, because they delay the development process. There is an identified gap, the lack of a product life development approach.
Life Development	The engineers and leadership stated that product life development is not where it should be. Operations staff felt that projects are accepted or taken on the basis of expiration with the aim of addressing a technological gap in the space environment. Government incentives are considered or recognised.
Cost Involvement	The engineers and leadership group stated that resources such as skills and resource capability, and more work-in-progress to create some balance in reducing cost are lacking. Operations personnel indicated that government incentives are utilised to support development phase management cost.

The following quotations are provided as evidence of the participants' responses to the objective in question, and participants are coded as mentioned above.

D1 - The evaluation of customer expectations against the resource available (Including project timeframes) - resources such as skills capability, the work environment, the cost involved, availability of required components for the project for both national and international suppliers, and relevant work experience within the current team.

D2 - Needs are always identified which is in line with government incentives – if there is a larger area identified by the government or there is an area of expiration that we think we can make a contribution – if there are development needs within the scientific world, we then contribute in addressing that particular need.

D3 - Product life development is one thing that is lacking. Documentation control has never been done, but now we are doing it more systematically…that slows the production/development process a bit and we don't want to bombard the development process with paperwork. Asking you a question is that you are the first in line of few systems engineers or industrial engineering researcher that we have to create some balance in reducing cost, but not compromising the quality of development process ultimately. It is still expensive and we don’t want to cluster space with things that we not sure will be of value.

Summary of findings based on the exact quotations:

Customer Expectations: Engineers and operations staff indicated that customers’ or interested parties’ specifications are taken as the primary matter to be looked at in all cases. The needs and expectation of an interested party must be monitored, understood and reviewed on a regular basis, to identify any possible challenges that can be encountered during project execution (ISO 9001, 2015:2)

Life Development: Engineers and leadership felt that the current life development plan does not necessary address all the needs. Hence a need for a new or revised production system is required. Therefore, to become leaner and to create new labour-intensive production models that have potential to generate distinctive internal process capabilities for survival and growth, a revision of the current process is required (Wickramasinghe et al. 2017:532). Then operations staff felt that projects are taken on the basis of explorations, considering the technological gap identifiedwhich addresses the needs.

Cost Involvement: Engineers and leadership indicated that cost is managed, because skills development for personnel performing work that affects the quality of an output is underway through sharing of innovation skills; however at the moment the organisation is suffering. Innovation is linked to skills – as the level of available skills increases, it will affect the ability of personnel to innovate and take advantageof the current technology transfer and adoption (Jack et al., 2013:272)

Conclusion: It seems that expectations and cost involvement of customers or interested parties is noted and carried out by personnel, whose level of competencyis still under development. However, full support based on knowledge-sharing remains a strong point within this environment.

5.6.4.3 Theme 3: Process Flexibility

Flexibility of a process is the ability to deal with any adhoc activities that might arise during the innovation and development process. For one to achieve flexibility, a streamlined process needs to be established. The literature provides evidence that lean production create a well streamlined, high-quality system that provides products and services with increased productivity, reduce cost and possibly shortened delivery lead times (Wickramasinghe et al. 2017:531)

In an attempt to establish the views of the respondents with respect to process flexibility within the research environment, the following question and sub-themes were established from the participants' feedback.

Table 5.8: Lead times, current policy and responsive environment.

Theme Question: What challenges did you face during the procument process?	
Subthemes	**Interview Findings**
Lead Times	Engineers stated that lengthy supplier's lead times are stumbling blocks. However, operations staff blamed it on internal time constraints and leadership believed that the current innovation timelines are not suitable for the existing university procurement procedures.
Current Policy	Engineers and operations personnel stated that current procurement policy contributes less to the demand of innovation and development activities. Leadership believed that the current procurement policy is not a hundred percent compatible with the need of this environment.
Responsive Environment	Engineers and leadership stated that the current development layout was able to respond to the needs of the development team. However, the procurement system tended to suffocate all the effort made. The operations personnel were of the view that the procurement policy was generic for local purchasing and did not cater for urgent demands or quick production turnaround activities.

The following quotations are provided as evidence of the participants responses to the objective in question, and participants are coded as mentioned above.

D1 - The challenges that I (we) face during the procument process lead time the F'SATI CPUT procument process has many internal red tapes. It is difficult to get one single quote through the procument system, sometimes the quotation get lost during the process and when it is discovered it is already expired and that calls for re-quote, our suppliers does not always stick to their lead time frames. “The procument process is really wobbling it this function set the tone for smooth development activities, without it being stable everything else delays”.

D2 - Time constraint is the biggest challenge and getting payment and invoice done is another burning issue. Our work is a much specialised environment and the current procument process is not fully effective, the process was design based for general procurement activities like buying stationary. It is normally difficult to get supplier who can provide what we are looking for, more especially within South Africa and based on that we are forced to look outside the country, and once we do that we are then subjected to a lot of challenges such as currency and we need to declare the product end user which we don’t usually do when we buy local.

D3 - We are trying to things that the environment is not design for, so if you talk about the production of product, a lot of product in our system of development, the university need to take research into another level , and then that need to be handed over to more responsive environment – quick turnaround environment. The procument process within the university is set up for academic research which has longer timelines. For instance that is the biggest challenge and we’ve too much dynamics requirements of time lines, which are not suitable for university systems. It is a challenge. I don’t blame them they are not design for production activities.

Summary of findings based on the quotations:

Lead Times: Engineers stated that lengthy supplier lead times become the major issue, in delivering the project to the clients. Therefore a better planning approach from the development point of view is needed so that goods are delivered in accordance with the arrangements. The planned lead time determines the probability that a batch will be available timeously from supplier to supplied (Enns and Suwanruji, 2003:95).

Operations personnel blame time constraint and the innovation and development team needs to factor in these possible delays that can surface during the initial planning, because time constraints are viewed as an external performance factor that a supply company cannot really control it (Bartezzaghi, Spina, and Verganti, 1994:5). However, operations personnel view this challenge as the improper alignment of existing procedure to the set environment.

Current Policy: Engineers and operations personnel believed that the current procurement policy does not really address the need for this kind of urgent turnaround delivery time range. The management team needs to establish, implement and maintain a policy that is appropriate to all the purposes of the organization including quick and sustained delivery turnaround (ISO9001, 2015: 4), while leadership stated that the current policy is not compatible to carry such, quick turnaround activities for CubeSat development. The existing procurement policy was developed and refined for long lead times and it was doing well until the existence of innovation and development of CubeSats. Every industry is defined by the type of final entity that it produces within the industry it occupies for its clients or market within set of requirements (Marterk and Chen, 2016:502).

Responsive Environment: Engineers and leadership believed that the current innovation and development structure makes the innovation process more challenging with respect to procurement issues and a positive shift is required to create some balance. The most tangible measure by firms may be compared to current activities that are underway to achieve stated requirement and to be able to respond to its product end-users (Martek and Chen, 2016: 501). The operations personnel felt that the current procurement policy was initially designed and developed for more generic and local procurement activities and therefore it struggles to respond to specialised components, overseas bought components.

Conclusion: It seems that development environment did its best to be productive. However, it became a challenge when it came to procurement activities, which are influenced by the institutional regulations and a relevant shift to maintain the internal relationship is required.

5.6.4.4 Theme 4: Components Segregation

The product or components that do not conform to specifications are regarded as non-conforming output and effective means to deal with such has to be determined by the innovation and development organisation. Therefore, non-conforming output needs to be identified, segregated, analysed and reworked where possible or disposed as necessary to prevent their unintended use or delivery to the client or next development phase within the assembl process (ISO 9001, 2015:16).

In an attempt to establish the views of the respondents with respect to the ways in which nonconforming output are dealt with, the following question was asked and sub-themes developed from the participants' feedback.

Table 5.9: Non-Conforming Output and Documentation

Theme Question: How do you deal with scrapped and failed product?	
Subthemes	**Interview Findings**
Non-Conforming Output	Engineers and leadership stated that product that failed specified requirements were identified, segregated and captured in a development system for later evaluation of the cause. Operations personnel maintained that expensive products do not fail, only micro element fail.
Documentation	Engineers and leadership stated that a register was established to record non-conforming output, for the benefit of building institutional memory. However, operations personnel believed that documented information is evaluated and causes for failure are analysed.

The following quotations are provided as evidence of the participants' responses to the objective in question and participants are coded as mentioned above.

D1 - The failed or scrap components are kept on the non-conformance zone and their status level is registered on the system. The failed components are downgraded from Rev A to Rev B and are used for other different related projects.

D2- I don't think we ever experience or encounter a failure really, because we are dealing with the most expensive material, we may have encountered a failure on micro components (small components) as for the high expensive material we do an extensive research before we procure the components – to make sure that all areas of concern are considered – we will look at the existing literature to see if anyone has ever used similar product or component, we also check if our components are space qualified.

D3 - We capture it …….I think we should capture it. I think the guys capture it as a task. It needs to be documented of course, you must build up the institutional memory because engineers and students come and go. We train them and they move, so you don't want to make the same mistakes every time. At least it needs to be documented and I think the guys are doing that. I am not sure if we had many of those. If so they make some improvement to increase the amplifier. I don't think it is a question that it does not work at all. You probably keep components that work better, remember if you design something, you design it according to certain specifications, and you don't use components that you know is not going to work. You design will show at least if it will work or not. Usually the product does work but you can further optimise it and as new components coming in and an old component get redundant.

Summary of findings based on the quotations:

Non-Conforming Output: Engineers and leadership collectively confirmed that non-conforming outputs were reworked, downgraded and recorded and the reworked product was then used for a different cause to avoid waste or increase in the cost of quality. Lean transformation could be implemented in order to identify and eliminate waste and subsequently improve the process; the key in mastering the lean concept is to understand the level of waste created which is fundamental (Kalong and Yusof, 2016: 341). Operations personnel stated that major components do not fail because meticulous planning is carried out prior work being done, while failure may happen to micro-elements, which is not that expensive. The waste of micro-elements bears hidden costs that require reworking, but are commonly viewed as normal and acceptable in an innovation and development situation (Kalong and Yusof, 2016:341-342).

Documentation: The engineers and leadership stated that documented information was kept safe as it was used to build up institutional memory (documented knowledge). Innovation and developers come and go, but documented organisational knowledge will remain behind to be used by the current and upcoming developers.

Conclusion: it seems that a process for handling of non-conformance has been established and a history of non-conformance has been kept. However, it was not clear if the recorded non-conformities were analysed in order to capture the root cause and for the determination of the level of waste.

5.6.4.5 Theme 5: Information Control

To minimise the level of waste in an innovation and development environment, information related to innovation and development activities requires intense controls. The way in which the information is distributed, accessed and retrieved among the developing teams needs to be addressed accordingly so that every participating individual contributes to managing the innovation information (ISO 9001, 2015:9). Poor management of information lead to the loss of information or redirection to wrong hands, possibly resulting in rumours, which can create resistance to change, and also tend to increase negativity (Elving, 2005:129)

In an attempt to establish the views of the respondents with respect to the way in which information is controlled, the following question and sub-themes were developed from the participants' feedback.

Table 5.10: Developed process and effective communication

Theme Question: Tell me about the ways in which new information is controlled and how is it used to improve the development process	
Subthemes	**Interview Findings**
Developed Process	Engineers and operations personnel stated that newly developed information was kept in accordance with the established procedure; means to access it were given to all involved parties. It was then integrated into existing design and development knowledge. Process to control outgoing information has been established. Leadership felt that new products coming from supplier needed to be delivered with conformance certificate (CoCs) or through utilization of performance test processes.

Effective Communication	Leadership and operations personnel stated that a ticketing system was used as means of communication amongst the development teams. The ticketing system was found to be effective for production activities, while engineers believed that regular meetings for design review feedback were held and group participation was strongly encouraged. These sessions were also used as an opportunity for learning. However, direct communication within the development/innovation teams was found not to be effective.

The following quotations are provided as evidence of the participants' response to the objective in question and participants are coded as mentioned above.

D1 - The process that deals with the new information has been developed, access control has been established and all relevant parties are allowed to access the information at any given time, the new information is then changed from Word document to PDF version and archived to our computerised system. The new information is then integrated with current information and utilised to progress the development process.

D2 - Within F'SATI itself probable it's where we do it the most, we engage with each other to make everyone aware of the new development. We are in constant communication, as somebody deals with something that person can learn or pick up a problem and that problem is then immediately shared within the group and thesharing of information happens through meeting,email and through ticketing system,here the information disseminated and everybody can make a contribution and the information get documented for future reference.

D3 - The acceptance testing that is done; ultimately we take full responsibility for the radios that goes out. We subcontracted to ETSI the production process. They have their own general process with their sub-suppliers, we don't do that anymore. They got their own sub-contractors to do PC board, for instance if we get the radio we do conformance testing which is our acceptance test in our own lab... which is thermo test. It could be physically ETSI but we jointly sign off on the test and I think Leon and Charl showed you the acceptance test that we've used. That is something that we've recognised and automated to human error input into the process. At least that is formal on our product. We do acceptance test and performance test.

Summary of findings based on the quotations:

Developed Process: Engineers and operations personnel stated that newly developed innovation information was kept in accordance with the established procedure and distributed throughout the flat structure of the organization, which form part of the organisational knowledge. It was the duty of the organization to determine knowledge relevant to its course and to devise means by which knowledge could be documented, maintained and made accessible as necessary (ISO9001, 2015:7). This knowledge was generally specific to innovation activities and was mostly gained from research investigations, product testing, evaluation results, and through experience.

Effective Communication: Leadership and operations personnel stated that a ticketing system was used as means of communication amongst the development teams. This percentage response suggests that communication was not effective as it should be. The success of a business depends on the manner in which different departments communicate amongst each other to disseminate knowledge to different operational levels. Malmelin (2007:298) argues that the success of most organizations today depends in the manner in which personnel interact amongst each other with regard to business operations as well with other relevant business stakeholders with respect to work in progress.

Conclusion: it seems that information is controlled, as far as it is kept as the organisational knowledge. However, the level at which teams communicate amongst each other with respect to innovation and development work in progress is viewed in a negative light based on the participants' responses reviewed.

5.6.4.6 Theme 6: Product Acceptance

The acceptance process presents an opportunity for the receiving organization to identify any discrepancies that might jeopardise the quality of an end or built product. The developing organization needs to create suitable means of checking or inspecting to ensure that externally provided product or process conforms to the stated requirements (ISO9001, 2015:13). A good product acceptance criteria process will assist in making sure that superior components are procured and delivered so that quality is built into a product.

In an attempt to establish the views of the respondents with respect to product acceptance criteria used within the research environment, the following question and sub-themes were developed from the participants' feedback.

Table 5.11: Conformance Test and Process Consistence.

Theme Question: Tell me about the process followed in accepting a product from internal and external suppliers,	
Subthemes	**Interview Findings**
Conformance Test	Engineers and leadership are of the opinion that relevant assessment tests are carried out to gauge if the component parameters in magnitude, model and efficiency, are exactly the same as stated in the purchased order or specification.
Process Consistence	Operations personnel mentioned that the process of accepting components from suppliers is sometimes carried out haphazardly, because sometimes products are delivered to wrong stations by the suppliers. Leadership and engineers accepted the conditions as being acceptable.

The following quotation is provided as evidence of the participants' response to the objective in question and participants are coded as mentioned above.

D1 - The Space Mission Components are so crucial; therefore our suppliers always deliver goods with Test Report Documentation. F'SATI CPUT accepts products or component based on availability of the test report and against the purchased order through delivery note. The F'SATI CPUT has outsourced skilled personnel to work on site so that they may read and interpret the product test report provided and make informed decision whether to accept or reject the delivered component.

D2 - it is not always very consistent, when we order a product an end user is specified, at time of delivery the end user will accept but if the end user specified is not available someone will accept on behalf. Our supplier do use couriers to deliver product and companies sometimes will require upfront payment upon receipt and we cannot accommodate that – the delivery truck will return back with the product until the financial arrangement has been made – because CPUT is very large entity with various entries - from time to time the product/part get delivered at the wrong point and we have to go all out looking for that components until we find it – more especially if it is of high cost.

D3 – performance assessment are carried out as per the innovation and development requirements.the Product is delivered the reception and whoever is available can still accept it and acknowledge the delivery by signed the corrierswabil.The institution is very big but current suppler know our receiving points

Summary of findings based on the quotations

Conformance Tests: Engineers and leadership argue that product verification assessment is carried out within the innovation and development process. Product assessment verification is viewed as a process to assess developed or under-development products to see if they conform to specifications stated by the customer (NASA Procedural Requirements NPR 7123.A, 2007: 23)

Process Consistency: Engineers and leadership confirm that the use of acceptance criteria such conformance certificates and assessment test records per product or component being delivered confirm controls. However, operations personnel state clearly that the process is not effective because the product is sometimes received at any point within the institution and that questions the effectiveness of how outsourced products are managed. The product destination, acceptance requirements and the owner of the products need to be outlined in purchasing information and the supplier needs to comply with the stated requirements (NASA Procedural Requirements NPR 7123.A, 2007: 90)

Conclusion: It seems that product acceptance requirements need to be clearly stated to the suppliers, and internal product verification processes are carried out in accordance with the requirements, and that it works well for the current period.

5.6.4.7 Theme 7: Process Examination

The importance of process or product evaluation in this environment is very significant, so that out-of-specification units are identified and dealt with in a manner that is acceptable. To achieve quality end product, the process owner is required to review the current development process through the use of concurrent engineering principles. The use of concurrent engineering principles within process design is a systematic approach that responds to stated specification or expectation and can embody team values within the corporation (NASA/SP, 2007:234).

In an attempt to establish the views of the respondents with respect to the process examination used within the innovation and development team, the following question and sub-themes were developed from the participants' feedback.

Table 5.12: Design Reviews, Identification and Systems Engineering Approach.

Theme Question: Tell me about the controls that are in place to preserve design review decisions:	
Subthemes	**Interview Findings**
Design Reviews	Engineers and operations personnel stated that development progress is monitored to check consistency with the stated requirements. However, leadership felt that an established plan is followed to maintain consistency within the development activities.
Identification	Engineers and operations staff stated that suitable identification is established in ensuring conformity of product being developed. They confirmed that a serialised identity number is issued to a revised component or programme.
Engineering Approach	Engineers and operations staff mentioned that an effective engineering process approach is in place. However, leadership felt that even though the approach is established, a lot still needs to done to establish a complete systems engineering environment.

The following quotation is provided as evidence of the participants' response to the objective in question and participants are coded as mentioned above.

D1 - the design review minutes are captured in the system and decision made are communicated to the relevant teams and utilised to progress the development process of that particular projects.

D2 - For every review /changes the information get communicated to all parties that are involved –documentation with reference unique serialised number is given to that particular product – all previous alterations are available to system document.

D3 - On there, we follow the system engineering approach that is on the SAMP, that I think you have access on it, we did not formally follow that on ZACUBE 1. We have the PDRs, SDRs and final review. We've had a PDR now with ZACUBE2 and all discrepancies have been raised, we had a workshop and discrepancies were dealt with afterwards the file was updated and it is a leaving document...... it is not as if you done PDR then you can't change anything. There is a certainty in how we are looking at fixing things. We are not there yet. We follow a system engineering management plan, that I would assume you have access to it for your thesis.

Summary of findings based on the exact quotations:

Design Reviews: Engineers and operations staff state that design reviews are carried out to ensure achievement of the stated innovation and development requirements. The main purpose of design reviews meetings is to improve work in progress or an existing plan. The design reviews focus on the design work and are informed by the manufacturing and operations department of the developing organization, so that discrepancies are captured and dealt with (Olivia et al. 2014: 249). The review decisions need to be carefully incorporated into the existing development plan to pursue effective and continuous improvement as well as the objective at hand.

Identification: Engineers and operations staff specified that after design review, the details of the previous plan are changed. A new serialised identity is created and developers work with the latest revised and updated information; the obsoleteversion is then archived for future reference. The innovation and development staffneed torecord and effectively communicate these changes to the entire team, so that all team members have the current information with a correct identification (ISO 9001, 2015:11).

Systems Engineering Approach: Engineers and operations staff stated that controls with respect to design information preservation had been put into place and managed through a systems engineering approach. The systems engineering approach is the discipline of engineering systems that are quantifiable, recursive, iterative and repeatable for development operations within the innovation development process approach (NASA/SP, 2007:276).

Conclusion: Based on respondent feedback, it seems that process evaluation within the nanosatellite development environment is well organised. However, a few areas still need more attention to effectively improve the process.

5.6.4.8 Theme 8: Information Preservation

The development of nanosatellites is carried out in an academic set-up, therefore development and student engineers come and go and information that is used to develop nanosatellites need to be preserved so that reference for future development becomes possible. There are two sets of information available in this field at CPUT F'SATI: industry sensitive information (ISI) and design and development information (D&DI). The design and development information needs to be effectively shared among teams, so that they may advance their knowledge as well as innovation and developments skills, but in a controlled manner. The system that is used to control the information may also at some point challenge the controls and obviously cause additional disruptions and possibilities for change within the process approach (Anthony and Stablein, 2015:208).

In an attempt to establish the views of the respondents with respect to the ways in which information is preserved within the innovation and development team, the following question and sub-themes were developed from the participants' feedback.

Table 5.13: Established Documents and Systems Engineering Plan.

Theme Question: How are design review decisions incorporated into the reviewed work-in-progress?	
Subthemes	**Interview Findings**
Established Documents	Engineers and operations staff confirmed that decisions taken during the review meeting are recorded on Engineering Change Documents. Once the change information is registered, then the initial version becomes obsolete. However, leadership felt that an established system approach ensured documentation of new informationd.
Systems Engineering Plan	The entire population (engineers, operations personnel and leadership) collectively stated that an established management plan was utilised and it worked well so far.

The following quotation is provided as evidence of the participants' response to the objective in question and participants are coded as mentioned above.

D1 - The design review decisions are registered in the established document called Engineering Change Document, once the changes are registered in the change document, the first plan become obsolete and the second revised document is then named revision B (Rev B). The Rev B is then used to further the development process.
D2 - the design review decisions are registered in the established document.
D3 - we follow a system engineering management plan, that I would assume you have access to it for your thesis.

Summary of findings based on the exact quotations:

Established Documents: Engineers and operations staff confirmed the use of a design review register to record changes or decisions taken. These reviews were carried out to test if the stated requirements are consistently met and there are no major challenges ahead. In order to achieve stated requirements and improved performance, reviews of the first plan needs to be carried out to confirm the achievement of the initially stated product performance or specification (Santin, Tweed, Zapata, Lancaster, 2014:246)

Systems Engineering Plan: The entire population (engineers, operations personnel and leadership) confirmed that an approved development plan model was fully utilised by the all-inclusive developing teams, and good process performance has been witnessed, while a system engineering approach is observed as effective. The system engineering model gives a decision maker better understanding of a complex process or system within the operation of choice in order to be able to predict performance under varying circumstances presented by the situation (Aslam and Amos, 2015:291).

Conclusion: from the collected participant's responses, it seems that information is recorded, maintained, and preserved as necessary; the adopted development plan has been accepted and effectively utilised by the teams.

5.6.4.9 Theme 9: Lean Effectiveness

The lean principle becomes the most crucial factor in an organization whose intention is to do away with activities that do not add value. In this time of fast growing technology and intense development competition, engineering innovation and development industries are use lean manufacturing as an effective principle to improve existing operations (Panwar, Jain, and Rathore, 2013:131). The lean manufacturing principle is a widely-used advanced manufacturing approach that aids delivery of defect-free products (GLD and Vathsal, 2017:531). Therefore for a nanosatellite innovation and development environment to maintain its position in delivering high-quality CubeSats, lean principles becomes one amongst many options to deploy.

In an attempt to establish the views of the respondents with respect to lean effectiveness within the research environment, the following question and sub-themes were developed from the participants' feedback.

Table 5.14: Product handling, discipline-specific (foundational knowledge) and movement of people or components.

Subtheme Question: Tell me about the movement of material or people during the assembly (building) phase of the CubeSat product:	
Subthemes	**Interview Findings**
Product Handling	Engineers and operations staff confirmed that various workstations were developed. Products were handled in manner that was convenient for all operations. Leadership felt that there was always a sense of urgency in the system, so there was no storage of components required, therefore the Just In Time (JIT) principle was applied.
Discipline-Specific	Leadership confirmed that the design process and production were carried out in dedicated laboratories. Therefore chances for a product to move were high. A product being developed were effectively transported with its entire works order or job card to the next workstations. Engineers felt that components are delivered to their respective workstations by the suppliers. However, operations personnel stated that for some projects, a specific storage area was used to keep the components and to draw them as needed.
Movement of people or components	Engineers and leadership stated that products and components moved between different workstations or laboratories. People remained at their respective workstations. The waste of movement with respect to manpower has been managed very well.

The following quotation is provided as evidence of the participants' response to the objective in question and participants are coded as mentioned above.

D1 - The various working (development) stations are established. The components are delivered to their respective workstations and when there is need to move people or components from one laboratory to another, the teams communicate and decide on the best way to execute that process. The movement of objects or people is planned prior, the team take a decision as to whether material move personnel.

D2 - One product/project where we set aside a separate storage area for it, anything related to that project will then be kept in that storage and drawn out as it is needed. For the rest of others - components get delivered at their point of use (laboratory). The components in this environment are used as soon as they are delivered – because there is always sense of urgency.

D3 - Okay that principle is critical in a production environment that operates 24/7 on ongoing production. We don't have that our workshops are discipline specific, design will be done in one lab, Integration in its lab.... eh...so yah, I will say the product moves, this is very important question, its where we want to be, we are geared towards building may be one, two or three of anything at any point in time what you asking is how we deal with it if we have hundreds of them. Then it became a production line. But we don't have that at this point in time.

Summary of findings based on the exact quotations:

Production Handling: Engineers and operations staff emphasised that planning set priorities for daily operations and confirmed that component were delivered to the point of use, and used as they are received for development. Lean manufacturing was effectively applied when process might improve production while reducing human effort, manufacturing space, tool investments and product development time, and a 200-500% improvement in the quality of products being developed (Shams, Tritos, and Amrik, 2010:841).

Discipline-Specific: Engineers and operations staff confirm that innovation and development workstations are discipline-specific. Therefore, the product handling is governed by the current development layout and assembly practice is still at its beginning phases which is the planned continual improvement for the development of nanosatellite capabilities. It seems that product handling and assembly are carried out effectively on identified and selected working stations and it is evident that with time it will be meritoriously deployed throughout the entire development process.

Movement of people: Engineers and leadership confirm that waste of movement within the innovation and development of nanosatellite systems is well managed, because components are delivered exactly to the point of use, and where a process needs to be performed at a different workstation, a decision is then made whom to move, whether it be objects or personnel.

Conclusion: Effective planning regarding elimination of waste of movement has been carried out. Component and product handling process has been efficiently established and this current operational working layout works for the benefits of the innovation team.

5.6.4.10 Theme 10: Personnel Competency

The failure of projects or products depends on many contributing factors, such as ineffective development processes used, personnel level of experience, specific knowledge required and attitudes of a team. The knowledge required by the nanosatellite developers in order to deliver a defect-free output is regarded as competence for the purpose of this study; it can also be described as specialised knowledge. The engineers make use of competency originating from their respective academic knowledge, and physical science, along with technical engineering principles or their background to develop engineering artefacts through the use of product realization approaches (Jobbours et al., 2015:294).

Product realization and better planning contribute to arresting possible failures that might occur during product application or deployment. The benefits of establishing a development process increases the confidence that requirements will be met, that the processes are under control, and that the team is motivated to perform to expectation (ISO9001, 2015:26).

In an attempt to establish the views of the respondents with respect to the reason for outsourcing of activities within the innovation and development team, the following question and sub-themes were developed from the participants' feedback.

Table 5.15: Outsourced skills, Capability vs Capacity.

Theme Question: Please take me through the outsourced activities that are performed in order to produce a product:	
Subthemes	**Interview Findings**
Outsourced skills	Engineers, operations personnel and leadership indicated that the internalised production process had been outsourced to an outside supplier, because it could not be done in-house owing to human capacity; there was not enough human capacity to carry all the required work. However, the controls in this process are managed between the supplier and the Research Innovation Centre. Individual personnel are also outsourced to perform the responsibilities of the chief engineer, who left the innovation and development team two years earlier.

Capability vs Capacity	Engineers and leadership stated that when the current assembly team was fully preoccupied with activities to be done and tight project deadlines, the innovation center was left with no choice but to outsource some particular innovation component at a cost. However, confirmed that the activities were outsourced not because of the lack of capability within the team, but because the available human capacity was insufficient.

The following quotation is provided as evidence of the participants' response to the objective in question, and participants are coded as mentioned above.

D1- The skilled personnel with well vested knowledge of the project at hand, the outsourced of the development process that cannot be done in our Bellville site. F'SATI has few organizations that usual carry out work for the work that cannot be done within the set environment.

D2 - Our chief engineer left us two years ago. We've seconded two external people on contract to carry out the chief engineer's work and that task was facilitated through the Technology Transfer Office and the legal department. We've internalized production process and it is done through a third party - we certainly ask who can produce circuit boards of certain quality and due process for these actions was followed.

D3 - it is not that we don't have the capability, we don't have the capacity – it is important that you understand that. Initially we do production in house but again the university mandate is that they must commercialize the IP. How do you do that? You don't do it by running the business within the University, you spin it out, you licence it someone. So when that crossing is over between running a business from within hub, to outsourcing, now we outsourcing production at least which is an enormous strain on the innovation team. Production is not innovation, do that component, but the other entire interface with customers for instance still goes through CPUT and we want to outsource that too. Production is the only one that we outsourced and the testing of our Interns because we don't have a certified testing chamber for them.

Summary of findings based on the exact quotations:

Outsourced Skills: Engineers, operations personnel and leadership attest that some core functions are released to certain suppliers whose competence is proven to expedite such activities. Therefore, this function is also carried out to reduce the possible high level of cost. In achieving better quality, lower production cost and minimising risk. If one compares the cost of in-house (single location) and outsourced (multi-offshore locations), it is proven that outsourcing tends to be more affordable than in-house production (Yoqiong & Danping, 2017:742).

Capability vs Capacity: Engineers regard the innovation and development team's capability to perform available tasks as acceptable. However, the capacity to exploit the available capability becomes the challenging issue. When cost is considered to further improve innovation capabilities and to improve the entire process, various innovation activities need to be implemented at the geographical distribution point and such activities needs to be carefully integrated to ensure seamless inter-operations and collaboration (Danping & Yoqiong , 2017:743)

Conclusion: It is clear from the participants' response that competency with respect to innovation resource capacity has forced the institution to outsource some critical activities in order to build quality into a product. However, the personnel level of competence remains acceptable with respect to innovation even though it has proved as lacking when it comes to production events.

5.6.4.11 Theme 11: Process Evaluation

Process evaluation in the innovation and development environment would mean to effectively scrutinise the level at which the process can perform, so that it can be manageable at all costs. The process needs to be able to deliver a product that meets the design and innovation parameters and minimise the level of variation as much as possible. Process management refers to the monitoring of the innovation and development process through the use of evaluation techniques and toolsappliedin order to capture any possible variation (Anh & Matsui.2013:456) In an attempt to establish the views of the respondents with respect to process evaluation used within the innovation and development team, the following question and sub-themes were established from the participants' feedback.

Table 5.16: Procedural System, Supplier Evaluation and Acceptance Criteria.

Theme Question: Please take me through critical evaluation processes that are deployed to assess the reliability of a process or product within this environment.	
Subthemes	**Interview Findings**
Procedural System	Engineers, operations personnel note that procedural systems such as job cards or ticketing systems are utilised to register work to be done, in-process activities and completed; the job card at end of production is scrutinized to check progress and challenges that were experienced. However, leadership feels that for purchasing activities, approved suppliers are found from the the list an approved accredited creditor.
Supplier Evaluation	Operations personnel confirm that the institution has a large database of creditors that are already on the system. The credit agreement between these suppliers and the institution makes it easy to get products from them without paying upfront. However, engineers only evaluate the product on delivery through use of agreed acceptance criteria, such material data sheets.
Acceptance Criteria	Engineers and leadership mention that in-house production acceptance criteria are performed by means of the ticketing system, while for incoming goods a criterion would be applied by means of product certificates of compliance or through in-house product performance evaluation.

The following quotation is provided as evidence of the participants' response to the objective in question and participants are coded as mentioned above.

D1 = The Job Card Procedural System is utilised to track whether products or components have met the expected development standard, as well as completed stages together with bottlenecks experienced during development. The results for in-house component tests are maintained and the product or component performance reports are performed in accordance with the requirement of the product qualification procedure.

D2 = Evaluation of the suppliers - CPUT has large database of creditors that are already on the system. If somebody (the supplier) is in the system that means there is a credit agreement between the CPUT and that particular supplier, so they do not necessarily have to pay these suppliers up front, but can make use of purchase orders. For persons not on the system, procurement is more problematic and suffers delays.

D3 = Ticketing system is utilised together with acceptance test results.

Summary of findings based on the exact quotations:

Procedural System: Engineers and operations personnel state that a procedural approach was developed and effectively utilized; these jobs cards or ticketing systems carry instructions and the results of the completed activities as well as the status of the work in progress. The information captured on job cards informs and describes the progress status and it significantly influences cost reduction, quality improvement and positive reinforcement within the innovation and development environment (Zeng, Anh, and Matsui, 2013:456).

Supplier Evaluation: Leadership and operations personnel state that supplier evaluation is carried out within the entire organization using specifications set by the nanosatellite innovation and development team. The suppliers are selected on the basis of their ability to provide a requested product or service. The organization that requires a service from an external provider needs to determine the controls needed and effectively communicate these requirements with its provider prior the delivery dates or execution of the intended task (ISO 9001, 2015:13).

The engineers and leadership stated that they make use of agreed acceptance criteria to evaluate the delivered product or service. The supplied organization needs to develop process or criteria needed for its product acceptance, and documentedinformation needs to be kept as evidence of such activity (ISO, 9001,2008:7)

Acceptance Criteria: Engineers and leadership stated that relevant and suitable product acceptance criteria have been established, and that product acceptance test reports were used as means of acceptable product quality. According to NASA/SP (2007:230), acceptance criteria include product verification and validation, therefore the technical team carries out required validation of product, technical data package as built and complete it within the innovation and development environment.

Conclusion: It seems that relevant critical evaluation is carried out within the organization's development process; production procedures, product acceptance criteria, and supplier evaluation are viewed as the most crucial factors at this stage.

5.6.4.12 Theme 12: Monitor and Measure

The monitoring and measuring process within the development of this small space craft becomes the supreme critical event. Therefore, an organization needs to establish effective means of monitoring its processes, so that it can detect interruption of necessary operations. A critical event is viewed as one that requires continuous monitoring throughout the entire project lifecycle of a product, a process which generates critical requirements that would then positively affect system design, development, and operations (NASA/SP2007:268).

In an attempt to establish the views of the respondents with respect to monitoring and measuring of the innovation progress within the research environment, the following question and sub-themes were developed from the participants' feedback.

Table 5.17: Qualification Test and Management Tool.

Theme Question: Tell me about the ways in which project progress is monitored and measured:	
Subthemes	**Interview Findings**
Qualification Test	Engineers and leadership are of the view that different monitoring and measurement of a product is carried out through use of prescribed qualification fine tests to match a product to identified specifications. Operations personnel remain convinced that a much is done at planning phase.
Management Tool	Engineers and leadership state that a ticketing system is utilised as a process management tool, to check and manage individuals' work progress; here job cards are outlined once a week and areas of interest are discussed and prioritized. However, operations personnel state that project management tools such as Gunt Chart are used to manage the innovation and development progress.

The following quotation is provided as evidence of the participants' response to the objective in question and participants are coded as mentioned above.

D1 - The fine tests are performed to gauge the positive progress and once the test results confirm compliance a product or component qualification test is then performed.

D2 - We make use of project management tools such as Gunt Chart; the project scope is discussed to view the possible timeframes set. The projects are scoped and planned meticulously - planning is done very well.

D3 - Here communication are shared, were an assembler know this is a ticketing system which we started throughout the months ago, where everyone task are ticked and visible and goes a certain way and every morning once a week again the team has a stand-up meeting where they go through all the ticket. it is not a project management thing, it does not balance resources etc. but it does give visibility to day to day task into the others and if there are bottlenecks they can be cleared in these meeting, because I found out that…….So for managing this ticketing system help to arrest this.

Summary of findings based on the exact quotations is provided as follows:

Qualification Test: Engineers and leadership state that the product performance assessments are carried out in all deserving and outsourced components. The use of a ticketing system that tracks the process is carried out and helps the team to view the current status of innovation and development, with respect to project quality management. The absence of product quality management success is not due to its abstract nature, but rather is a result of the implementation of selected organizational processes in any innovation and development environment (Zen et al., 2013:455)

Management Tool: Engineers and leadership state that project progress is monitored through the use of relevant management tools; in this case job cards are used as a means of communicating progress across different stations. The successful implementation of quality strategies requires more communication of innovation engineers together with a lower management team so that a common philosophy is obtained and better results are achieved (Zen et al., 2013:455).

Conclusion: from the response provided, it is clear that monitoring and measuring innovation tools are adopted to gauge progress, even though attention to monitoring processes still needs to be given consideration and other alternative approaches need to be given a chance.

5.6.4.13 Theme 13: Process Sustainability

The process evaluation defines the process output and clearly indicates the areas that require further improvements. The development environment needs to capture the evaluation results and determine the best practice and retain it for sustainability reasons. There are many techniques reported in the literature for capturing knowledge about the process and possible representation of knowledge with single or mixed techniques such as protocol analysis or grid analysis techniques (Tiwariet al., 2010:586).

In an attempt to establish the views of the respondents with respect to the evaluation of a product before being deployed within the innovation and development team, the following question and sub-themes were developed from the participants' feedback.

Table 5.17: Test Results and Certified Environment.

Theme Question: How is the process/product capability evaluated within the environment before its application?	
Subthemes	**Interview Findings**
Test Results	Engineers, operations personnel and leadership state that series of different tests are carried out on components to assess the performance and these results were recorded for future references.
Certified Environment	Engineers indicated that test are carried out in respective laboratories in accordance with the product requirements; the reason for this is to evaluate the performance ability of a product with respect to stated requirements. However, operations personnel and leadership state that a simulated environment is used to evaluate the products' or components' ability, and the procedure for such activities is in place.

The following quotation is provided as evidence of the participants' response to the objective in question and participants are coded as mentioned above.

D1 - The product capability is considered based on the different test results that are required or performed on that particular component or product.

D2 - The product themselves are produced to certain specifications of quality and they are subjected to testing process, such as a environment, vibration to make sure that products are able to withstand harsh space environment. Test are carried at the certified environment – part per million static test is performed and we make sure the environment that product are developed under is a suitable environment.

D3 - You are talking about the process. Here for instance we are doing thermo analysis, using a very advanced software, so we do move piece by piece in to different scenario, where we emanate and assimilate different environment that the satellite operate in. Of course we use design tools to design the RF or anything in the radio so as is very much as a simulation base and there we just use industry reading application that gives you a good idea of reality. We don't really look at process, we look at the product.

Summary of findings based on the exact quotations:

Test Results: The entire group indicated that product capabilities are checked through series of relevant assessments to attain performance guarantees. The main aim is to maintain conformance to stated specifications to validate the stated requirements. The validation testing is carried under a realistic simulated environment in all the products or components with the purpose of determining the suitability and effectiveness requirements from the product (NASA/SP, 2007:72). The assessment results are used to make a decision about whether the product can beused or not.

Certified Environment: Operations personnel and leadership confirmed that product assessment is carried out under a controlled environment. This means a parametrically controlled environment suitable for the product or component that is being assessed. The organization needs to determine, provide and maintain the environment necessary for the operations of its processes in order to achieve product conformity (ISO 9001, 2015:6). However, engineers and leadership maintain that in cases where the environment is not suitable, then that activity is outsourced to control any possible risks that could result in a failure and to consider safety concerns. Regardless of the mission objectives, the mission vehicle (satellite) has to be developed for safety, and reliability considerations must be an intricate part of the systems design and innovation process (NASA/SP 2007:63)

Conclusion: It seems that test results are captured in controlled / certified testing facilities and results are recorded for continuous improvement sustainability and reference, whenever required in the future.

5.7 SUMMARY

Data collected by means of qualitative and quantitative methods has been analysed in detail, and interpreted through use of percentage rating. Primary and secondary research themes were derived from the research interview data and from the research objectives. The results were compared to the literature review conducted in Chapter 3. The method of analysis was discussed, the collected data was formatted so that it could be analysed, sample utilised in this study were selected as a whole, the use of statistical and interpretive analysis methods were further elaborated, and then lastly, findings and conclusions were drawn in accordance with analysed themes from qualitative and quantitative methods. Chapter 6 will revisit research objectives and questions and put emphasis on the interpreted research findings to derive recommendations as well as possible further relevant research areas.

Taking into consideration Table 5.2 Likert scale data presentation of the quantitative analysis, it was noted that the particiapants' reaction was just **above 66%** in supporting the outlined research objectives. It was also noted in regard to **<20** % respondent rates in some cases that there is a possible gap of understanding in the personnel concerning the processes within the innovation and development team. However, **fewer than 14%** of the participants demonstrated that they did not see the research organisation progress in accordance with the outlined research objectives. The descriptive analysis that is carried out through thematic interpretation is detailed in section 5.4 to 5.6, and the defined themes are further supported by theoretical knowledge.

In Chapter 6, the research will be concluded. The chapter summary, the research problem, research question statement, investigative questions, key research objectives, findings and recommendations will be presented in response to the research problem; recommendations for future research will be tabled and a final research summary will concluded.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 INTRODUCTION AND CHAPTER CONTENT

The main objectives of conducting this research are to evaluate the level at which continuous improvement is applied and monitored within the research environment process set-up in an effort to improve the current set-up. Quality outputs are possible to achieve when an innovation and development process approach is used so that manufacturing capability can be monitored. It will then be flexible enough to allow incremental progress.

In Chapter 6 a brief summary of each chapter is presented, which includes the revisiting of research problem, research question statement, investigative questions, key research objectives, research findings; research recommendations. The research problem, future research areas and research recommendations are tabled in this chapter and presented for the innovation and development team benefits, so that mitigation around noted areas of improvement is made possible and lastly the research conclusion

6.2 SUMMARY OF PRECEDING CHAPTERS

Chapter 1

In Chapter 1 a brief introduction and the background to the research is presented. The research process is explained, followed by the formulation of the research problem, research question, and the study’s supportive investigative questions. The research assumptions and constraints to the research are listed, together with the overall research design and methodology.

Chapter 2

In Chapter 2 a holistic perspective of the research environment is presented. Here, research background and holistic overview of the Cape Peninsula University of Technology with respect to French South African Institute of Technology of Cape

Peninsula University of Technology (CPUT F'SATI) innovation and development systems engineering was briefly discussed.

Chapter 3

In Chapter 3 a literature review discussed the relevant work studies conducted in related fields of study and in relation to quality continuous improvement processes. The review looked at the quality issues and as well as successes and failures experienced in 1950s up to early 2017 in this technological advancement. Quality influence on design and development, manufacturing capabilities and process management in engineering and other related areas are discussed in the context of lean manufacturing principles and process approach. The focus was, however, more on gauging the current continuous improvement effectiveness of the nanosatellite innovation and development capabilities and to view the effectiveness of quality tools that are or could be used to eliminate possible non-value added activities within the current innovation and development set-up.

Chapter 4

In Chapter 4 the research data collection methodologies deployed in the research is presented. The study utilises a mixed research method in collecting data which are qualitative and quantitative. A qualitative data collection method, such as observations, and interviews were effectively expedited. The quantitative process was also carried out through a thirty statement questionnaire and this approach was used as the secondary data collection method. The application of mixed research methods was influenced by the nature of the innovation and development team's maturity and capability, with regard to resources, and technical capability regarding its product.

Chapter 5

In Chapter 5 data collected through qualitative and quantitative methods was examined and analysed through an interpretative process approach and literature review that support results where needed. Throughout the data analysis, research objectives were taken into account , and the interpretative process for quantitative data was carried out through effective use of histograms or bar charts, for qualitative analysis main themes as well as subthemes that were developed. The results of the research presented in Chapter 4 were then interpreted. The measurement scales used were also explained in detail.

Chapter 6

In Chapter 6 the research findings, recommendations in accordance with the research objectives, and suggestions for future research to be conducted to advance and retain good innovation and development activities or process approaches within CPUT F'SATI are provided. Lastly, the chapter closes with a summary.

6.3 RESEARCH PROBLEM

The research problem for this study is “Lack of continuous improvement evaluation within the nanosatellite innovation and development process leads to increased non-value added activities and to poor product quality."

6.4 RESEARCH QUESTION STATEMENT

The research question within the domain of this research is “How can non-value added activities be eliminated and improved product quality achieved through continuous improvement in the innovation of nanosatellite development”?

6.5 INVESTIGATIVE QUESTIONS

The investigative sub-questions are listed below:

- How can the implementation of continuous quality improvement reduce cost of poor quality?
- What continuous quality improvement programmes are engaged to deliver defect-free product?
- How are lean principles implemented and practiced to the gradual condensed development process cycle?
- What tracking and monitoring process are applied to measure and analyse current situation against the intended targets?
- What can be done to sustain good quality improvement process and low development cost?

6.6 KEY RESEARCH OBJECTIVES AND FINDINGS

The key primary research objectives of the study conducted in the nanosatellite innovation and development process environment are tabled as follows:

- To address the effectiveness of the key lean manufacturing principles that are in place.
- To determine whether current continuous quality improvement reducesvarious costs.
- To examine the effectiveness of the current development process.
- To identify main reasons that cause continuous quality improvement to fail
- To define and recommend an effective approach that can be utilised tosustain continuous quality improvement.

The research objectives together with research findings are explained in detail as follows and each research objective has its own aligned research findings that are extracted from both qualitative and quantitative analysis.

6.6.1 Research objective one:

To address the effectiveness of the key lean manufacturing principles that are in place. The research is carried out in a space innovation and development setting. In this scenario, innovation becomes the focal point for every activity. For the researcher to make a decision as to whether the lean manufacturing principles are effectively applied or not within the innovation and development team, the following key areas needed to be taken into consideration: process establishment, challenges in procurement, non-conforming output handling, information integration and preservation and lean process effectiveness. The listed points were observed as findings with respect to the research objective in question.

- Based on the level of maturity of the innovation and development system, it was noted that product life development process was still in its early development phase; therefore more attention with respect to this area needs to be stressed so that all participating individuals are well-versed.
- The control of documented information was effective to some degree, though it was noted that not all personnel were aware of the process to be followed in expediting the information preservation process.

- The process of capturing development activities during innovation and development process was in some cases viewed by the process owners as time-consuming, which implies that there is a possibility of losing development activities data.
- Human and facility capacity with the competence to effectively carry outinnovation and production activities were found to be insufficient to somedegree, hence outsourcing of other activities was used.
- The retention of skilled personnel within the current set-up was viewed as a challenge, and that contributed to increase in the cost of quality, because external personnel were outsourced to carry out certain functions.
- Records for non-conforming output could not be traced. Therefore, it was not clear if or how analysis of non-conformities was carried out.
- The customer specifications were judged against the availability of the resources, such as competence and equipment. However, areas that were found not viable within the set environment were outsourced to competent and approved suppliers, including some core processes such as production.
- The manner in which design reviews and innovation alterations were handled with respect to work-in-progress was effective, even though innovation and development team communication was viewed as a glaring area that needed further attention.
- The non-conforming outputs were identified, and reworked items were segregated and disposed-of as necessary, or redeployed to different applications; it was not clear if the root causes of the non-conforming outputs were addressed.
- The majority of personnel when responding to quantitative questionnaire demonstrated little knowledge as to how the movement of components or personnel was managed within the environment. However, qualitative results showed a positive trend. Therefore systems in managing waste of movement needs to be looked at.
- The process to be followed in accepting supplied product from the suppliers is known, but a number of participants seem not to understand the procedure to be followed when performing this particular task.

6.6.2 Research objective two:

To determine whether current continuous quality improvement reduces various costs.

For the researcher to make a decision as to whether the current continuous improvement decreases various costs or not within the nanosatellite innovation and development of CPUT F'SATI, the following key areas had to be considered: procurement challenges, acceptance criteria and delays in production. The listed points were observed as findings with respect to the objective in question.

- The suppliers' lead times were viewed as inconsistent and that created a challenge for set product or project delivery dates.
- The procurement policy has many control gates in approving the request for quotations and the waiting period sometimes goes beyond the quotation deadline dates.
- The procurement policy is viewed as generic, and it is able to deal with the short turnaround for generic products and extensive research turnaround activities. However, it was found unable to to respond to quick turnaround of such specialized products that are required for space development that are sometimes sourced outside of the country.
- The shortage or unavailability of local suppliers who can provide a range of of space-qualified components for innovation and development was a challenge.
- The issues with currency fluctuation for internationally procured specialised components compromised the budget and led to excessive expenditure.
- The product that is being developed is viewed as specialised one. Therefore, the current procurement set-up finds it challenging to respond to needs as quickly as expected even if in the case of a local supplier.
- It was noted that activities outsourced to specialised industries sometimes contributes to increasing cost because on receiving components, performance tests still need to carried out on them.
- The product or component delivery or acceptance points are not clearly communicated to suppliers, hence products get lost sometimes, and products that are delivered in wrong stations sometimes are recovered once they are

obsolete status, which has the potentialto increase increase waste of time and cost.

- It was noted that sometimes risk analysis is conducted during the planning phase. Therefore, the innovation department does not always assess the likelihood of risk so that such menaces can be mitigated.
- Alternative means to do away with outsourcing activities could not be determined because it was the innovation department's intention to outsource more activities relating to production, as its intention is to focus mainly on innovation and development activities.

6.6.3 Research objective three:

To examine the effectiveness of the current development process.

In order for the researcher to address this objective effectively, the following key areas had to be considered: control of information, process evaluation, review changes, data preservation. The listed points were observed as findings with respect to the objective in question.

- The innovation and development department was unable to carry out all expected innovation and development activities, such as the main production function and the assessment of antennas, so these processes were outsourced to an outside company with the right resource and technical capacity to expedite.
- It was noted from the participants' responses that innovation and development information was controlled and access to it was granted at a certain degree, while some team members did not have access to it.
- Development information was viewed as initially discussed at certain forums, approved as necessary and disseminated to diferent department accordingly. However, the degree of dissemination of this information was not effective at the operational level, as far as some employees were concerned.
- The production feedback was managed through the use of weekly job cards or work tickets and design briefing sessions, and was carried out weekly. However, this function did not balance or address all the day-to-day activities with respect to planning.

- Controls for outsourced activities or process were established and the suppliers were found compliant to some of the stated requirements.
- The process owner acknowledges the hard work performed by the innovation and development teams. However, the institutional controls (Procurement Policy) slowed down procurement of goods and services drastically, and delayed innovation and development promised delivery dates.
- The design review decisions or changes were approved, registered in engineering change documents and controlled, but the manner in which these changes were communicated to all the relevant teams was not effective.
- It was noted that revised or outdated information was identified through revision status and archived as necessary. However, timeframe (archive period) for archived organisational information was not determined.
- It was noted that an effective System Engineering Management Plan (SEMP) or approach was established and effectively followed by the team. However, it was noticed that not all team members were aware of this plan and its usability.
- The production and innovation discrepancies discovered during the weekly innovation and development briefs or meetings were discussed amongst the teams and amicable solutions were formulated (production discrepancies should not only be discussed at the end of the week, they should be dealt with as soon as they appear).
- Potential suppliers or creditors that could supply space-qualified components were not all on the approved suppliers list. Therefore, it was difficult to purchase from these until they were officially approved.
- The evaulation of suppliers is a lengthy process, which tends to delay project delivery dates.
- Work-in-progress was monitored through job cards or work orders and bottlenecks discovered were dealt with as they occurred. However, it was not clear how effective these actions were.
- It was noted that outsourced work or components were subjected to conformance assessment such as performance tests to determine acceptance performance efficiency. Products that failed assessment criteria were rejected and return to the suppliers.
- Preservation of customer property was not controlled. Therefore, the risk of it being damaged while at innovation and development centre were high. If the

customer property is damaged while on premises, it will contribute to increases in the cost of quality.

- The process to be followed when handling a non-conforming output from the development activities was not established within the environment, based on the fifty (50%) percent “undecided” response rate, as shown in the quantitative analysis.
- Project tracking and monitoring strategies deployed within the innovation and development centre to gauge the success of development was unknown to the majority of the team, as shown in the quantitative analysis.
- The innovation and development teams were working towards improving development activities. However, at the time of writing, there were no clear directives as to how to proceed, and when is this expected to be fully implemented.

6.6.4 Research objective four:

To identify main reasons that cause continuous quality improvement to fail.

In order for the researcher to address this objective effectively, the following key areas had to be considered: outsourced activities, process monitoring and measuring and product evaluation. The findings in this regard are listed below.

- The unavailability of more local space component suppliers or products was viewed as a challenge; international suppliers are then used, which leads to long lead times and high prices.
- The outsourcing of production to an external supplier does not capacitate nanosatellite engineers with that particular skill; instead it increases internal cost and risk of quality variation.
- The operational focus was viewed as was biased towards innovation, and growth in production activities was not planned during the execution of this study.
- The innovation department could not operate independently of the university procurement policy, which in some cases does not react positively to quick development turnarounds of the innovation and development requirements.

- The weekly innovation and development stand-up meetings were effective as far as innovation issues were concerned, but could not balance daily activities and resolve communication gaps. The project manager was required to carry out planning of daily activities and to balance resources.
- Communication with respect to innovation activities between the innovation teams was not fully effective, and that left some members uninformed about the progress or future work that needed to be done.
- Team consultation with respect to information that needed a team decision amongst the engineers was found not effective; there was a gap in the interpersonal skills of the innovation and development team.
- Components assessment labolatories used was found to be unable to carry out all the required product assessments, e.g. the assessment of antennas could not be done in-house.
- The suppliers lead times were found to be inconsistent for outsourced activities, which shows ineffectiveness of the adopted supplier review process.
- The planning of activities was carried out effectively in accordance with the SEMP requirement. However, team participation during planning was at some point not considered and the decision was made for the team by only some team members.
- The majority of the personnel did not know about the supplier evaluation process that needs to take place before a the supplier; further, the evaluation of suppliers took to long, and delayed procurement as well.
- The personnel viewed the available resources as insufficient to complete some tasks within the agreed time frame.

6.6.5 Research objective five:

To define and recommend an effective approach that can be utilised to sustain continuous quality improvement.

In order for the researcher to be able to address this objective effectively, the following key areas had to be considered: capability evaluation, process and information retention. The findings are listed below.

- Product capability was carried out through a series of required conformance assessments. However, innovation process capability was not considered at all – the main focus was on the product, not on process.
- Controlled conditions for carrying out product capability assessments were in place. However, the team was not able to carry out all the required assessments; some major and core process had to be outsourced to external service providers.
- The job card or ticketing system was used as work instructions, to capture work in progress and the information was retained for further review. However, the manner in which the information was controlled and protected from possible alteration could not be determined.
- Product capability industry reading applications were used as master data to compare in-house product assessment capability results; these results were kept irrespective of the outcomes. However, it was not clear if or how people accessed these results and how long the information was retained.
- Acess Configurations to controlled information were established, but it was not clear if the access codes were distributed to the entire team.
- The innovation information was viewed as subject to privilege and a product share drive was used to retain the information, but it was not clear if all innovation and development personnel were given access to this drive.
- Some personnel were not aware of the reasons why they should record or document the work that they did on job cards. Therefore, were inconsistent in keeping records. This reduced the the effectiveness of the stand-up meetings in addressing innovation challenges because insufficient information was recorded on the job cards)

6.7 RECOMMENDATIONS BASED ON RESEARCH OBJECTIVES

The recommendations are made from the research findings that were derived from both qualitative and quantitative data analysis. These recommendations are outlined for the benefits of F'SAT and made with the intention to create awareness and understanding of the identified gaps within the system. It is then the prerogative and responsibility of the innovation and development team in question to pinpoint the most critical recommendations that are most relevant to the innovation and development process approach and to address them accordingly.

There is a possibility that some of these recommendations are implemented already or are in in progress, based on observation of the ZACUBE-2 development progress. The recommendations are then tabled out in accordance with research findings and objectives as follows:

6.7.1 Recommendations on Research objective one

- The process of documenting information needs to be a common responsibility, because the more data gathered, the more chances are to build a strong institutional memory.
- The human and facility (resources) capacity needs to be seriously looked at because the right mix of competence coupled with capability resources tends to deliver promised quality within the set delivery timeframes.
- The employee’s retention strategy needs to be revisited in order to maintain and to retain the right competence mix within the team. The innovation and development unit needs to create an attractive work environment and evaluate its employees’ needs and address them accordingly.
- The recorded non-conforming output need to be analysed to determine the level at which waste is created, and to determine the root causes so that stringent measures are put in place to avoid reccurrence.
- On the job communication training needs to be given to development teams so that communication within the environment becomes more effective, in order to enhance innovation activities.
- The personnel involved need to fully understand the entire nature of the development and innovation process, especially when it comes to operational activities.
- The entire team needs to be taken through training of product acceptance criteria so that everyone is aware of its value to innovation activities.

6.7.2 Recommendations on Research objective two

- The manner in which planning is carried out needs to be relooked at considering challenges that are caused by Procurement Policy, so that promised project delivery dates are set realistically and are met.
- The innovation team if possible needs to be given independent buying power; if possible, a completely detached procurement system from the university to advance the innovation and development activities. Such independent buying power has to come with responsibility for reporting back to the university for every 25% completed project scope, for proper monitoring and accountability.
- The innovation and development unit needs to identify and evaluate all possible potential suppliers' in time and maintain records of approved suppliers so that when they need to buy components, it then becomes easy.
- The product delivery process for externally provided products or processes needs to be explained to the suppliers and the process owners, to avoid loss of products being delivered.
- The operational risks and opportunities need to be identified by the innovation team, so that likelihood is known and properly aligned measures are put in place to contain risks before they appear.
- For skills and knowledge capacity building reasons, benchmarking initiatives with the product or service supplier needs to be established; so that the current innovation team can be further skilled too in this regards and future cost will be reduced.

6.7.3 Recommendations on Research objective three

- The most crucial facilities need to be increased so that all critical core activities are carried out on site in an attempt to reduce cost and quality variation.
- The rate at which access to innovation information is given needs to be revised, so that correct and relevant knowledge is accessible by all relevant personnel.
- For monitoring reasons, visible management tools need to be established and used to achieve transparency with respect to work-in-progress for everyone.
- Means of access to design review decisions need to be communicated and to be centralised for greater ease of access to the entire innovation and development team.

- In order to build strong institutional knowledge, effective means to collect innovation and development information needs to be determined and captured in a more controlled documented format.
- The Systems Engineering Management Principle (SEMP) needs to be effectively implemented throughout the entire innovation department so that all members are able to operate within its requirements and also to be aware of it.
- The innovation and development teams need to urgently attend to development discrepancies as soon as they are discovered, and development line stops authority needs to be implemented to guard against any further escalation of an acknowledged problem.
- Potential suppliers need to be researched, identified, and evaluated in advance to gauge their ability to supply the required components to the innovation department within stated timelines.
- The procedure that describes the process to be followed in the handling of customer property and identified non-conformities needs to be developed and effectively communicated throughout the entire innovation team.
- The means to track progress and monitoring strategies within the innovation centre needs to be clearly defined or explained throughout the entire team and the intention for this initiative needs to be clearly explained and understood.

6.7.4 Recommendations on Research objective four

- To reduce internal innovation costs, alternative means with respect to production and innovation activities need to be established, e.g. human capacity in skills development to be increased through a partnership with capacitated resource institutions.
- The means to develop an independent procurement process that is able to respond to innovation timeframes need to be considered, to effectively respond to the innovation and development mandates.
- A more structured planned and layout of activities needs to be addressed, so that day to day activities are well balanced and teams are aware of current and upcoming events in time.

- The weekly development reviews serve their purpose. However, alternative means of enforcing interactive communication with respect to project activities needs to be established to advance entire team cooperation.
- More responsive innovation and development facilities with an ability to expedite all core function would reduce quality challenges as well as internal cost for future development.
- The supplier evaluation and reassessment process needs to be reviewed and suppliers to be clearly informed about the impact and its severity of late service or product delivery with respect to set timelines.
- The innovation group needs to adopt group planning sessions, where customer specifications and expectations are scrutinised and everyone's contribution is recognised through evaluation and accepted, provided it adds value to the innovation process approach.
- The innovation team needs to be formally informed about the risks involved in using an unapproved supplier to provide development material.

6.7.5 Recommendations on Research objective five

- The control of documented information needs to be strengthened a bit, so to avoid the use of an unapproved work instruction as well and incomplete design alteration, and for effective value-adding analysis results.
- The manner in which access to information is given needs to be reviewed and teams need to be able to draw a line between sensitive and critical information as compared to development information and trust issues amongst the teams need to be addressed accordingly.
- The recording of activities on a job card needs to be emphasized throughout the entire team and be made a culture of innovation and development so that the review and analysis of innovation and development data become effective.
- Development initiatives such as benchmarking and supplier developments need to be considered to advance as well as to expand and to advance the personnel skills capabilities of the existing team.

6.8 SUGGESTION ON FUTURE RESEARCH

The research was carried out in a nanosatellite innovation and development environment, with the intention to determine the ability of current continuous improvement to reduce possible non-value added activities. Therefore throughout literature being reviewed, data collected was analysed, interpreted and recommendations were drawn from the study. The research objectives together with research question were revisited and based on these compared to the research results, it was clear that value-adding continuous improvement is in progress. However, a lot still needs to be done to improve as well as to sustain the current innovation and development process approach. Therefore, it becomes the duty or the responsibility of the process owner to decide which areas within the research project require first hand attention.

The collected data as well as the interpreted results show a strongly progressive curve of delivery of quality outputs. However, considering continuous improvement that requires more small positive initiatives of incremental growth to improve innovation and development activities, more work still needs to be done. The research results together with research topics, research objectives, research question reveals further areas that needs to be researched in order to effectively better operations of the innovation and development innovation and development team. The research provides areas of interest that could add value or advanced this work or the innovation and development team if research studies can be carried too. The itemised areas below urgently requires attention so that possible opportunities for improvement of quality inferiority, innovation and development process approaches, and growth development are dealt with without undue delays:

- The achievement made by the innovation and development centre for the past four years in this field has proven beyond reasonable doubt that the ability to innovate and build more satellites is available. The university contribution to this field has been noted, as well as the challenges presented by the established governing operating procedure during the development phase of ZACUBE-1 and ZACUBE-2. The integration of activities between the university, F'SATI and ASIC were noted as effective, but further improvement is required, especially in the resource and technical capability establishment. The research findings and observation of controls enforced by standard operating procedures of the university suggest that a possible business spin-out (independent commercialized operation) option would free the innovation and development team from other internal governing procedure but still maintain the excellent relationship between the two entities.

- Sufficient personnel technical skills and resources capability is viewed as an area of improvement and as a challenge within the innovation and development centre. Therefore a benchmarking approach would assist the organisation to establish a solid and experience-based reference point, define and select the best practices, be able to identify relevant improvement opportunities (reduce cost level) and be able to create a healthy and competitive innovation and development environment within itself.
- To assess the current in-house assimilated testing station's capabilities, look for alternatives to best utilise the available resources and ,more efficient data collection for in-process activities can contribute to building current interpersonal skills and enhancing the innovation and development activities for better operational innovation and development process output.

The above points are recommended by the researcher as further areas of investigation for this innovation and development team; the motivation to suggest such decision was derived from the findings and a decision was made with the intention to continually improve the innovation and development centre to increase its innovation and development performance quality outputs as well as to create more sustained independent operational capabilities. The innovation and development team might consider investigating the above mentioned critical areas for further research, and further look at the tabled research findings and recommendation and from there take a decision as to which areas might really require the first-hand attention.

6.9 SUMMARY OF THE RESEARCH

As mentioned, the problem statement of this study is "Lack of continuous improvement evaluation within the nanosatellite innovation and development process leads to increased non-value added activities and to poor product quality". The study deepened the investigation of the current CPUT F'SATI innovation and development process approach in order to understand the internal dynamics of continuous quality improvement strategies, considering the nature or the context of disruptivetechnological innovation factors.The study utilised a mixed research method approach to gather and analyse data.

The study tabled its findings in chapter six in section 6.6.1 - 6.6.5, and recommendations in 6.7.1 - 6.7.5. The research further reviewed and presented possible future research areas that can be researched in addressing critical findings within the intentions to advance the current innovation and development activities: spin-out possibilities that might relinquish university control of some of the most critical activities in this environment; partnership possibilities with product or service suppliers in order to learn and build the competence level of the current assembled development team; to further investigate alternative means of achieving quality output products or service, considering the exponential cost, and with little effort exerted on outsourcing of main and sub-core processes.

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APPENDIX A: LETTER REQUESTING MEETING WITH THE INNOVATION AND DEVELOPMENT TEAM.

Mr. Z. Nkonzo: 209181257

Department of Industrial Engineering and Systems

Cell: 072 949 1864

Tell: 021 6816 705

Email: nkonzoz@yahoo.com **Date: 24/06/2015**

Dear Mr. L Steenkamp

I am Zukisa Nkonzo, an MEng Engineering Quality Degrees Industrial Engineering Student at CPUT Bellville campus with student number 209181257. I am planning to conduct an academic research in Systems Engineering of CPUT F'SATI. My topic is – "**Continuous improvement practices within a nanosatellite manufacturing capability**". The research focuses on assessing the effectiveness of the quality practice that is deployed within the innovation and development, in an effort to create consistence of purpose and possible suggest means to reduce waste associated with quality effirts within the environment. As an outsider from the research environment .I am currently establishing way to learn more about the environment and I will reaaly appreciate any possible exposure that can be offered to me.

I am aware about the maturity of process established and I am taking into consideration that the development of nanosatellites environment is under progressive stages. I am requesting the current status information and further request a special meeting with the F'SATI team, so that I am able to explain my intentions in an effective interaction and to allow members of the team to ask me questions for clarity reasons. I would appreciate is we may have the meeting scheduled for 24 June 2015 just after 15:00 Hours.

For your information and the team, please accept the attached research poster, which briefly explains the purpose of my research together with my research objectives. In this research, I am being mentored by Prof C M Moll from CPUT and Prof G Hillmer from Autria. As far as permission form the leadership is concerned, Prof R Van Zyl has already gave me an assurance of your cooperation and a verbal permission to conduct this research.

Your contribution in this regard will be highly appreciated and thank you in advanced for your effective ccoperation.

Sincerely

Zukisa Nkonzo: MEng Engineering – Quality Candidate (072 949 186

APPENDIX B : RESEARCH POSTER

Continuous improvement practices within a nanosatellite manufacturing capability"

Presented by Zukisa Nkonzo (Student), Supervisors are Prof C M. Moll and Prof. G .Hillmer and

Abstract

The study investigates the level at which continuous improvement process is applied withing the innovation and development activities within the CPUT F'SATI. The reason for conduction this study is wanting to assess and table the level at which continuous improvement within the manufacturing capabilities is applied and to present findings as well as recommendation. Two sets of data will be colleted through group interviews (n=3) through use of questionnaire (n=10)

Introduction

Continuous improvement on system engineering process is required to maintain quality assurance and measurement. System engineering is an assembly that has two significant disciplines, which are technical and system engineering management. Risk based thinking and measurement apparoaches should be entrenched in our nanosatellite development process cycle to improve human working condition, in pursuing the quality of a process or product output for better performance in all related quality dimensions. Actual success comes from an improvement process that is flexible enough to be examined to identify possible waste. Therefore to maintain positive development, troubling areas needs to be identified and countermeasures to deal with such must be premeditated.

Methodology

The researcher elect an inductive approach through application of total field observation phenomeno, because inductive approach allows the interaction of different individual phenomenon and it has a capability to permit access of common link in gauging any possible relationship that out surface from the history and the current (development process adopted for ZACUBE1 to ZACUBE2).

The literature review was conducted to expand the knowledge of the researcher on the history of the satellite development till to the inception of nanosatellite together with challenges and successes encountered, evaluation of continuous improvement in manufacturing capabilities, lean manufacturing principle, supplier performance, eight deadly wastes and six sigma principles has been reviewed.

Objectives

- To improve systems engineering operational processes, through the implementation of Prevention, Appraisal and Failure (PAF) analysis system approach.
- To measure the current existing process effectiveness through application of quality tools and relevant quality methodology.
- To track the progress of small increment that are set to add value to the existing process against the target setting of the environment.
- To understand how quality improvement is considered in nanosatellite development through application of value stream and process maps.

SIGNIFICANCE OF THE PROPOSED RESEARCH

The research will be carried out through use of action research approach and field observation principle will be applied, however the independednce of the researcher to innovation and development team will be managed through application of total field observation principle. The research has a potential to rationalise the entire operational set-up in completing the current and new innovation and development set-up , while it displays different ways to minimise the cost level as well as to improve the current working conditions.

ANTICIPATED FINDINGS OF THE RESEARCH

The researcher anatipated findings are drawn from the field observation condacted and it is anaticipated that there is lack of resources to effectively carried out all tasks within the research hub, Nonexistance of industrialised development layout, lack of access to waste reduction tools, little evidence to demonstrate the effectiveness of documented information.

APPENDIX C.: F'SATI CPUT DATA COLLECTION REQUEST

Mr Z. Nkonzo: 209181257
Department of Industrial Engineering and Systems
Cell: 072 949 1864
Tell: 021 6816 705
Email: nkonzoz@yahoo.com **Date: 08/02/2016**

Dear Professor Van Zyl

Permission for data collection for the purpose of conducting research towards the degree MEng: QUALTY.

I am Zukisa Nkonzo, a student at Cape Peninsula University of Technology (CPUT) with a student number 209181257. I have a National Diploma in Mechanical Engineering, National Professional Diploma in Education and BTech in Quality with experience in engineering design and development, product development, manufacturing & production, teaching experience in technical vocation and in quality management applications.

Throughout the years, I have been involved in the quality related process and I found quality interesting in engineering design and development environment and I took a decision to study this exciting area. I am currently busy with my degree in MEng: Quality. I am doing my research project in the Innovation and Development environment at Cape Peninsula University of Technology (CPUT) F'SATI.

I am doing this research under the watchful eyes of three Professors, Prof M C Moll, Prof S, Bosman all from Cape Peninsula University of Technology (CPUT) and Prof G Hillmer from MCI MANAGEMENT CENTER INNSBRUCK, Austria, and my research topic is "**Continuous improvement practices within a nanosatellite manufacturing capability".** I am hoping to collect data under three categories, which are group interviews, use of questionnaire/s and through previous organizational documented information review.

Please allow me to collect data in your research environment and I promise to treat all data collected confidential and with respect. Prof, you are more than welcome to contact my supervisors for clarity if need be. Prof M C Moll; +27 71 333 9339, mollcm@cput.ac.za, Prof S, Bosman; *+27 (0)21 959 6225,* bosmans@cput.ac.za and Prof G, Hillmer +43 512 2070 -4110, gerhard.hillmer@mci.edu

Sincerely

Zukisa Nkonzo (MEng: Quality Candidate – 208 181 257)

APPENDIX D.: F'SATI CPUT DATA COLLECTION PERMISION

APPENDIX E: REQUEST FOR PARTICIPATION IN QUANTITATIVE QUESTINNAIRE.

Mr. Z. Nkonzo: 209181257
Department of Industrial Engineering and Systems
Cell: 072 949 1864
Tell: 021 6816 705
Email: nkonzoz@yahoo.com Date: 05/03/2017

Dear Sir / Madam

INVITATION: TO PARTICIPATE IN A RESEARCH DATA COLLECTION OF MEng: QUALTY QUALIFICATION

The questionnaire is part of an extensive Masters Degree's study in Quality on an approach to evaluate the current deployed current innovation and development process approaches, with the intentions to elucidate, understand, and to improve the internal dynamics of the deployed continuous improvement strategies within the French South African Institute of Technology (F'SATI) of the Cape Peninsula University of Technology (CPUT).

It will be highly appreciated if you, the director, operations management, Satellite Chief Engineer, Space innovation and satellite Systems Engineers, would participate in the interviews or in completion of the Inqwise Questionnaire as thoroughly as possible. Please note that, all information gathered will be honestly treated **STRICTLY CONFIDENTIAL** and will only be used for academic purpose.

The access to the questionnaire is through the following link *http://c7.inqwise.com/c/1/1db91bc5-ba61-48bd-8897-affe9368bbc3/1*.Please feel free to contact the researcher in case of any queries at the mentioned contactable details or my supervisors Prof Mellet Moll +27 71 333 9339, mollcm@cput.ac.za, Prof S, Bosman; *+27 (0)21 959 6225,* bosmans@cput.ac.za, and Prof G Hillmer +43 512 2070 -4110, gerhard.hillmer@mci.edu from MCI MANAGEMENT CENTER INNSBRUCK, Austria

1. Please read the questions and instructions to answer them carefully.
2. Please answer the questions as objectively and honestly as possible.
3. Please answer based on your experiences as much as possible.
4. Please mark the option which reflects your answer the most accurately by marking an (√) in the space provided.
5. Please answer all the questions as this will provide more information to the researcher so that an accurate analysis and interpretation of the data can be made.
6. Example - in completing the questionnaire: To what extent do you agree or disagree, please tick an appropriate box.

Strongly Disagree			**√**			**Strongly Agree**

Sincerely,

Zukisa Nkonzo (MEng: Quality Candidate – 208181257)

APPENDIX F: QUANTITATIVE QUESTIONNAIRE

I give my consent

2. I do not give my consent

☐ 1

☐ 2

2. * Different components are produced in different stages?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

3. * Work is always available?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

4. * The quality of work is monitored in every stage?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

5. * Suppliers provide standard parameters for our operations?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

6. * Design reviews are carried both formal and informal?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

7. * Components and people move between working stations efficiently?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

8. * Information is documented at all stages during operations?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

9. * Our procurement policy is flexible?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

10. * Supplier evaluation is performed prior to business engagements?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	**Strongly agree**

11. * Working areas are clean and organised?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	**Strongly agree**

12. * Sometimes quotations and components get lost through procurement system?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	**Strongly agree**

13. * Product testing is performed to all products and components?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	**Strongly agree**

14. * Components that fails during evaluation process are downgraded for a different use?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	**Strongly agree**

15. * Level of defects is recorded and measured?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	**Strongly agree**

16. * Risk based thinking is performed during planning?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	**Strongly agree**

17. * Supplier evaluation process is time consuming?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	**Strongly agree**

18. * Components are subjected to evaluation prior their use ?

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	**Strongly agree**

19. * Logbooks are used to record the machine usage?

	1	2	3	4	5

Strongly Disagree ○ ○ ○ ○ ○ Strongly agree

20. * Previous projects documents are always available when needed?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

21. * Documented information is accessible to all personnel?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

22. * people's complaint/concerns are recorded and resolved without undue delays ?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

23. * project scope is always clear and communicated?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

24. * Some work activities are given to skilled external providers?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

25. * Project tracking and monitoring process is practiced?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

26. * Space qualified components are used?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

27. * Fully equipped testing stations are used for product evaluations?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

28. * Formal development process layout is established?

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	○	Strongly agree

29. * Customer property is preserved as required?

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly agree

30. * Targets are sets to improve the existing development process?

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly agree

31. * Controls for outsourced activities are established?

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly agree

Finish

Powered by Inqwise:

APPENDIX G: REQUEST FOR PARTICIPATION IN QUALITATIVE QUESTIONNAIRE

Mr Z. Nkonzo: 209181257
Department of Industrial Engineering and Systems
Cell: 072 949 1864
Tell: 021 6816 705
Email: **nkonzoz@yahoo.com** Date: 10/11/2016

Dear Sir / Madam

INVITATION: TO PARTICIPATE IN A RESEARCH DATA COLLECTION OF MEng: QUALTY QUALIFICATION

The group interview is part of an extensive Masters Degree's study in Quality on an approach to evaluate the current deployedcurrent innovation and development process approaches, with the intentions to elucidate, understand, and to improve the internal dynamics of the deployed continuous improvement strategies within the French South African Institute of Technology (F'SATI) of the Cape Peninsula University of Technology (CPUT).

It will be highly appreciated if you, the director, operations management, Satellite Chief Engineer, Space innovation and satellite Systems Engineers, would participate in the proposed group interviews as thoroughly as possible. Please note that, all information gathered will be honestly treated **STRICTLY CONFIDENTIAL** and will only be used for academic purpose.

The research interviews questions will be provided to you on the day of the interview and you will be given 10 minutes to go through it, prior the interview process commenced. For the time being please receive Annexure D: Project Research Poster and familiarise yourself with research objectives, questions and research background.

Please feel free to contact the researcher in case of any queries at the mentioned contactable details or my supervisor Prof Mellet Moll +27 71 333 9339, mollcm@cput.ac.za, Prof S, Bosman; *+27 (0)21 959 6225,* bosmans@cput.ac.za, and Prof G Hillmer +43 512 2070 -4110, gerhard.hillmer@mci.edu from MCI MANAGEMENT CENTER INNSBRUCK, Austria

1. Please read the questions and instructions to answer them carefully.
2. Please answer the questions as objectively and honestly as possible.
3. Please answer based on your experiences as much as possible.
4. Please answer all the questions as this will provide more information to the researcher so that an accurate analysis and interpretation of the data can be made.

Sincerely,
Zukisa Nkonzo (MEng: Quality Candidate – 208181257) Signed ……………………………………….

APPENDIX H: QUALITATIVE QUESTIONNAIRE

Dear F'SATI CPUT Research Participant:

Thank you for showing interest in participating in this study. It is important that you understand why the research is being done and what it will involve. Please read the following information carefully – You may ask the Researcher if there is anything that is not clear or if you need more information.

TITLE OF THE STUDY AND RESEARCHER DETAILS:

"Continuous improvement practices within a nanosatellite manufacturing capability"

Purpose of the Study

The main purpose of conducting this research is to determine possible ways in which CPUT F'SATI development process can be industrialised in a better way. Industrialisation is also influenced / hindered by non-value added activities that out-surface during nanosatellite development process.

I am inviting you to participate in this study. The information provided to the Researcher will be used for academic purposes only. In cases where the information will be used otherwise a written agreement will be required from you as participants in this study.

Study Procedures

Qualitative data: The Researcher will conduct a semi-structured interview with you, which will last approximately for 30 minutes. The interview will be recorded (sound only) and will later be transcribed.

Quantitative data: The Researcher will provide you with a questionnaire in five days after the interviews and you will be given five working days to complete it.

Risks

The Researcher does not anticipate any foreseeable risks associated to any of the procedures used in the study. You may decline to answer any or all questions and you may terminate your involvement at any time if you choose.

Benefits

The findings will be of value for the overall development process. You will then get the copy of the research conclusion on request once the study has been fully completed. The completion of this study will benefit the researcher to obtain a **MEng Degree** Quality in Industrial and Systems Engineering.

Confidentiality

Your responses to this semi-structured will be anonymous. Every effort will be made by the Researcher to preserve your confidentiality including the following measures taken by the Researcher:

CONSENT SECTION:

Please read the following statement and, if you agree, please initial the corresponding box to confirm agreement.

I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactory. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reasons.

	Mark √ / x
I confirm that I have read and understand the inform tion sheet for the above study.	
understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason.	
I understand that my data will be treated confidentially and any publication resulting from this work will report only data that does not identify me.	
I freely agree to participate in this study.	

____________________ ____________________

Participant Position : CPUT F'SATI Signature

Zukisa Nkonzo 10-11-2016

____________________ ____________________ ____________________

Researcher (block capitals) Date Signature

Supervisors : Prof C M. Moll

: Prof G. Hillmer and Prof S. Bosman **(Co-supervisors)**

Researcher : Zukisa Nkonzo

Master's Degree Student : 072 949 1864 and 021 6816 705

nkonzoz@yahoo.com

Department of Industrial and Systems Engineering : CPUT Bellville Campus, Symphony Way, Bellville

Postal: PO Box 1906, Bellville, 7535

Cape Peninsula University of Technology

Topic: "Continuous improvement practices within a nanosatellite manufacturing capability

1. **Tell me about the different techniques that are used to reduce cost and waste within the nanosatellite development process :**
   - *Tell me about the process followed to begin any new space related project:*
     ..
   - *What challenges that you face during the procument process?*
     ..
   - *How do you deal with scrape and failed product?*
     ..

2. **Tell me about the ways in which new information is controlled and how is it used to improve the development process:**
   - *Tell me about the process followed in accepting a product from: Internal and External suppliers:*
     ..
   - Tell me about the controls that are in place to preserve design review decision:
     ....
   - How design review decisions get incorporated to the reviewed work in-progress?
     ....

3. **Tell me about the movement of material or people during the assembly (building) phase of the CubeSat product:**
   - Please take me through the out-sourced activities that are performed in order to produce a product:
     ....
   - Tell me about lead time (waiting period) that is set for outsourced activities for both external and internal provider.
     ....
   - Please take me through risk mitigating factor that are perform to minimise delays of a production process:
     ....

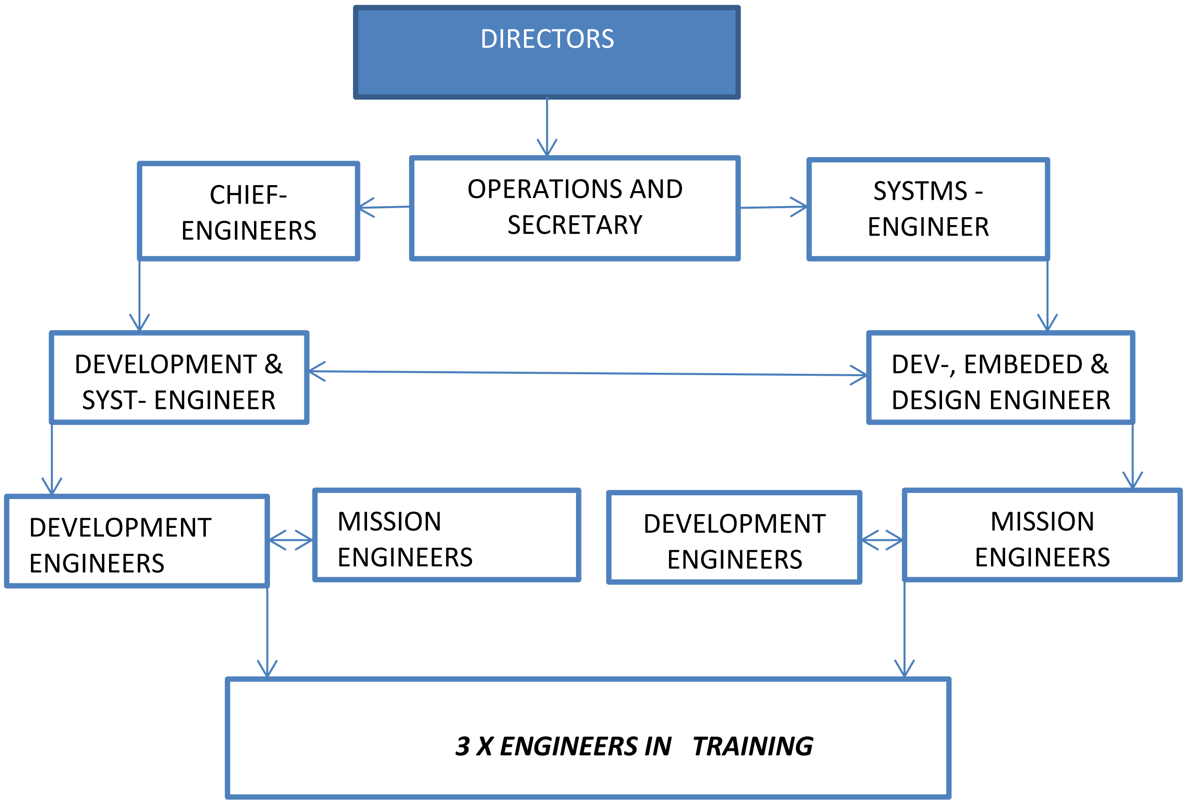
4. **Please take me through critical evaluation processes that are deployed to assess the reliability of a process or product within this environment.**
   - *Tell me about the ways in which project progress is monitored and measured:*
     ..
   - *How is the process / product capability is evaluated within the environment prior it application?*
     ..

5. **Tell me about the different techniques that are used to retain the effective development process of nanosatellite.**
   - *Tell me about the different testing /evaluation process that are performed during development process.*
     ..
   - *How do you retain product testing / evaluation result within this environment?*
     ..
   - How easy it is to access retained information?
     ....

6. **Given a chance, what would you like to change/ improve in the current development set upset-up and why do you think your strategy will make the environment better to produce quality products?**

....

APPENDIX I: F'SATI CPUT ORGANISATIONAL ORGANOGRAM



APPENDIX J: FREQUENCY TABLES DESCRIPTIVE STATISTICS DATA PRESENTATION

Notes

Output Created		11-MAY-2017 11:14:55
Comments		
Input	Data	C:\DELLE4310\@LaCie\Research\ResearchPostGraduate\MTech\CPUT\2017\NkonzoZukisa\Data View -08-05-2017 - Zukisa Nkonzo.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	10
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases withvalid data.
Syntax		FREQUENCIES VARIABLES=Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 Q23 Q24 Q25 Q26 Q27 Q28Q29Q30 /STATISTICS=STDDEV MEAN MEDIAN MODE/BARCHART FREQ/ORDER=ANALYSIS.
Resources	Processor Time	00:00:03.49
	Elapsed Time	00:00:03.84

Frequency Table

different components

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DA	1	10.0	10.0	10.0
	UD	2	20.0	20.0	30.0
	A	4	40.0	40.0	70.0
	SA	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

moves between stations

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	UD	5	50.0	50.0	60.0
	A	2	20.0	20.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

clean and organised

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	DA	2	20.0	20.0	30.0
	UD	1	10.0	10.0	40.0
	A	4	40.0	40.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

delivered wrong point

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DA	1	10.0	10.0	10.0
	UD	5	50.0	50.0	60.0
	A	2	20.0	20.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

layout establised

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	A	4	40.0	40.0	50.0
	SA	5	50.0	50.0	100.0
	Total	10	100.0	100.0	

standard parameters

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DA	1	10.0	10.0	10.0
	UD	3	30.0	30.0	40.0
	A	5	50.0	50.0	90.0
	SA	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

procurement policy

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	UD	2	20.0	20.0	30.0
	A	4	40.0	40.0	70.0
	SA	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

risk based thinking

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	6	60.0	60.0	60.0
	DA	3	30.0	30.0	90.0
	A	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

always cleare

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	UD	3	30.0	30.0	30.0
	A	4	40.0	40.0	70.0
	SA	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

outsourced activities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	UD	3	30.0	30.0	40.0
	A	4	40.0	40.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

work is monitored

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	DA	2	20.0	20.0	30.0
	A	3	30.0	30.0	60.0
	SA	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

formal and informal

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	A	4	40.0	40.0	50.0
	SA	5	50.0	50.0	100.0
	Total	10	100.0	100.0	

testing process

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	3	30.0	30.0	30.0
	UD	6	60.0	60.0	90.0
	A	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

recorded and measured

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	UD	5	50.0	50.0	50.0
	A	3	30.0	30.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

evaluated prior

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	UD	3	30.0	30.0	30.0
	A	4	40.0	40.0	70.0
	SA	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

previous project

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	UD	2	20.0	20.0	30.0
	A	3	30.0	30.0	60.0
	SA	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

resolved immeditely

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DA	1	10.0	10.0	10.0
	UD	2	20.0	20.0	30.0
	A	6	60.0	60.0	90.0
	SA	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

project tracking

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DA	1	10.0	10.0	10.0
	UD	5	50.0	50.0	60.0
	A	2	20.0	20.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

preserved as required

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	3	30.0	30.0	30.0
	DA	1	10.0	10.0	40.0
	UD	3	30.0	30.0	70.0
	A	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

improve existing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	2	20.0	20.0	20.0
	DA	2	20.0	20.0	40.0
	UD	3	30.0	30.0	70.0
	A	1	10.0	10.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

have work

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	2	20.0	20.0	20.0
	DA	1	10.0	10.0	30.0
	UD	3	30.0	30.0	60.0
	A	3	30.0	30.0	90.0
	SA	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

evaluation performed

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DA	1	10.0	10.0	10.0
	UD	5	50.0	50.0	60.0
	A	3	30.0	30.0	90.0
	SA	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

product testing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	A	6	60.0	60.0	70.0
	SA	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

supplier evaluation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DA	1	10.0	10.0	10.0
	UD	2	20.0	20.0	30.0
	A	4	40.0	40.0	70.0
	SA	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

testing station

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DA	1	10.0	10.0	10.0
	UD	4	40.0	40.0	50.0
	A	3	30.0	30.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

control outsourced

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	A	4	40.0	40.0	50.0
	SA	5	50.0	50.0	100.0
	Total	10	100.0	100.0	

information documented

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	DA	1	10.0	10.0	20.0
	UD	2	20.0	20.0	40.0
	A	5	50.0	50.0	90.0
	SA	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

record machine usage

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	UD	4	40.0	40.0	40.0
	A	4	40.0	40.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

access to information

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	UD	7	70.0	70.0	80.0
	A	1	10.0	10.0	90.0
	SA	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

space qualified

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SDA	1	10.0	10.0	10.0
	UD	3	30.0	30.0	40.0
	A	4	40.0	40.0	80.0
	SA	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

APPENDIX K: UNVARIATE GRAPHS

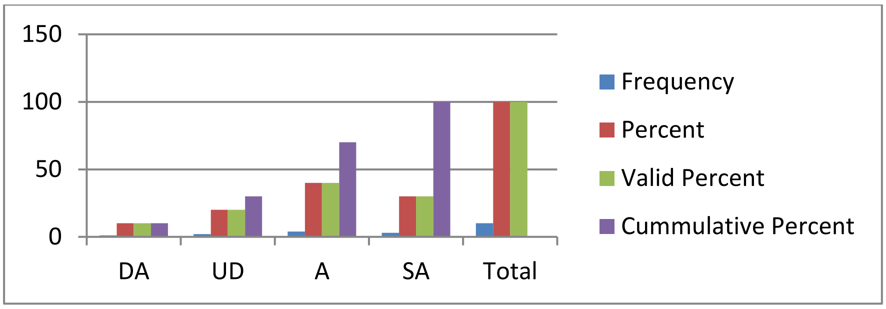


Figure 5.1: different components

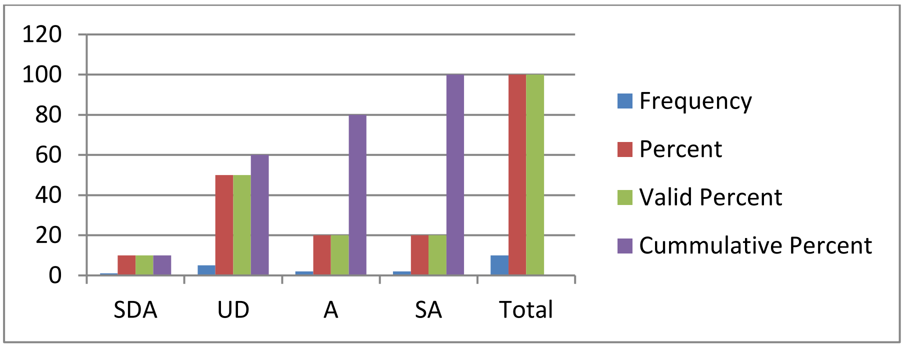


Figure5. 2: moves between stations

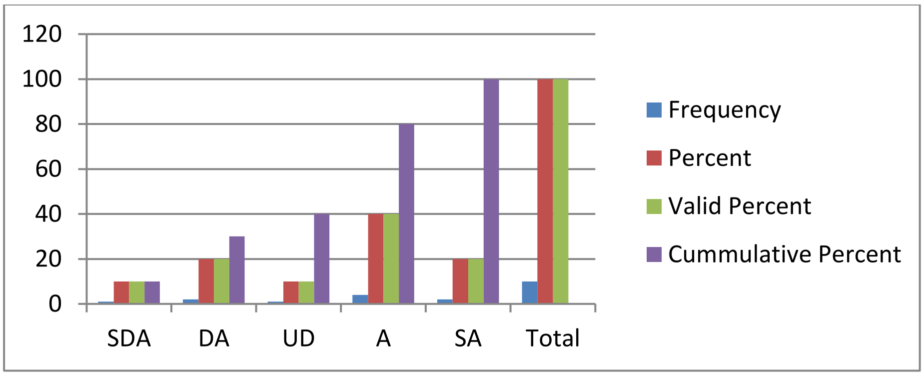


Figure5. 3: cleaned and organised

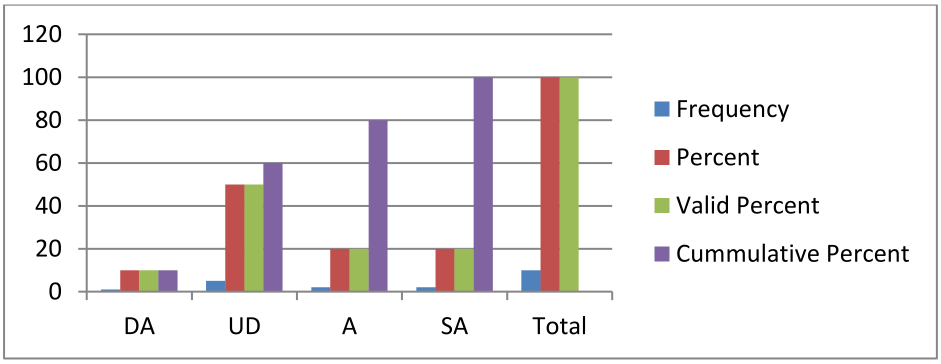


Figure 5.4: Delivered at wrong point

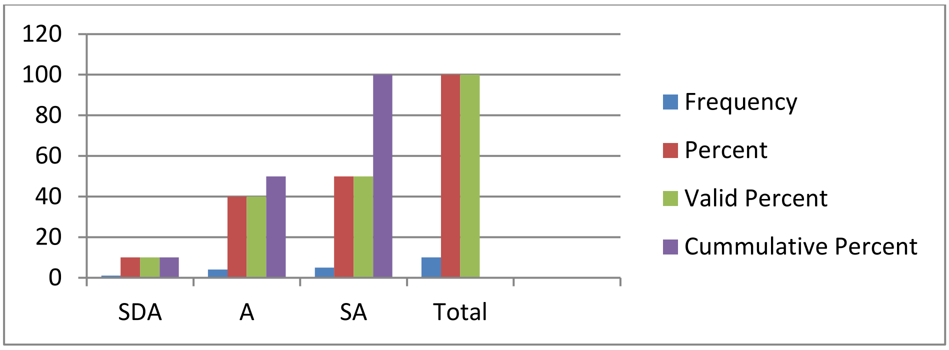


Figure 5.5: Layout Established

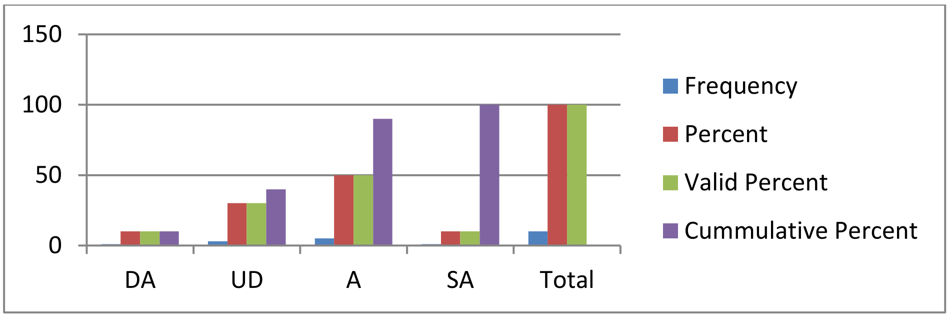


Figure 5.6: Standard Parameters

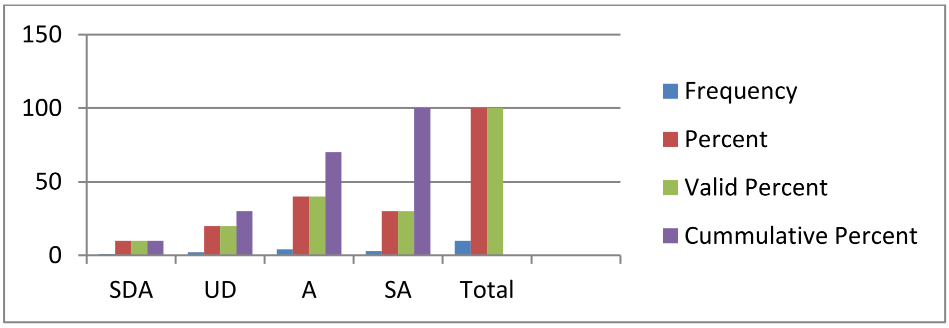


Figure 5.7: Procurement Policy

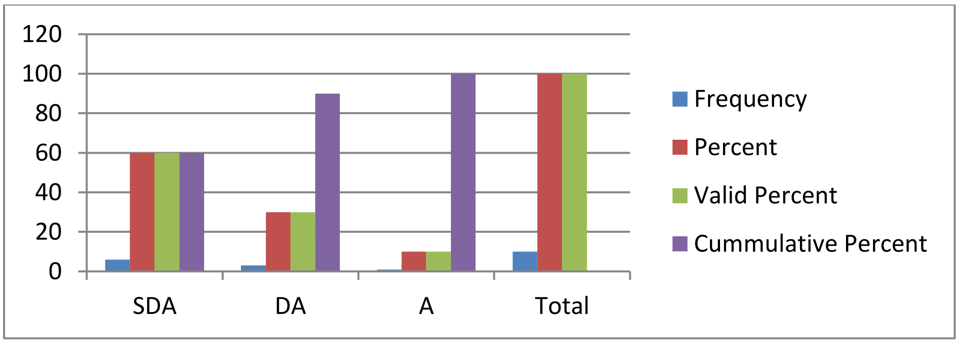


Figure 5.8: Risk Based Thinking

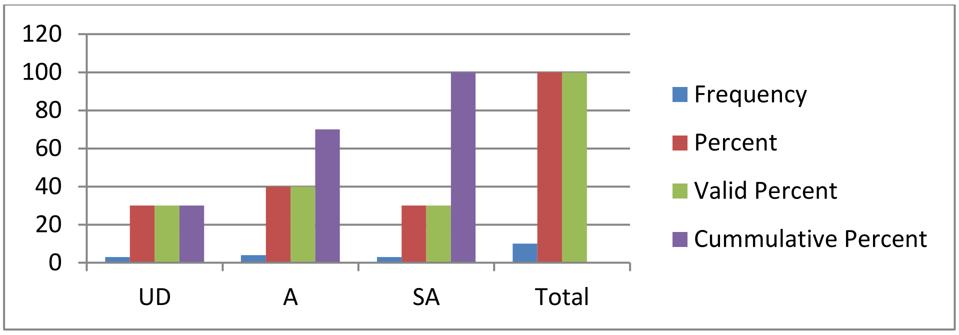


Figure 5.9: Always Clear

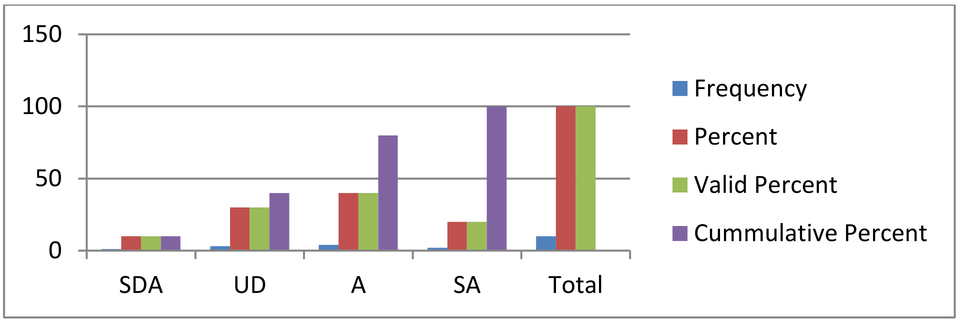


Figure 5.10: Outsourced activities

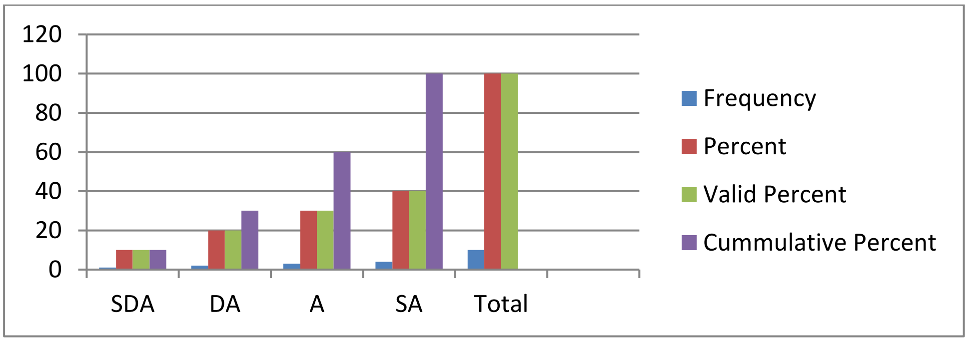


Figure 5.11: Work Monitored

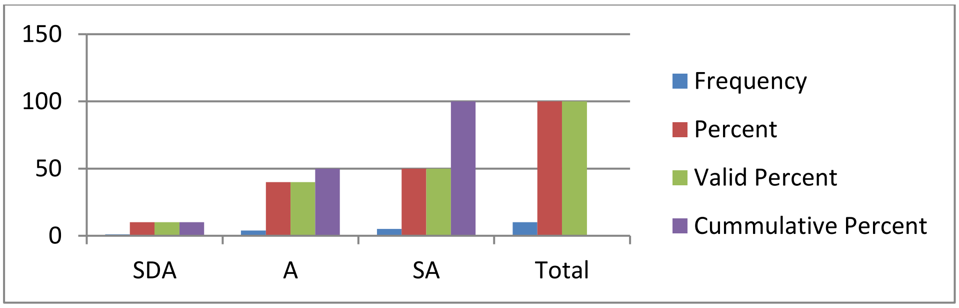


Figure 5.12: Formal and Informal

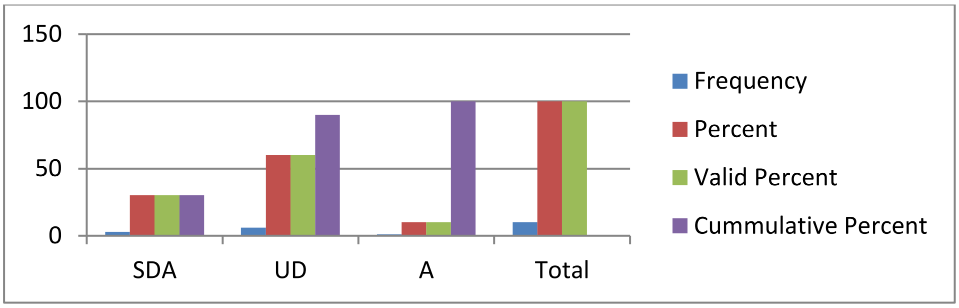


Figure 5.13: Testing Process

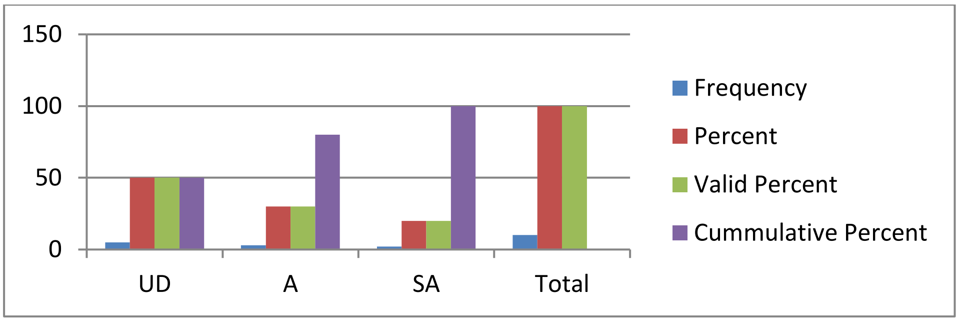


Figure 5.14: Recorded and measured

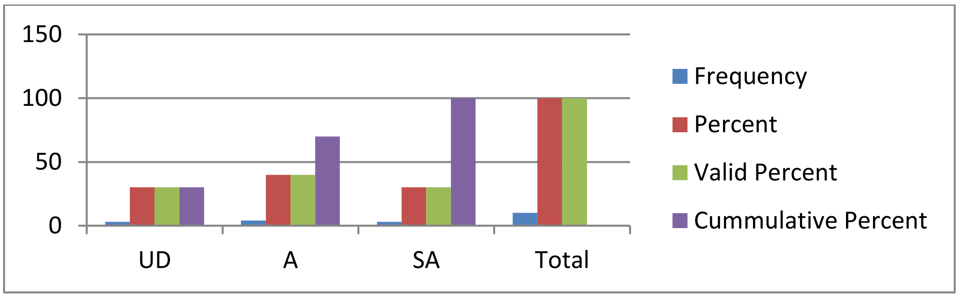


Figure 5.15: Evaluated Prior

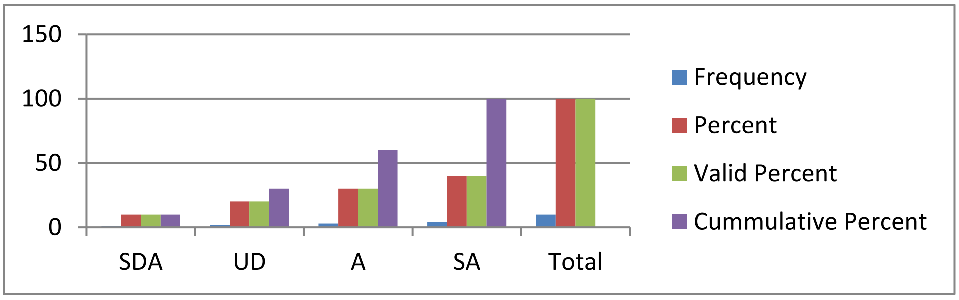


Figure 5.16: Previous Project

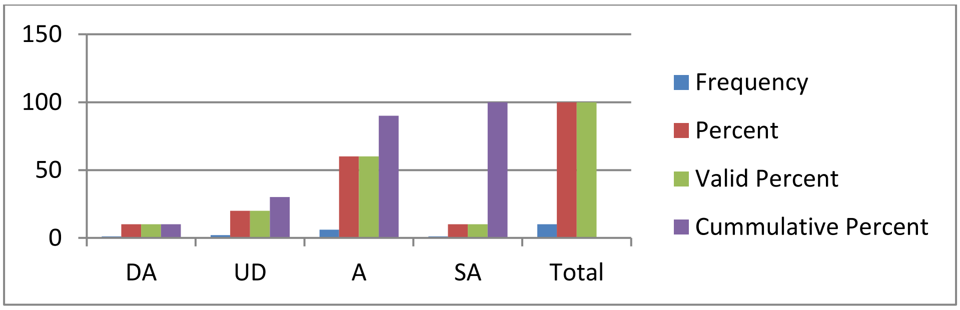


Figure 5.17: Resolve immediately

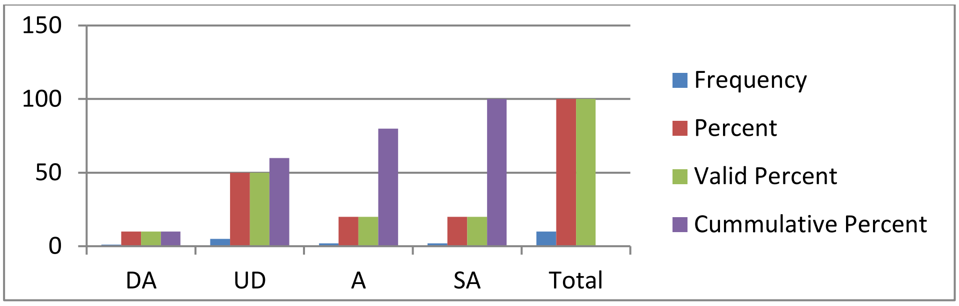


Figure 5.18: Project Tracking

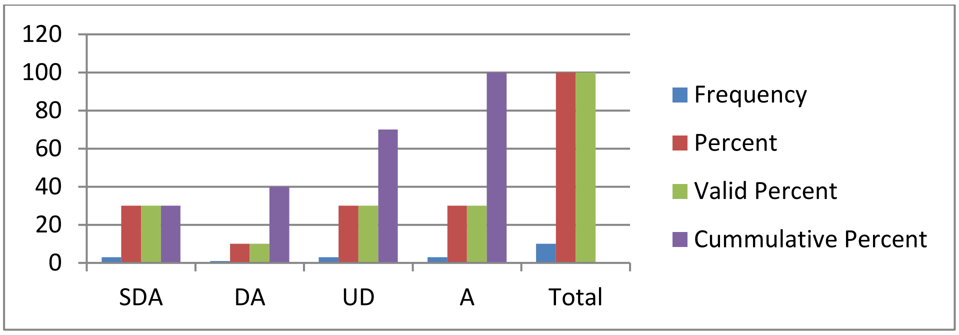


Figure5. 19: Preserved as required

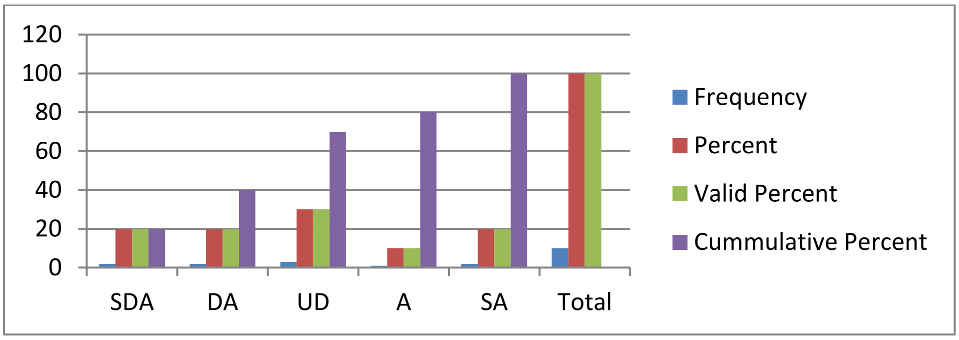


Figure5. 20: Improve Existing

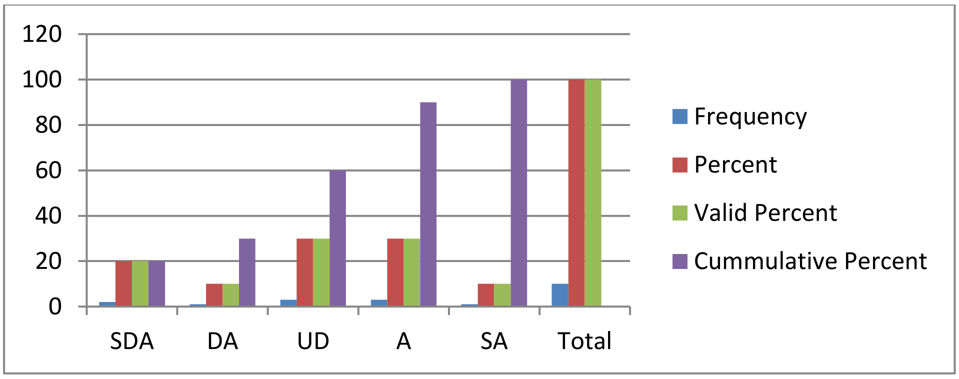


Figure 5.21: Have Work

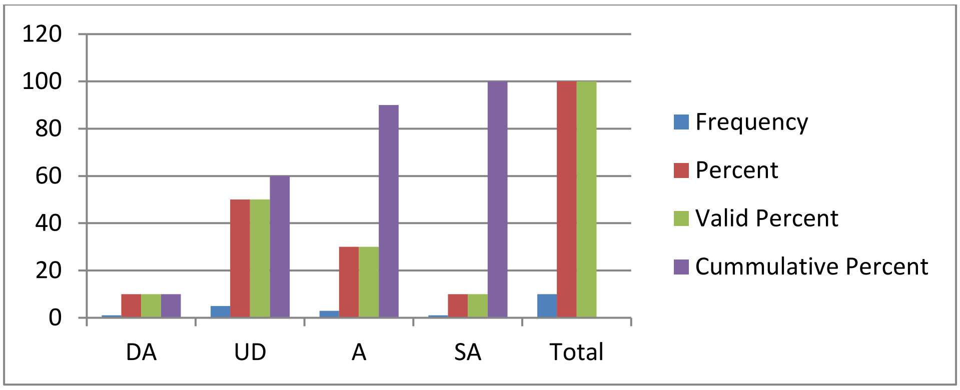


Figure 5.22: Evaluation Performed

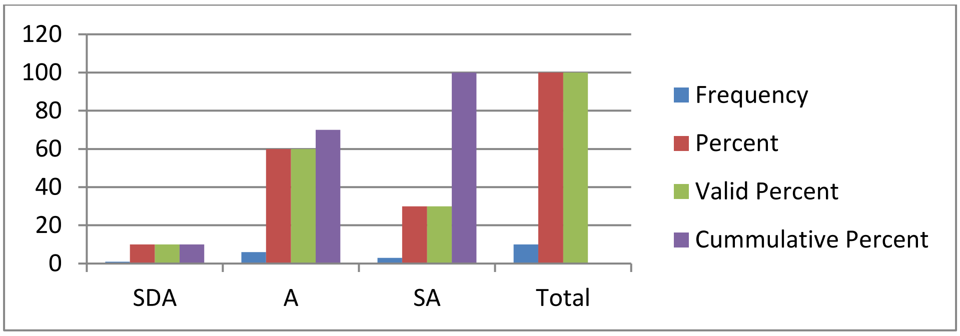


Figure 5.23: Product Testing

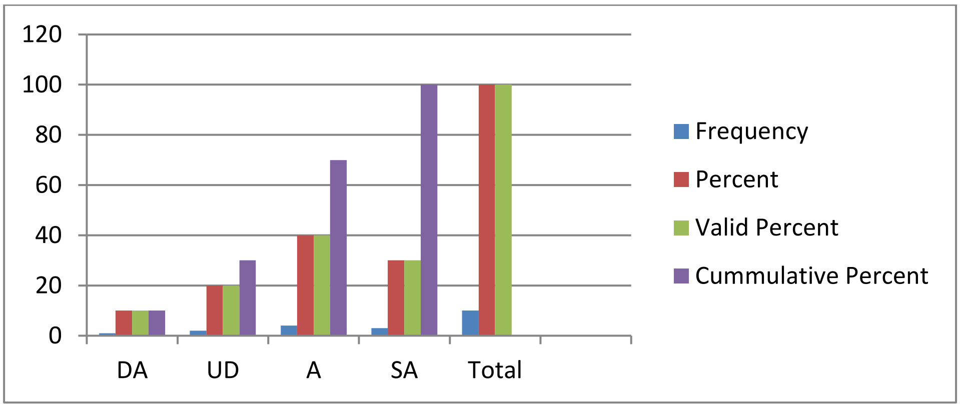


Figure 5.24: Supplier evaluation

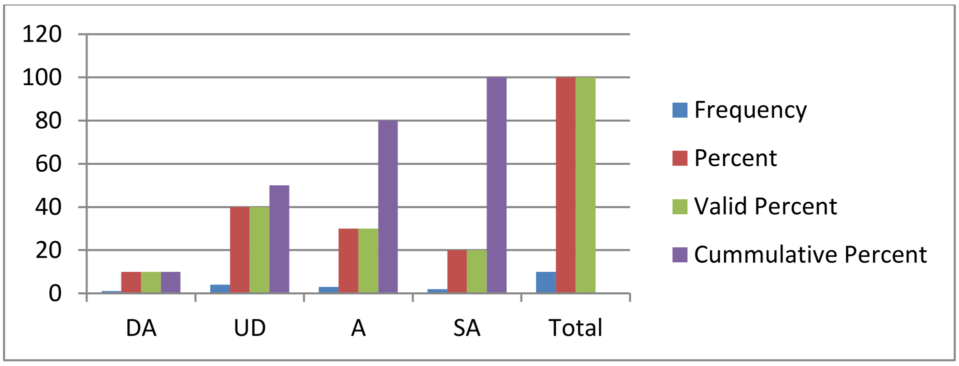


Figure 5.25: Testing station

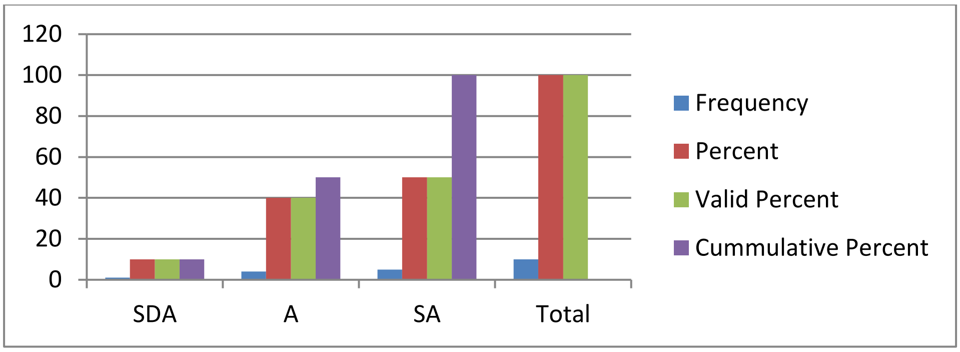


Figure 5.26: Control Outsource

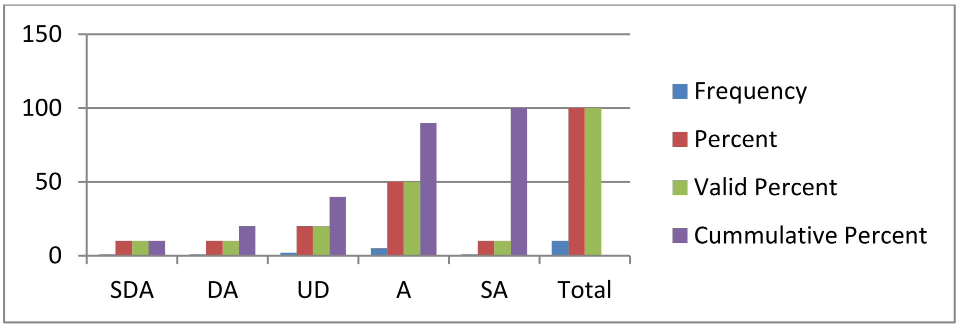


Figure 5.27: Information documented

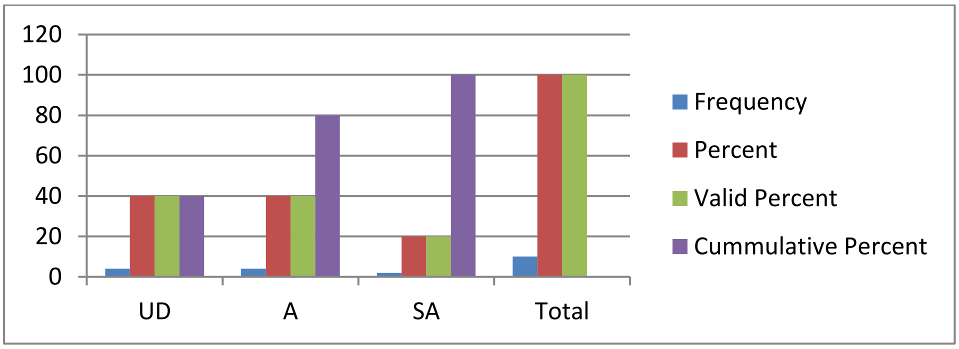


Figure 5.28: Record machine usage

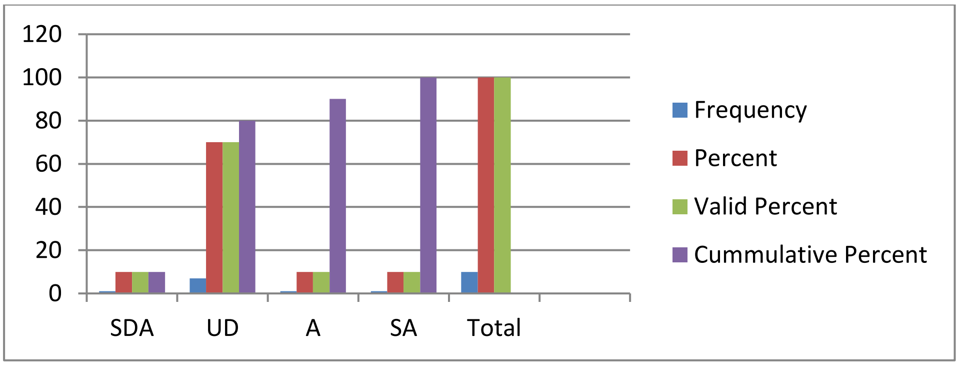


Figure 5.29: Access to information

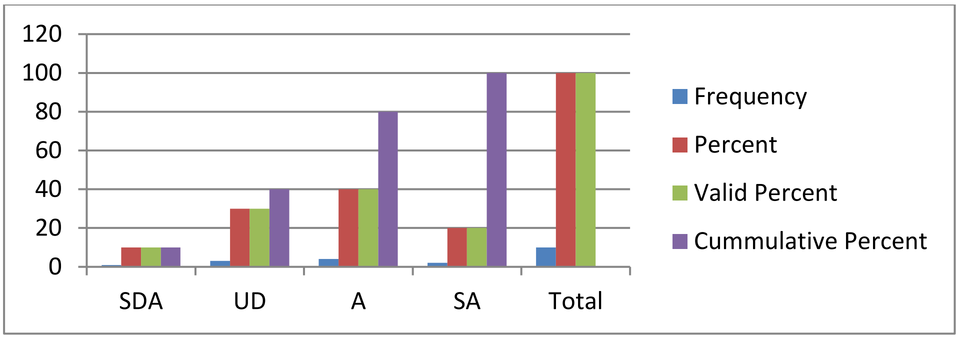


Figure 5.30: Space qualified

APPENDIX L: DESCRIPTIVES VARIABLES FROM Q1 - Q30 AND STATISTICS=MEAN, STDDEV, MIN & MAX.

DESCRIPTIVES VARIABLES=Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 Q23 Q24 Q25 Q26 Q27 Q28 Q29 Q3/STATISTICS=MEAN STDDEV MIN MA/SORT=MEAN (D).

Descriptive

Notes

Output Created		11-MAY-2017 11:15:08
Comments		
Input	Data	C:\DELL E4310\@LaCie\Research\Research Postgraduate\Masters\CPUT\2017\Nkonzo Zukisa\Data View -08-05-2017 /Zukisa Nkonzo.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	10
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20 Q21 Q22 Q23 Q24 Q25 Q26 Q27 Q28 Q29 Q30/STATISTICS=MEAN STDDEV MIN MAX /SORT=MEAN (D).
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.03

Descriptive Statistics

CODES	N	Minimum	Maximum	Mean	Std. Deviation
layout establised	10	1.00	5.00	4.2000	1.22927
control outsourced	10	1.00	5.00	4.2000	1.22927
formal and informal	10	1.00	5.00	4.2000	1.22927
product testing	10	1.00	5.00	4.0000	1.15470
evaluated prior	10	3.00	5.00	4.0000	.81650
always cleare	10	3.00	5.00	4.0000	.81650
supplier evaluation	10	2.00	5.00	3.9000	.99443
previous project	10	1.00	5.00	3.9000	1.28668
different components	10	2.00	5.00	3.9000	.99443
procurement policy	10	1.00	5.00	3.8000	1.22927
record machine usage	10	3.00	5.00	3.8000	.78881
resolved immeditely	10	2.00	5.00	3.7000	.82327
recorded and measured	10	3.00	5.00	3.7000	.82327
work is monitored	10	1.00	5.00	3.7000	1.49443
standard parameters	10	2.00	5.00	3.6000	.84327
space qualified	10	1.00	5.00	3.6000	1.17379
testing station	10	2.00	5.00	3.6000	.96609
outsourced activities	10	1.00	5.00	3.6000	1.17379
project tracking	10	2.00	5.00	3.5000	.97183
delivered wrong point	10	2.00	5.00	3.5000	.97183
information documented	10	1.00	5.00	3.4000	1.17379
evaluation performed	10	2.00	5.00	3.4000	.84327
moves between stations	10	1.00	5.00	3.4000	1.17379
clean and organised	10	1.00	5.00	3.4000	1.34990
access to information	10	1.00	5.00	3.1000	.99443
have work	10	1.00	5.00	3.0000	1.33333
improve existing	10	1.00	5.00	2.9000	1.44914
preserved as equired	10	1.00	4.00	2.6000	1.26491
testing process	10	1.00	4.00	2.5000	1.08012
risk based thinking	10	1.00	4.00	1.6000	.96609
Valid N (listwise)	10				

APPENDIX M: CRONBACH ALPHA MEASURING INTERNAL CONSISTANCE RELIABILTY OF A QUANTITATIVE DATA.

Cronbach's Alpha	0.512925897
Split-Half (odd-even) Correlation	0.43428871
Spearman-Brown Prophecy	0.605580602
Mean for Test	108.1818182
Standard Deviation for Test	6.450062464
KR21	8.044744017
KR20	8.95359829

Reliability Calculator

created by Del Siegle (dsiegle@uconn.edu)

Questions	Subjects
30	11

	Question 1	Question 2	Question 3	Question 4	Question 5	Question 6
Subject1	2	1	2	3	3	1
Subject2	3	3	1	1	2	1
Subject3	1	5	2	1	3	4
Subject4	1	5	2	1	2	2
Subject5	3	5	1	1	3	2
Subject6	1	2	2	1	2	2
Subject7	2	4	2	1	2	1
Subject8	1	4	1	1	1	2
Subject9	3	4	1	1	1	4
Subject10	3	2	2	1	2	2
Subject11	3	5	2	2	2	4
Subject12						

Question 7	Question 8	Question 9	Question 10	Question 11	Question 12	Question 13	Question 14
4	5	5	5	3	3	3	5
4	4	4	5	4	4	4	4
5	5	5	5	1	3	1	5
5	5	5	5	1	4	1	5
5	4	5	5	1	3	1	5
5	5	5	5	4	5	2	5
4	5	5	5	2	3	2	5
5	5	5	5	4	5	2	5
5	5	5	5	1	4	1	5
4	5	5	5	2	4	5	5
5	4	5	5	1	3	1	5

Question 15	Question 16	Question 17	Question 18	Question 19	Question 20	Question 21	Question 22
4	4	3	5	4	5	5	4
4	4	4	4	4	4	4	4
5	5	2	5	5	3	5	5
5	4	2	5	5	2	5	4
5	5	4	4	5	2	5	5
5	5	3	4	4	4	5	4

4	4	3	5	4	4	5	4
4	5	3	5	4	5	5	5
5	5	1	5	3	1	5	5
5	5	4	5	5	4	5	3
5	5	4	4	5	2	5	5

Question 23	Question 24	Question 25	Question 26	Question 27	Question 28	Question 29	Question 30
2	2	2	4	4	2	2	4
4	4	5	3	4	4	5	5
3	2	3	5	4	3	3	3
3	2	2	5	4	3	3	3
5	5	5	5	5	5	4	3
2	2	3	5	5	2	5	5
4	3	2	4	5	3	3	4
4	2	4	4	4	3	4	3
3	2	2	5	4	2	2	3
3	3	3	5	5	4	4	5
5	5	5	5	5	5	4	3