A Knowledge Sharing Framework for Improving the Testing Processes in Global Product Development

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This research programme was carried out in collaboration with Cummins Power Generation Kent.

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DECLARATION

"I certify that this work has not been accepted in substance for any degree, and is not concurrently being submitted for any degree other than that of Doctor of Philosophy being studied at the University of Greenwich. I also declare that this work is the result of my own investigations except where otherwise identified by references and that I have not plagiarised the work of others."

Joseph Paul Zammit

Professor James Gao

Supervisor

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ABSTRACT

In new product development, knowledge is the key to innovation. In order to remain competitive in today's engineering world, knowledge is a crucial asset for organisations that enable them to gain a sustainable competitive edge. An extensive industrial investigation has been conducted in this project to bring out real industrial requirements in the product development and testing context within the collaborating company. Based on the industrial investigation and literature survey, the research direction is identified, i.e., to develop methodologies to capture and share testing related knowledge to address the special nature and application context of the integrated global product development and testing operations of multi-national companies. Currently, engineering companies are still mainly using traditional information systems with structured databases such as computer aided engineering, enterprise resource planning and product lifecycle management systems. This project explores whether the fast developing social media tools are capable of facilitating the capture and sharing of employee knowledge, especially tacit and un-structured knowledge, and addressing the social aspects of knowledge management. The project also explores the benefit of using a knowledge framework that is directly driven by the knowledge users by providing both knowledge content and how it is structured, rather than relying on the role of knowledge administrators. The developed methodology with social media, video sharing and storytelling techniques would substantially enhance and extend the capabilities of traditional engineering knowledge management tools, by providing the ability to quickly browse and absorb user-contributed testing knowledge, like lessons learned, suggested product improvement or process training material, and identify specific knowledge experts within an global organisation. A comprehensive case study has been conducted within the collaborating company to validate the usefulness and effectiveness of the developed methodology. While keeping the collaborating company's requirements in mind during the research, the developed methodology and tools can also be applied in other product development and engineering business environments as an enabling tool to promote collaboration, learning and knowledge sharing in global operations.

PUBLICATIONS

Journal Papers

Zammit J., Gao J., Evans R., (2016) Development of a Knowledge Sharing Framework for Improving testing processes in Global Product Development. International Journal of Product Lifecycle Management.

Conference Papers

Zammit J., Gao J., Evans R., (2016) Capturing and Sharing Product Development Knowledge using Storytelling and Video Sharing. DET 2016 - The 9th International Conference on Digital Enterprise Technology. Nanjing, China, 29 -31 March 2016.

Evans R., Zammit J., Wang G., El Souri M., (2016) Four-view analysis of the perceived organisational changes required to implement micro-blogging during product conceptualisation for capturing consumer conversations. DET 2016 - The 9th International Conference on Digital Enterprise Technology. Nanjing, China, 29 -31 March 2016.

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GLOSSARY

BPD:	Business Process Diagram
BPM:	Business Process Model
BPMN:	Business Process Model and Notation
CAD:	Computer Aided Design
CAD/CAM:	Computer-Aided Design / Computer-Aided Manufacturing
CAE:	Computer Aided Engineering
CE:	European Conformity
CMS:	Content Management System
CPGK:	Cummins Power Generation Kent
DVP&R:	Design Verification Plan & Report
DR:	Design Roadmap
.DOC:	A Word Processing Document
ERP:	Enterprise Resource Planning
EU:	European Union
GDP:	Gross Domestic Product
GLIMS:	Global Lab Information Management System
HTML:	HyperText Mark-up Language
H&S:	Health and Safety
ICT:	Information and Communication Technology
ISP:	Internet Service Provider
IT:	Information Technology
KBE:	Knowledge Base Engineering
KM:	Knowledge Management
KMS:	Knowledge Management System
KRF:	Knowledge Request Form
KVA:	Kilo Volt Ampere
kW:	Kilowatt
MUMS:	Metric Utilization Monitoring System
NPD:	New Product Development
OEM:	Original Equipment Manufacturer
PD:	Product Development

PHP:	Hypertext Pre-processor
PLM:	Product Lifecycle Management
PPA:	Precisions Power Analyser
.PPT:	A PowerPoint Presentation Document
RPM:	Revolutions per Minute
RV:	Recreational Vehicle
R&D:	Research and Development
R&T:	Research and Technology
SME:	Small and Medium Enterprise
SMED:	Single Minute Exchange of Die
TAM:	Technology Acceptance Model
TUV:	Technical Inspection Association
UL:	Underwriters Laboratories
UML:	Unified Modelling Language
VPI:	Value Package Introduction
WWW:	World Wide Web
WYSIWYG:	What You See Is What You Get
.XLS:	An Excel Spread Sheet Document

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Chapter 1: Introduction

In this Chapter, the general trends and current challenges of the UK and global manufacturing industry are discussed. An introduction is provided to the industrial requirements and issues that this project will be addressing, aiming to reduce the product development cycle in a sustainable and smart way in order to get to the market quickly. The importance of communication and knowledge sharing in new product development is also discussed. The aim and objectives of this research are presented, and the structure of this thesis is explained.

1.1 Importance of the Manufacturing Industry

In the world today, there are approximately 7.3 billion people (Worldometer 2015) contributing to a global Gross Domestic Product (GDP) of £50.6 trillion (World_Bank 2015). While the UK has a population of 64.1 million, only 46.4% of the population, amounting to 29.8 million people, actively contribute £1.8 trillion towards the UK GDP (Penfold and Foxton 2015, World_Bank 2015).

During the last few decades, manufacturing industry has reduced its influence on most Western countries' GDP, although it still remains an important contributor to the world economy which amounts to £ 6.7 trillion. Specifically in the UK, manufacturing industry employs approximately 2.6 million people (Manufacturer 2014) and accounted for 10% of the UK GDP in 2014, which in real terms is about £180 billion of national economic output (World_Bank 2015). Contrary to common belief, UK manufacturing is strong and currently sits as the 11th largest manufacturing nation in the world. In the last decade, manufacturing industry has underperformed and suffered a significant decline during the 2008/09 recession. After a short period of growth, it declined again in early 2012. More recently, however, economic data suggests that manufacturing industry is showing significant signs of strengthening and growing, both in the UK and globally. Each year more than 70% of business research and development goes into the manufacturing sector, and goods produced in the sector account for nearly half of all UK exports (Rhodes 2014).

Innovation and engineering research is the key to success in any manufacturing industry (Toole 2012). Manufacturing dominates UK Research and Development (R&D) spending; one of the reasons behind this is that manufactured goods account for a large share of total exports, amounting to 46% of the value of all exports. In 2013, manufactured goods were worth around £230.7 billion. In 2012, R&D spending in manufacturing totalled £12.2 billion, accounting for 72% of total R&D funding within the UK (Rhodes 2014).

1.2 Trends and Challenges in the Manufacturing Industry

Throughout history, mankind has always challenged current thinking and developed new ideas to innovate and improve existing manufacturing techniques and technologies in order for products to be manufactured in less time and more efficiently, fulfilling customer needs in the shortest time possible and increasing corporate customer base (Kemp 2013). This trend has been observed in constant progress in the manufacturing industry over the last 200 years. Looking back, the evolution of the manufacturing industry can be clearly defined by six main paradigm shifts, that of the craft industry, mass production, lean and agile manufacturing, digital manufacturing, knowledge-based manufacturing and the latest trend of the Smart Factories of Industry 4.0 (Audretsch and Thurik 1999, Chryssolouris, Mavrikios et al. 2009, Brettel, Friederichsen et al. 2014). Originated from a project of high-tech strategy by the German government, which promotes the computerization of manufacturing, the main phases of manufacturing evolution is summarised and is shown in Figure 1.

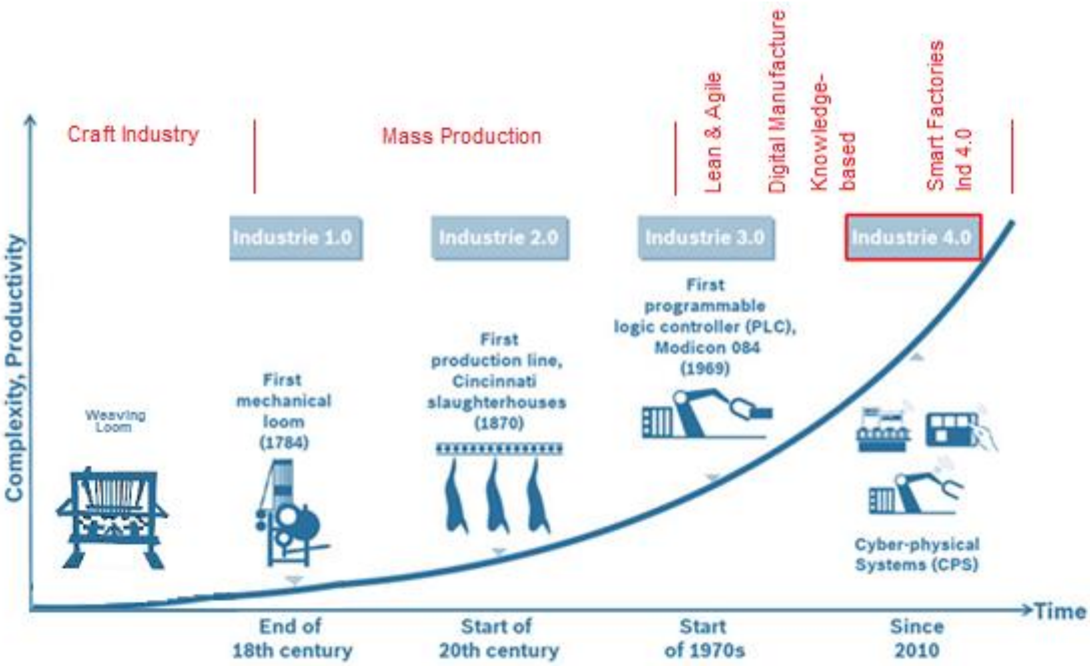


Figure 1. Evolution of Manufacturing adapted from (Heng, Slomka et al. 2014)

The first form of manufacturing, before the start of the industrial revolution, consisted of the craft industry, in which small quantities of products were produced by highly skilled craftsmen (Industrie 1.0 in Figure 1). These products were typically very costly, resulting in only a few people being able to afford them, making the overall market very small (Bartholdi III and Eisenstein 2005). Once the industrial revolution had started, the concept of mass production emerged (Industrie 2.0 in Figure 1). Mass production involves making many copies of a product, very quickly, using assembly lines to move partially complete products between workers who each work on an individual step, rather than having a worker assembling a whole product from start to finish. This manufacturing technology, quickly changed the socioeconomics of the world by creating standardized and cheaper products and, at the same time, increased the market segment because more people could afford these new products rolling off the production line (Alptekinoglu and Corbett 2008).

The next paradigm shift involved companies exploring methods for reducing resources required during manufacturing. The philosophy of ‘Lean Manufacturing’ is to create added value with less work. Lean manufacturing is a management philosophy derived in part from the Toyota Production System and identified as ’Lean‘ only in the 1990s (Womack, Jones et al. 1990, Holweg 2007, Monden 2011). Toyota’s Production System is renowned for its focus on the reduction of the original Toyota seven wastes to improve overall customer value. However, there are varying perspectives on how this is best achieved. The steady growth of Toyota, from a small company to the world's largest car maker (Bailey 2008), has focused greater attention on how they have achieved this success.

The next manufacturing trend developed was that of ‘Agile (and flexible) Manufacturing’. This was a reaction from the US manufacturing industry in response to the Lean philosophy (Kidd 1996, Inman, Sale et al. 2011). Agile manufacturing is a recent concept and has been advocated as the 21st century manufacturing paradigm. It is seen as a successful strategy to be adopted by manufacturers bracing themselves for dramatic performance enhancements to become national and international leaders in an increasingly competitive market of fast changing customer requirements (Yusuf, Sarhadi et al. 1999, Wu, Thames et al. 2012). (Lean and Agile manufacturing can be regarded as the later stage of Industrie 2.0. in Figure 1).

The most recent manufacturing paradigm being developed is that of digital manufacturing (Industrie 3.0 in Figure 1). Digital manufacturing utilizes Computer-Aided Engineering (CAE) technology for virtualization of plants, buildings, resources, equipment, workers, and skills through modelling and simulation, as well as for product and process development (Chryssolouris, Mavrikios et al. 2009). Moreover, digital manufacturing is described as the technology through which manufacturing knowledge can become formalized and as the technology that can fill the gap between the definition about the product and the actual manufacturing. Westkämper (2007) stated that digital manufacturing is the core technology and key modernized tool for engineering and control, supervision, and management in the global manufacturing age.

Knowledge-based manufacturing can be regarded as the transition from Industrie 3.0 to 4.0, where expert, theoretical and historical knowledge are embedded into knowledge-based systems in a way that automates and supports decision making in design, process planning and the whole product lifecycle, which in-turn, produces more sustainable manufacturing methods (Giovannini, Aubry et al. 2012). Complex tasks in the manufacturing industry are normally undertaken by expert manufacturing planners/engineers, but the idea of knowledge-based manufacturing is that these expertise should be embedded into a system, whatever the complexity of the problem the knowledge-based system is intended to solve (Vosniakos and Giannakakis 2013).

Anderl (2014) described Industrie 4.0 as a strategic approach for integrating advanced control systems with internet technology enabling communication between people, products and complex systems (Industrie 4.0 in Figure 1). The term refers to the fourth industrial revolution and is often understood as the application of the generic concept of Cyber Physical Systems (CPSs) to industrial production systems (cyber physical production systems) (Drath and Horch 2014).

Manufacturing Industry has not been limited to changing the methods in which products are manufactured, but has evolved into where industries are located. During the 18th century, most industries were located in Western Europe, mainly due to the industrial revolution started in the United Kingdom and, at the time, labour work forces were low in cost. However, throughout time, this has evolved and the tendency in the last decades has been for companies to shift their manufacturing operations to emerging markets, such as eastern bloc countries, including China, India and Brazil. This has been mainly driven by reduced operating costs found in these countries which are still low enough to mitigate the logistical costs of shipping finished products to the European markets. European industries therefore now need to compete with these emerging economies to remain competitive and drive innovation to create new growth and jobs in Europe. One of the main European Union directives; Horizon 2020, is a research and innovation programme with a budget of €80 billion aimed solely at securing Europe's global competitiveness (Horizon2020 2015) by providing funding for every stage of the innovation process from basic research to market uptake, in line with the EU's commitments under the "Innovation Union".

One of the ways to achieve this is to develop new and innovative ways of improving current processes and manufacturing methods to reduce product development time which in turn will result in getting the product to market first and, therefore, obtaining a larger market share (Horizon2020 2015). This drive to improve Europe's market position is not limited to product innovation and accelerated development time, but is also directed towards a more environmentally conscious Europe (Scoullos, Roniotes et al. 2012). Product quality and limiting the environmental impact are other challenging areas in product development and innovation being faced by the manufacturing industry.

1.3 Trends and Challenges in New Product Development and Testing.

Innovation and New Product Development (NPD) are critical to the success and sustainable competitiveness of manufacturing enterprises. NPD projects require different engineering disciplines such as Design and Product Development (PD) testing to combine and collaborate their efforts in order to achieve agreed goals (Kratzer, Leenders et al. 2010). PD testing is a critical part of the NPD, consuming a large portion of the PD cycle and in many cases can be the bottle neck in the project completion timing plan (Takeuchi and Nonaka 1986). The interactions between the different teams are crucial for any project to succeed, as in the collaborating company, who are dispersed in different countries around the world. Several issues can hinder communication, knowledge sharing and the sharing of ideas between different global engineering teams. This hindrance in communication and knowledge sharing can derive from simple aspects, such as geographical distances and time differences, to more complex issues such as cultural beliefs and cultural differences. Frost (2014) analysed in detail why failure in communication and knowledge sharing occurs, stating that although Knowledge Management (KM) has shown great promise since the early 90's, it is yet to be successfully tamed and controlled. Frost (2014) provided a list of the symptoms of the failure including: inadequate management support, problems with organisational culture, and lack of responsibility and ownership *inter alia*. From the literature and the investigation findings, there is clear evidence that industry sees potential and value in creating KM systems. But insufficient attention is given to it and it is sometimes treated as an after taught. In PD testing, the trend is to better manage and integrate testing centres and operations in the overall PD process by consolidating available resources (Hanks 2015), providing better visibility and sharing experiences to improve testing operations and cycle times.

The effective management of communication and knowledge sharing activities in global NPD teams, between different departments like design, purchasing and testing, requires sensitivity to the uniqueness of global product development. The capabilities of multiple types of communication mechanisms and an understanding of which of these mechanisms best meet a team's needs for information is a huge undertaking (McDonough, Kahn et al. 1999, Felekoglu, Maier et al. 2013).

Getting communication right between the different NPD teams and re-using the knowledge that already exists within a company can determine whether a new product is launched on time and/or on budget. Recreating and re-collecting the same knowledge for different projects is both costly and time consuming, which shows the importance of capturing and managing pre-existing knowledge already available among employees, so that further knowledge can be built upon it, which constitutes innovation. The lack of communication, understanding or requirements, timing, and sharing of knowledge is a challenge also faced by PD testing (Ward, Sobek et al. 2014). A further knowledge development aspect, which is being developed by all major Computer Aided Design (CAD) and Product Lifecycle Management (PLM) software companies, is the inclusion of social media in NPD (Evans, Gao et al. 2014). This enables NPD teams to go beyond the traditional NPD engineering teams and gain access and develop knowledge from a different perspective, promoting brainstorming and bouncing off ideas within a larger audience environment, which ultimately can provide the end user with greater valuable input to product development projects. However, as with all new ideas, this trend is still being developed.

The focus of this project is to propose a framework to capture employee testing knowledge so that it can be easily shared and made accessible to colleagues to improve efficiency, and allow PD team and testing team to work and share knowledge timely. The notion that everyone in a company is an expert in one field or another, dictates that anyone should be able to contribute to a knowledge system in order to enrich the company’s collectively knowledge (Wilkesmann and Wilkesmann 2011). A secondary target is to improve communication within the NPD team. This has been attempted by improving the accessibility of the shared knowledge and by using social media tools as a way to encourage people into engaging into knowledge discussions and enhance trust amongst employees (Harden 2012).

1.4 Knowledge and Innovation in New Product Development and Testing

Knowledge is the key to innovation and in order to remain competitive in today's engineering world, it is a crucial asset for organisations that enables them to gain a sustainable competitive edge on their competitors (Grant 1996, López-Nicolás and Meroño-Cerdán 2011). Improving and creating new ways for how knowledge is captured and shared amongst NPD engineering teams will determine if companies can capitalize on this valuable, readily available resource. This statement cannot be more truthful when it comes to NPD projects where innovation is the critical ingredient that enables cutting edge products to be developed. In PD testing, capturing and sharing testing related knowledge to address the special nature and application context of the integrated PD and testing operations is a challenge. Various situations arise during PD testing in which complex information needs to be captured and shared with the team, for scenarios for training or share experiences or scenarios to improve or correct an issue, highlighting the problems in the products or facilities.

Knowledge management is a discipline that promotes an integrated approach to identifying, capturing, evaluating, retrieving, and sharing all of an enterprise's information assets. These assets may include databases, documents, policies, procedures, and previously uncaptured expertise and experience from individual workers (Duhon 1998, Meihami and Meihami 2014). Over the years, various KM systems have been developed and have taken many forms, such as purpose-built databases, data capture and workflow solutions, social analytics and engagement solutions or content life cycle management systems; these are all described as process driven solutions.

It has been shown, through the literature available, that knowledge sharing provides individuals, teams and organisations with the opportunity to improve their work performance as well as creating new ideas and innovations (Cummings 2004). This clearly indicates that sharing knowledge is primarily a social, interactive and complex process that involves both tacit and explicit knowledge (Polanyi and Sen 2009). The challenges for knowledge management initiatives are finding solutions to people-centric problems, such as motivations and personality factors and creating organisational antecedents to ensure a smooth knowledge flow (Von Krogh and Roos 1996, Wiig 2012) through the organisation.

Innovation consists of successfully implanting creative ideas within an organisation (Myers and Marquis 1969, Lakhani, Lifshitz-Assaf et al. 2012) and is, therefore, closely related to organisational learning. Innovation conceived in this field is considered as an individual or collective learning process that is aimed at finding new ways of solving problems (Alegre and Chiva 2008). Knowledge sharing has received considerable attention over the years (Eisenhardt and Santos 2002), due to it being vital for innovation, organisational learning, the development of new skills and capabilities, increased productivity and maintaining a competitive advantage (Von Krogh 1998, Mooradian, Renzl et al. 2006), which are all key elements that will be utilized for the knowledge capturing and sharing framework developed for product testing facility developing and testing NPD projects.

During product development and product development testing, knowledge is the key to innovation, in order to remain competitive. It is a crucial asset for organisations that enables them to gain a sustainable competitive edge over their competitors. Improving and creating new ways for how knowledge is captured and shared amongst PD engineering teams will aid companies to capitalize and make this valuable, readily available resource, accessible for their employees. The ability to quickly browse and absorb user-contributed testing knowledge like lessons learned, suggested product improvement or process training material and identify those knowledge experts within an organisation is what provides this competitive advantage.

1.5 Proposed Research Area

A pilot literature search for *NPD*, PD, Time to Market and Knowledge Sharing identified that a substantial number of publications had emphasised the importance of shortening product life cycles and bringing products to market first in order to establish competitive advantage and gain greater market share before competitors enter the market (Cooper, Edgett et al. 2001, Minderhoud and Fraser 2005, Afonso, Nunes et al. 2008, Richtnér, Åhlström et al. 2014). However, in the literature survey, it was found that reported research work primarily focused on product design and manufacturing. This indicated that there is a gap in the niche field of product development testing which is of high value and, although the testing processes are repetitive, the nature of the testing is complex and typically one-off. Consequently, this seems to be overlooked by previous research projects. However, product testing and design validation is a major time consumer within the NPD cycle, and streamlining this process and improving testing knowledge sharing will reduce time to market while still keeping quality and reliability right at the first time (Lu, Loh et al. 2000, Feng, Sun et al. 2012). Since the reviewed literature has not reported much in-depth investigation into bringing out real industrial requirements in the PD testing context, this will be explored in this project.

In any engineering process, streamlining methods and procedures only go so far. Communication and the sharing of information between project team members, both on site and global stakeholders, is crucial in order to avoid miscommunication and misunderstanding, which could easily arise causing costly and timely delays for the product development cycle which is clearly indicated in research literature (Alavi and Leidner 2001, Bhatt 2001, Becker and Zirpoli 2003, Kušar, Duhovnik et al. 2004, Mohannak 2013).

Following the identification of the issues mentioned above, this research project will focus on investigating and developing a methodology to improve communication and the capture and sharing of testing knowledge to enable a product development testing team to address the special nature and application context of the integrated PD and testing operations.

1.6 Research Aim and Objectives

The aim of this research is to investigate how a product development testing facility's performance can be improved by developing and implementing a knowledge sharing and capturing framework, with the potential that it will be adopted by multiple sites in different geographical locations on a global scale by multi-national manufacturing enterprises, such as the collaborating company. This should reduce the time to market of the product development cycle. To meet the above aim, the following research objectives are planned:

i. To investigate industrial requirements of knowledge management for product development focusing on testing operations in multi-national manufacturing companies and comparisons with other industries by literature survey;

ii. To investigate previous theoretical and industrial methods and current research into the representation and analysis of testing related knowledge, and tools to improve communication;

iii. To propose a new methodology for capturing and sharing PD and testing employees knowledge, and addressing the social aspects of using advanced information and communication technologies such as social media, video sharing and storytelling;

iv. To design and develop a prototype framework and methodology to improve communication and sharing of knowledge within the testing teams of multi-national companies and their main stakeholders in product design, in order to reduce the overall time to market; and

v. To carry out an industrial case study of the created methodology to evaluate and verify the benefits from the proposed framework and knowledge capturing and sharing methodologies in the context of the collaborating company.

1.7 Research Scope

The scope of this research is in PD testing for complex engineering products, such as high power electrical generators which are considered as high value engineering products. The research will explore the theory of knowledge management, including the capture of employee knowledge and the communication and sharing of the captured knowledge as a means to improve product development testing processes, mainly within the PD testing facility and the product development team and other related functions that support the PD testing facility before, during and after product testing. Knowledge to be captured includes knowledge which is limited to a single employee, as well as knowledge from processes and producers. This knowledge should be captured in a rich media format that can be shared with others within the organisation locally and globally.

1.8 Collaboration with Industry

This project was industry-based, being conducted in collaboration with Cummins Power Generation, Kent, with the aim of improving the performance of their PD testing facility.

1.8.1 Introduction to the Collaborating Company

Cummins Inc. is a global power leader and a corporation of complementary business units that design, manufacture, distribute and service engines and related technologies, including fuel systems, controls, air handling, filtration, emission solutions and electrical power generation systems. The company is headquartered in Columbus, Indiana, (USA), and employs approximately 54,600 people worldwide, serving customers in approximately 190 countries and territories through a network of more than 600 company-owned and independent distributor locations and approximately 7,200 dealer locations. Cummins earned a net profile of $1.65 billion on their sales of $19.2 billion in 2014. Today, Cummins is a multinational Fortune 500 company that operates and serves customers around the globe (Cummins 2015).

Cummins' roots are planted in soil nourished by innovation, persistence and a commitment to the community. Founded in Columbus, Indiana, in 1919 as Cummins Engine Company, for its namesake Clessie Lyle Cummins, the fledgling firm was among the first to see the commercial potential of an unproven engine technology invented two decades earlier by Rudolph Diesel. After a decade of fits and starts, during which time the diesel engine failed to take hold as a commercial success, a stroke of marketing genius by Clessie Cummins helped save the Company and slowly increase their market share (Cummins 2015).

Cummins Inc. is organised into four distinct but complementary business units shown in Figure 2. ***Cummins Engine Business*** manufactures and markets a complete line of diesel and natural gas-powered engines for on-highway and off-highway use. Its markets include heavy-and medium-duty truck, bus, recreational vehicle (RV), light-duty automotive and a number of industrial uses including agricultural, construction, mining marine, oil and gas and military equipment. Cummins Engine Business also provide a full range of new parts and services, including remanufactured parts and engines through an extensive distribution network.

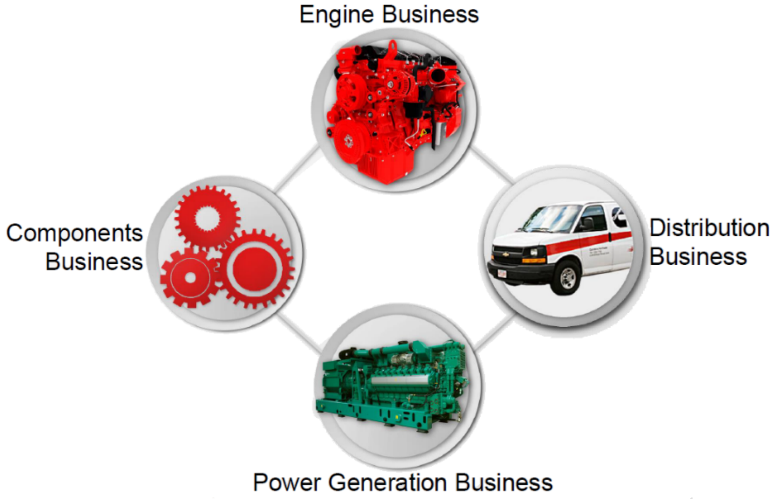


Figure 2. Cummins Inc. Business units (Cummins 2015).

Cummins Power Generation Business is a global provider of power generation systems, components and services in standby power, distributed power generation, as well as auxiliary power in mobile applications to meet the needs of a diversified customer base. The ***Components Business*** Segment consists of four businesses: Cummins Filtration, Cummins Turbo Technologies, Cummins Emission Solutions and Cummins Fuel Systems. ***Cummins Distribution Business*** drives a comprehensive global distribution strategy and channel management. Capitalizing on synergies in parts and services, the business helps Cummins by providing support to our customers, while growing a less cyclical and less capital intensive business.

1.8.2 Introduction to the Collaborating Company Products

Cummins Power Generation in Kent develops and manufactures power generation systems (called Gensets) which are either used for back-up power supply for power critical facilities, such as hospitals or direct electric generation for sites which are not connected to the power grid.

Apart from developing new products, the plant in Kent also manufactures them. It is predominantly an assembly line where it assembles different components in order to build up a complete standalone power generation system (Genset). This system in its simplest form is made up of 5 main components, which are: 1) the engine to drive the system, 2) the alternator which produces the electrical power, 3) the cooling pack which keeps the engine running at optimal temperatures, 4) a controller that manages all of the different components, and finally 5) the skid on to which all of the above mentioned components are assembled; this assembly is shown in Figure 3. The systems produced at Kent mainly vary from the type of fuel they run on (diesel units and gas units) and their output electrical range. The higher the horsepower the engine produces, the higher the electrical output will be. Figure 3 shows a QSK-60 Diesel Genset, to place things in perspective the below Genset measures 6.17mx2.2mx2.5m (LxBxH) and has a mass of approx. 14.8 tones and is able to produce an electrical power output in the range of 1200kW – 20000kW.

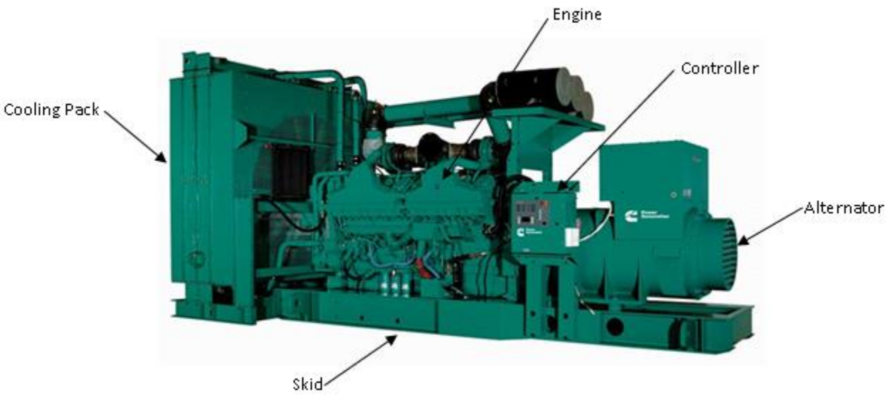


Figure 3. QSK-60 Diesel Genset (Courtesy of Cummins)

All of the components used to build up a Genset are delivered to the Kent Site as sub-assemblies. The majority of these sub-assemblies are designed and produced by other Cummins business units, all except for the cooling pack. The cooling pack is a large radiator similar to the one found in automobiles. The main function of the cooling pack is to keep the engine running at optimal temperatures in order to avoid overheating, which would ultimately result in engine failure.

The first observation noticeable of the product was that the majority of the components are designed and manufactured by different businesses at other locations within Cummins. This vertical integration should give the company more control on the development of the product and increase the design input from the upstream clients within the company, which should result in better quality components, but from comments received during initial discussions with testing facility staff, their input is not always considered, which is a lost opportunity to optimise product quality and functionality from the perspective of the product’s first users. The diagram shown in Figure 4 shows the different sub-assemblies and their logistical origin, which make up a Genset. All green boxes are businesses within Cummins, which indicates clearly the amount of control the company should have on the development of the different components it manufactures.

Cummins Power Generation Product Tree

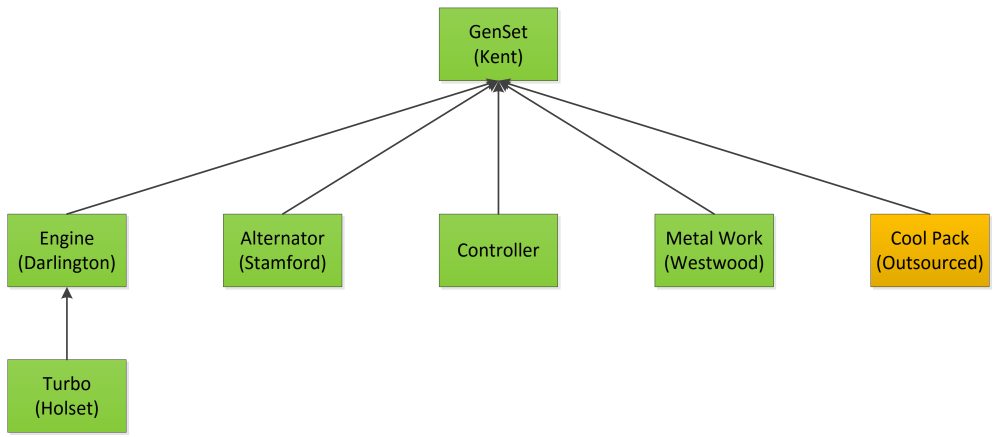


Figure 4. Cummins Genset Product Tree

1.8.3 Testing Facility in the Collaborating Company

The Cummins product testing and validation section in Kent is composed of 14 people divided into 4 categories: planning, testing, test systems and applied technology. This section is known as Lab Ops, which stands for Laboratory Operations and is responsible for all PD testing and validation. Figure 5 shows the sections and the human resource distribution amongst them. The planning section, as the name implies is the primary point of contact for development engineers to discuss projects which will require testing. Test systems engineers are responsible for the testing facilities and it is their job to ensure that the facilities are prepared for the Genset testing requirements.

Testing technicians are the engineers that run the development tests on the Gensets in the different test cells, while the people working in applied technology are the specialists in areas such as vibration, stresses, noise and Genset thermal performance which support the development testing in their defined areas.

This project is aimed at addressing the knowledge requirements of the testing facility and its main stakeholders that interact with them during the product development process.

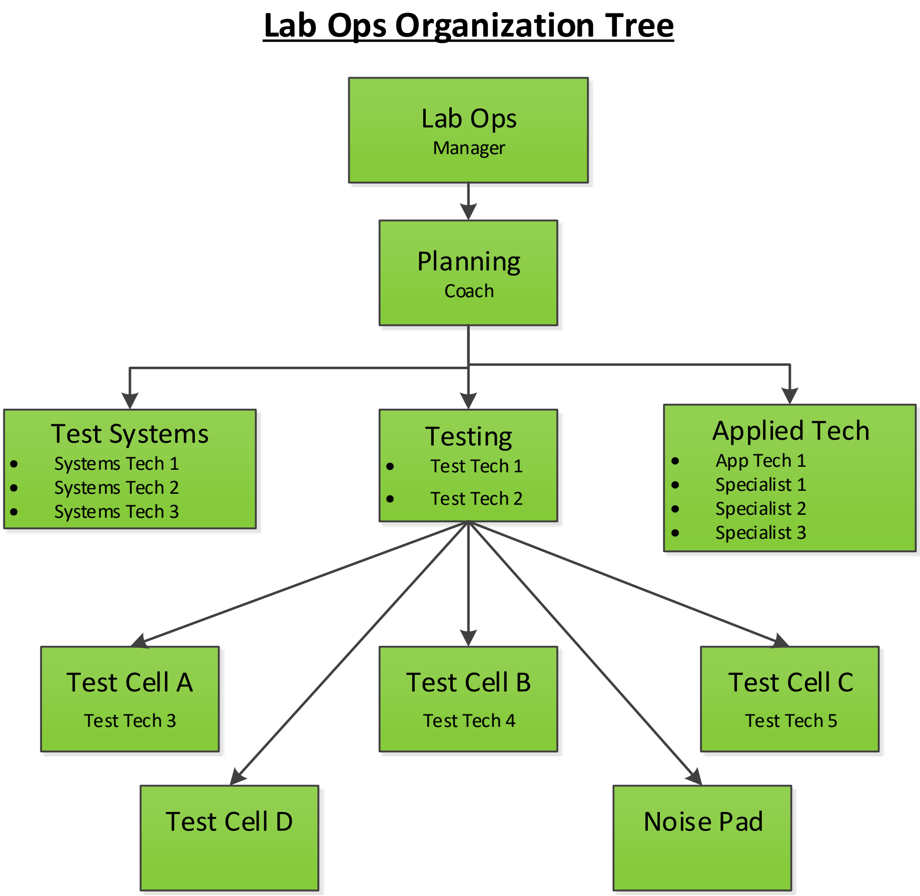


Figure 5. Lab Ops Organisation Chart

1.9 Thesis Structure

This thesis is structured in to eight Chapters. Chapter 1 (Introduction) explores the latest trends in manufacturing and highlights the importance of innovation in product development and manufacturing processes in order for companies to remain competitive and become a market leader. It then introduces the aim and scope of the project and goes on to introduce the collaborating company, in which this research is based.

Chapter 2 (Research Methodology) reviews currently available research methods and techniques, and describes the developed research methodology used to fulfil the research aim and objectives of this project.

Chapter 3 (Literature Review) identifies and describes relevant literature in the research domain, including communication, knowledge management, NPD and the modelling techniques utilized in this project. Further, it critically analyses the literature identified by first examining who, when and where the research is being conducted and then examines in more detail a selection of key papers in the relevant research fields.

Chapter 4 (Industrial Investigation and Findings) explains how the industrial investigation was conducted, the rationale behind the investigation, how data and information was collected, and further discusses the results of the industrial investigation.

Chapter 5 (The Proposed and Designed Knowledge Sharing Framework and its Implementation) introduces and discusses the proposed framework and the concepts behind it, and describes the developed knowledge sharing and collaboration tools and its implementation and functionality.

Chapter 6 (Knowledge Sharing Framework User Case) presents a storyline of an example / user case of the typical use of the knowledge sharing framework.

Chapter 7 (Validation of the Created Framework) presents and evaluates the outcomes of the case studies carried out at the collaborating company.

Chapter 8 (Conclusions and Future Work) reports on the conclusions of the research project and explores areas for further research.

Chapter 2: Research Methodology

The aim of this Chapter is to review the different research methods available, from which, it is possible to identify a suitable research approach and select appropriate methods for this research project.

First, a brief description and explanation of the term research methodology is provided. Following this, the research methods used in this project are described and justified. Finally, a brief explanation of the research project evolution is provided.

2.1 Definition of Research and Research Methodology

Research refers to a search for new knowledge, and can be defined as a scientific and systematic search for pertinent information on a specific topic. It is generally classified as an academic activity and comprises of defining and redefining problems, formulating hypotheses and/or suggesting solutions, and carefully testing the conclusions to determine whether they fit the formulating hypotheses (Kothari 2004). A similar definition of research was provided by Leedy and Ormrod (2005) who described research as a procedure by which one attempts to find systematically, and with the support of demonstrable fact, the answer to a question or the resolution of a problem. Manual (2014) also defined research as "creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. Looking further into the field of business administration, Uma and Roger (2003) defined business research as an organised, systematic, data-based, critical, objective, scientific inquiry or investigation into a specific problem, undertaken with the purpose of finding answers or solutions to it. In essence, research provides required information to further knowledge in a systematic manner to successfully deal with problems.

Research methodology is defined as a method to systematically solve a research problem. It may be understood as a science of study how research is conducted scientifically (Kothari 2004). Wisker (2007) provided a more philosophical definition by defining research methodology as the rationale and the philosophical assumptions underlying a study, rather than a collection of methods, though the methodology leads to and informs the methods used for a project. Research methodology not only talks of the research methods used, but also consider the logic behind the methods used in the context of the research study and should explain why it uses a particular method or technique and why it does not use others so that the results obtained, are capable of being evaluated either by the researchers themselves or by others (Kothari 2004).

From this definition, the term ‘research methodology’ can be characterised as a method which defines how researchers conduct their research and identify their conclusions, and such methodology will allow the results to be replicated.

2.2 Research Classification

For any research project to be completed successfully, a researcher needs to follow an appropriate and well planned methodology. A carefully planned and executed methodology is clearly pointed out in the literature as a critical part of any research project. Wisker (2007) emphasised this point on how important planning your research is and re-planning as you proceed in your project, as an essential element for a good research project.

In order for a researcher to outline their methodology, a sound understanding of the type of research they are conducting is required. Several types of research methodology have been developed over the years. Kumar (2005) used the following three questions to help classify research, i.e.:

- What is the application of the research findings?
- What are the objectives of the study?
- What is the mode of enquiry used in conducting the study?

In the first question, the application of the research can be either classified as pure research or applied research. Pure research is concerned with generalisation and with the formulation of a theory, without concern for its short term utility (Miller and Salkind 2002). Whereas applied research is defined as finding a solution for an immediate problem faced by society or industry (Kothari 2004). Similarly, Uma and Roger (2003) defined applied research as an investigation undertaken to acquire new knowledge directed primarily towards a practical aim or objective. This PhD research project can be classified as applied research, as the aim and objectives of this project are to fulfil the needs of industry by developing formal methods and practical tools to solve the identified practical problems. The second question asked by Kumar, regarding the objectives of the study, can be further divided into four categories, i.e.; Descriptive, Explanatory, Exploratory, and Correlational study.

Descriptive research attempts to describe systematically a situation, problem, phenomenon, service or a problem. The main purpose of such studies is to describe what is prevalent with respect to the problem under study. Explanatory research attempts to clarify why and how there is a relationship between two aspects of a situation or phenomenon, while exploratory research is undertaken with the objective either to explore an area where little is known or to investigate the possibilities of undertaking a particular research study. Finally, correlational studies refer to the discovery or establishing the existence of a relationship/association between two or more aspects of a situation (Kothari 2004, Kumar 2005).

This PhD research project is a mixture of descriptive, exploratory and correlational research. The first step of this project was to identify the problem areas and before these issues can be identified and defined, the need to understand the working environment was required, which brings to the descriptive part of the research, that of establishing and understanding the AS-IS situation of current processes adopted by the collaborating company. This included documenting the existing process flows of NPD, and observing testing facility operations. This allowed the researcher to identify the basic requirements which led the research to the next objective type, that of exploratory research. This was conducted with the help of an open ended questionnaire study, which highlighted other issues, problems and requirements which were missed in the first descriptive part of the research. Finally, the correlation part of the research was demonstrated by means of metrics and user perception feedback of the improvement the project has on the testing facility.

The third question asked by Kumar is regarding the mode of enquiry used in the study. This can be divided into two types: Quantitative and Qualitative research. Quantitative research aims to measure quantity or amount, and compares it with past records and tries to project for the future. In social sciences, "quantitative research refers to the systematic empirical investigation of quantitative properties and phenomena and their relationships" (Gordon 2011). The objective of qualitative research is to develop and employ mathematical models, theories or hypothesis pertaining to phenomena. The process of measurement is central to quantitative research because it provides fundamental connection between empirical observation and mathematical expression of quantitative relationships (Bryman 2006).

Qualitative research refers to the collection, analysis and interpretation of data by observing what people do and say. It refers to the meanings, definitions, characteristics, symbols, metaphors and description of things. Qualitative research is much more subjective than quantitative research and uses different methods of collection, mainly individual, in-depth interviews and focus groups. The nature of this type of research is exploratory and open-ended (Bryman 2006).

This PhD research project is predominantly qualitative in nature, with some quantitative aspects. During the industrial investigation and system implementation, an open ended questionnaire / interview was adopted as a method for data collection. Also, a metrics system to monitor utilisation was introduced at the start of the research as a means of collecting utilisation data with the hope to identify bottle necks and, at a later stage, as a tool to measure and quantify improvements. Therefore, this research includes both characteristics of quantitative and qualitative research.

2.3 Overview of Research Types

In the previous section the different classifications of research methodologies were discussed. In this section, different research methods that are available, i.e, action research, case study, ethnographic, focus groups, in-depth surveys, and participant – observer are briefly explained. N.B. this list only includes research methods which can be considered relevant to this research.

2.3.1 Action Research

> *"Studies carried out in the course of an activity or occupation, typically in the field of education, to improve the methods and approach of those involved" (OxfordDictionary.com 2015).*

As the name suggests, action research involves real life situations and people. The purpose of this research type is to understand and improve those actions being done. The main driver behind action research is to influence or change an immediate research problem, by actively intervening in the research environment being studied (Robson 1993). According to Carr and Kemmis (2003), action research relates to; the improvement of practice; the improvement of the understanding of practice; and the improvement of the situation in which the practice takes place.

Denscombe (2010) wrote that the purpose of an action research strategy is to solve a particular problem and to produce guidelines for best practice. This research method has its own problems, however. Generally, action research and the interpretation of data is subjective, depending on the person evaluating and interpreting the information produced and generally takes a long period of time for changes to be noticed and, therefore, can result in difficulty in validation and duplicating the results produced.

2.3.2 Case Study

> *"A process or record of research into the development of a particular person, group, or situation over a period of time" (OxfordDictionary.com 2015).*

Yin (2009) defined a case study as an empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenon and context are not clearly evident. According to Woodside (2010), case studies aim to achieve a deeper understanding of processes and other concept variables, such as participants' self-perceptions of their own thinking processes, intentions and contextual influences, and is identified as the principle objective of case study research.

Typically, a case study utilises multiple methods of data collection, such as observations and interviews *inter alia*. According to Denzin (1978), in order to achieve a deep understanding of a case study, a researcher needs triangulation, meaning collecting their information from three different sources. Van Maanen (1979) offers an example of triangulation which includes the following steps; direct observation by the researcher within the environments of the case study; probing, by asking case study participants for explanations and interpretations of "operational data"; and analyses of written documents and natural sites occurring in case study environments.

Yin (2009) also provided a case study methodology by identifying two methods: single case approach and multiple case approaches. The single case study design analyses one setting, allowing for a more in-depth analysis of a phenomenon, while multiple case study design offers the chance to compare evidence from different cases, providing an additional advantage of 'enabling differences in context to be related to constants in process and outcome'. Secondly, research findings can be cross-checked following theory building. Yin (2009) recommended that the findings of case studies should be generalised to theories and not to other case studies, in the way that scientists generalise experimental results to a theory.

The rationale to adopt a case study approach is due to the flexibility this methodology offers to support research questions through variety of evidence. It is also useful for understanding and exploring emerging processes and building theory. As a result, this approach will be used as an investigation and validation tool of the proposed conceptual framework.

2.3.3 Ethnographic

> *"a branch of anthropology dealing with the scientific description of individual cultures" (Dictionary.com 2015).*

The term 'ethnography' arises from the Greeks and broadly refers to 'writing about people', but has a narrower meaning of writing about particular groups of people, that is to say ethnically, culturally or socially defined groups. An ethnographic text is an interpretive and explanatory story about a group of people and their sociality, culture and behaviours, but it is not a fictional account. It is narrative, based on systematically gathered and analysed data (Madden 2010). Ethnography is a subjective research tool which is heavily influenced by the lack of control over the field setting where the research is being carried out. It is predominantly cultural-based, which is not applicable for this research project and it tends to be a lengthy research method which could take longer than the time available to complete this project.

2.3.4 In-depth Surveys

> "*Investigate the opinion or experience of (a group of people) by asking them questions" (OxfordDictionary.com 2015).*

A methodology which employs in-depth surveys seeks to collect data of a subject, typically a small number of people that represent a larger group of people by means of formulized interviews (Remenyi 1998). These interviews are generally aided by a carefully designed questionnaire that the interviewee is asked to answer. These interviews are typically recorded in order to aid the flow of the process, from which recording transcripts are transcribed. This methodology can be considered subjective, because interviewee responses can be influenced by a number of factors such as the way the interviewer askes the question or due to the nature of the questions, the interviewee might be embarrassed to answer truthfully due to lack of anonymity. Due to the nature of the research project, this method of enquiry might be used at the start of the research as a means of determining the high level requirements of the project.

2.3.5 Focus Groups

> *"Representative group of people questioned together about their opinions on political issues, consumer products, etc." (Dictionary.com 2015).*

Focus groups are used to explore and examine what people think, how they think and why they think the way that they do about issues of importance to them, without pressuring them into making decisions or reaching a consensus (Liamputtong 2011). According to Kitzinger (2005), focus group research is the ideal approach to examine stories, experiences, beliefs, concerns and the needs of an individual, making it an ideal research tool when you need participants to develop their own way to define their needs and requirements. This approach is generally used in business as a marketing tool to better understand the motivations of the end user and their perception of the products being tested. Due to the nature of the research tool, data collected will be subjective and not objective. This approach will be used at the end of this research project, in order to support the research findings and obtain end user feedback.

2.3.6 Participant – Observer

> *"A technique of field research, used in anthropology and sociology , by which an investigator (participant observer) studies the life of a group by sharing in its activities" (Dictionary.com 2015).*

Remenyi (1998) described this research method as *"researchers making first hand observations of activities and interactions, sometimes engaging personally in those activities as a participant-observer".* This research technique provides first-hand and hands-on experience into a research area, providing greater insight and understanding, rather than depending on user input. Participant observation is similar to ethnography, with the main difference that it caters for observational processes, rather than cultural experiences. This method provides the possibility to better understand the process and the day-to-day situations of the collaborating company, aiding in identifying research requirements.

2.4 Selected Research Methodology

Before explaining the rationale behind the methodology selected, the research methodologies used in similar projects in the field of capturing and sharing knowledge using similar methods to this research project, are now examined.

Figure 6 shows a table of previous studies in this domain and the research approaches used.

These papers are further examined and critically analysed in Chapter 3. From the table, it can be seen that the preferred method by previous researchers in this domain is that of case study. The adopted high level research approach is shown in Figure 7 and in more detail in Figure 8. Due to the scope and requirements of this project not being identified and set out at the start of the project, the industrial investigation and literature review were conducted concurrently covered in stage 1 of Figure 8.

Author	Description	Research Type
Leung and Fong (2010)	Storytelling as knowledge transfer mechanism in contruction projects	Action Research
Katušcăkovă and Katušcăk (2013)	The effectiveness of Storytelling in transferring Different types of knowledge	Case Study
Martin-Niemi and Greatbanks (2009)	SME Knowledge Transfer through social networking:	Case Study
Savita and Hazwani (2011)	The development of a narrative management system	Case Study
Gurney and Horlings (2014)	Analysing knowledge capture mechanisms	Case Study
Forbus and Usher (2002)	Sketching for knowledge capture: A progress report	Case Study
Schirru (2010)	Topic-based recommendations in Enterprise Social	Case Study
Cao and Guo (2011)	Understanding the influence of social media in the workplace	In-depth surveys
Murphy and Salomone (2013)	Using social media to facilitate knowledge transfer in complex engineering environments	Case Study
Chen and Hsiang (2007)	A study on the critical success factors of corporations embarking on knowledge community based e-learning	Case Study
Shehabat and Mahdi (2009)	E-Learning and its impact to the educational system in the arab world	Case Study

Figure 6. Previous Research in the Domain

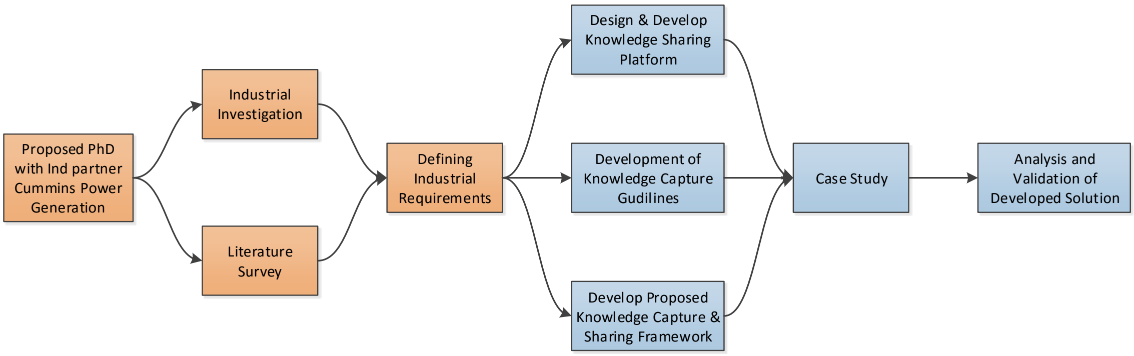


Figure 7 Research Approach Adopted in this PhD Project

This approach provided an understanding of the current processes and problems experienced in the collaborating company and, concurrently investigating these, highlighted issues through the literature review, from which examples within literature were found that satisfied or solved the identified requirements. At the same time, the identified gaps in literature provided the novelty for this research. The initial industrial investigation consisted mainly of participant observations, by observing and taking part in day-to-day processes. At stage 2 of the project, both of these methods that of the industrial observations and the literature survey, allowed the development of in-depth surveys by means of a number of questionnaire studies conducted using the following three methods: online survey, face to face interviews and telephone interviews. These were conducted with interviewees based at other sites in the UK and overseas. These survey studies produced good quality results, from which the supervisory team suggested to circulate the research on a US trip to visit three other sites of the collaborating company. From this research, the proposed framework of a system to capture and share knowledge using rich media and social networking, was proposed and approved by the supervisory team.

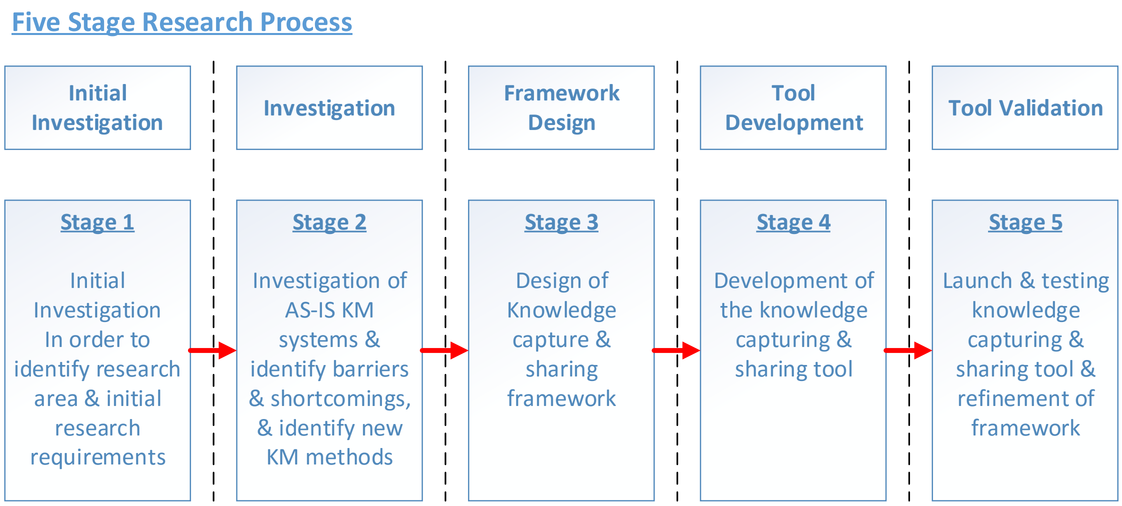


Figure 8. Research Process.

Stage 3 of the project consisted in the design of the knowledge framework, developing elaborate flow charts depicting how the knowledge will be captured, stored electronically and shared, and utilizing social media as a knowledge transfer medium. This was followed by stage 4, that of tool development. Before starting to develop the actual tool, an in-depth software selection process was undertaken to identify the most appropriate software that could be adapted and delivered as the required tool.

The final step, stage 5, consisted of designing the case study that was to be used for the testing of the designed framework and finally for the validation and evaluation of the created tool. This consisted in getting knowledge contributors to capture tacit knowledge items form their normal work day and store it on the knowledge portal so that it could be shared with others. The second part of the case study was to conduct workshops with the knowledge contributors and knowledge users in order to gauge the efficiency and usefulness of the created knowledge tool, as a means to capture and share employee knowledge to other staff in the company. The case study approach was selected for the following reasons; it provides a rich and deep understanding of the domain of interest, it is suitable for application in a business environment, it has sufficient academic credibility and rigour for use in a doctoral research investigation, it may be used to carry out exploratory and theory testing research, it allows the use of multiple sources of data and data collection methods; and it is the most commonly used research methodology in similar research projects published in international, peer-reviewed literature, as previously discussed.

2.5 Validity and Limitations of the Selected Research Methodology

It was stated by Denzin (1978) that the validity and quality of case study research is achieved by data triangulation which provides a deeper understanding of the information collected. This means that the data collected needs to be obtained from different sources. In this investigation, data triangulation was used during the initial investigation to determine the gaps and to develop the proposed framework in order to remove a bias and improve data quality during the collection and interpretation. This was achieved by using different data collection methods, including surveys, participant observations, case studies and consulting users at different levels of the business to get a representative snapshot picture of the requirements and feedback from the created framework. This method of multiple data sources improves the rigour of the research (Robson 1993).

During the validation period of the created tool, a single case study was utilized due to the constraints enforced by the company. It is believed that the research remains valid for other industries which are in a similar engineering discipline and/or industrial environment. This could be determined by future project work. Furthermore, the global spread and standing of the collaborating company, provides an ideal platform offering similarities that are associated with other industries. The issue of confidentiality can be considered as a limitation but, on the other hand, confidentiality offers a level of openness within the company that gives weight to the research findings.

The design of the case study used is intended to both validate the concept of the framework and assess the capability of the knowledge sharing tool created. The participant's selection criteria used during this study varied by age and education level in order to obtain a balanced user experience, representing the complete workforce from the collaborating company. The sample size for the validation process was relatively small (16) and, therefore, the results may only be considered as indicative, but the feedback obtain suggested that the developed knowledge sharing tool showed promise and was effective. The developed tool will be used as a knowledge repository and a communal area for knowledge discussions. This tool is not intended as the end product, but only to provide a proof of concept, that the developed tool operates as intended. The back end of the knowledge sharing tool was developed using an open source video sharing platform which could be easily modified and structured into the requirements developed and identified in this research. The actual development of the end product software for this KM system is out of the scope of this project.

The methodology and tools that were created during this research are considered to apply for the product development testing process in an industrial setting. An electrical power generation equipment manufacturer has been the collaborator of this project and provided facilities and resources for case studies to test the proposed methodology. It needs to be stated that the research methodology adopted was conducted within the financial and collaborating company's time constraints, and it must be acknowledged that some limitations / constraints within the methodology deployed is a direct result of these constraints, while other limitations / constraints are a direct result from the research methodology selected.

2.6 Project Evolution

The project commenced on the 1st October 2012 and initially was intended to focus on improving the performance of two test cells in the PD testing facilities that the collaborating company has at its Kent site. Following several observational exercises and process modelling, key areas were identified, including, knowledge base system, communication, process optimization within the PD testing facility, process improvement – Product life cycle implementation; and PLM framework.

Once these areas had been identified, the project moved away from focusing solely on improving performance on the two test cells and instead retargeted the research to improving time to market for new product development within the context of the testing facility. This new project scope was intended so that any proposed framework would also be absorbed by the four other Cummins sites in the UK and the US, which are all related to the same business unit. This new direction greatly broadened the project scope, from which the spider diagram shown in Figure 9, was developed; the diagram captures the main items identified in the first three months of the project as possible avenues which this project could progress into.

At this stage, project stakeholders were identified and asked to complete a pilot study from which the project direction was refocused. From the responses received, the main issues highlighted on several occasions were communication improvement and the capturing and sharing of employee knowledge. These findings refocused the project to explore the development of a framework which will aid the capture and sharing of knowledge and its communication between the PD teams which could be located at different sites.

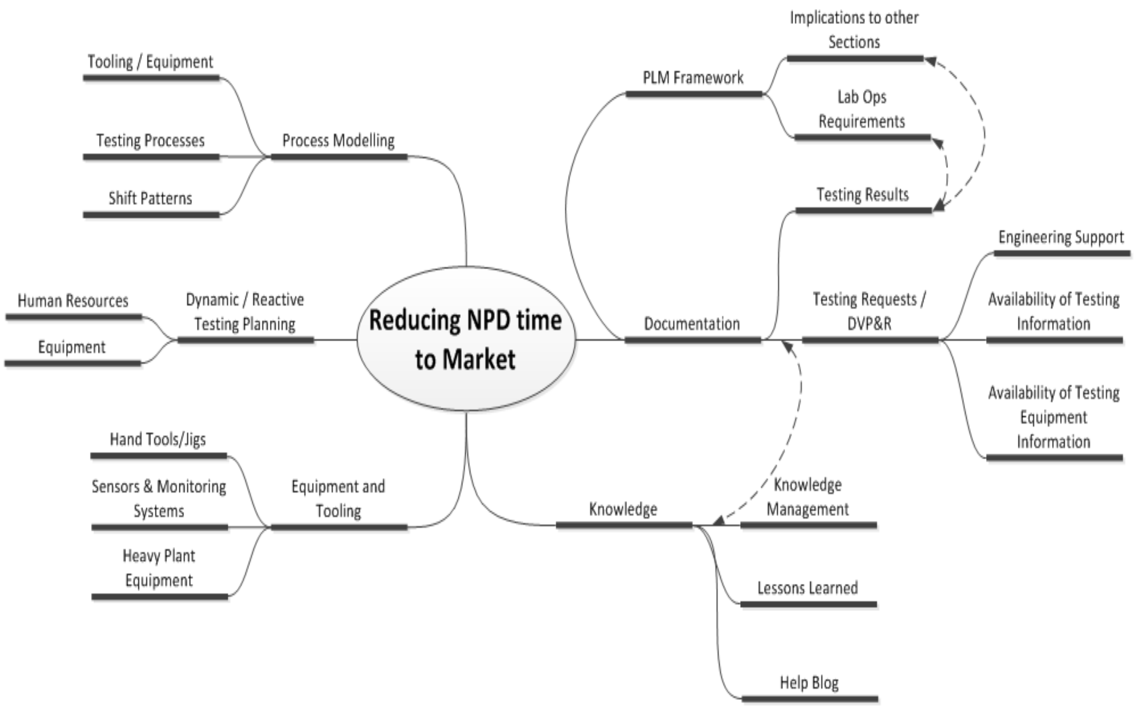


Figure 9. Spider Diagrams of Possible Research Directions

2.7 Summary

Research methodology is defined as a way to systematically solve a research problem, by selecting a research method that can justify ones research findings. This PhD project is considered as applied empirical qualitative research, developed in collaboration with an industrial partner, meaning that the developed framework and tool is the main focus and the main deliverable of this project. The research includes an extensive in-depth survey to understand and identify industrial requirements. This was followed with a second survey developed from these requirements to determine the end user requirements for the developed tool. The developed tool was than validated using a mixture of case study and proof of concept methods where users were asked to use the developed methodology and tools as part of the validation process.

Chapter 3: Literature Review

This Chapter provides the key sources from the literature which have major bearing on the research in terms of theoretical foundation, current research status and significant related work. Some definitions, assumptions, and a basis for classifying and positioning the research are also provided.

This is followed by a critical review of recently published literature relating to the capture and sharing of knowledge, and how this knowledge can be transferred in the context of product development testing projects and NPD Teams' Learning environments. The purpose of this analysis is to show where and who carried out related research; followed by an explanation of the highest cited publications related to this research project. The review also seeks to identify research gaps and the novelty in order to position the knowledge contribution of this research.

3.1 Literature Review: Scope and Methods

The main sources of the literature review are the University of Greenwich Library and, more importantly, the externally managed electronic journal databases, including Elsevier Science Direct, SCOPUS, INSPEC, IEEE Explore, Emerald, and e-book repositories, such as Cambridge book online, MyiLibrary and Oxford Scholarship Online. Other resources include internet search engine Google (Web & Scholar).

Other literature was obtained indirectly from the initial literature search. This was carried out by examining the reference list found in highly relevant journal papers from the initial search. These relevant sources provided reference to other similarly relevant papers. This technique was utilized to examine the keywords used in journal papers which aided the search by identifying the correct terminology to direct further searches.

The areas for the literature review include product development, knowledge management, classification of knowledge, NPD testing, communication for NPD, social media, learning, storytelling, video sharing and other related areas.

3.2 New Product Development Management

In business and engineering, NPD refers to the development of a new product which is launched in the market place. A product can be either tangible (i.e. a physical object) or intangible, such as a service. The idea of a new product may have originated either from the engineering team, with the hope that the market place would accept it (called technology push), or from market research (called market pull). Both strategies have their advantages and disadvantages (Ulrich and Eppinger 2000, Kušar, Duhovnik et al. 2004).

A successful product is typically determined by five factors: good quality, low production cost, short development time, low development cost and effective development capability (Kidder 2011). These key factors are normally managed by different departments or groups, such as R&D, testing, marketing, sales and finance within a company. The success of a product may only be achieved if these departments and groups cooperate and work together in harmony to achieve the end NPD goal.

Managing a NPD project is a complicated and challenging task and the success of a project can be hindered by several factors, such as incorrect description or interpretation of requirements, late product launch or bad managerial practices (Karniel and Reich 2011). Even when management practices in existing PD projects within a company are considered as state of the art, this does not necessarily mean that these practices would be effective in new projects. NPD projects may be extremely innovative, whilst the management practices still need to be continuously reviewed and checked to see if they are in line with the new technology being developed.

Clark and Wheelwright (1994) argued that the rules of the game in new product development are changing. Many companies have discovered that it takes more than the accepted basics of high quality, low cost, and differentiation to excel in today's competitive market. It also takes speed and flexibility (Takeuchi and Nonaka 1986). This new emphasis on speed and flexibility calls for a different approach for managing NPD projects. Traditional approaches to NPD were a sequential process, while the latest trends encourage a more concurrent approach, which is better known as ’scrum‘ or sometimes concurrent engineering. Figure 10 shows three types of product development processes project durations. Type A is a sequential PD process, while type B and C are overlapping PD processes, similar to the scrum methodology.

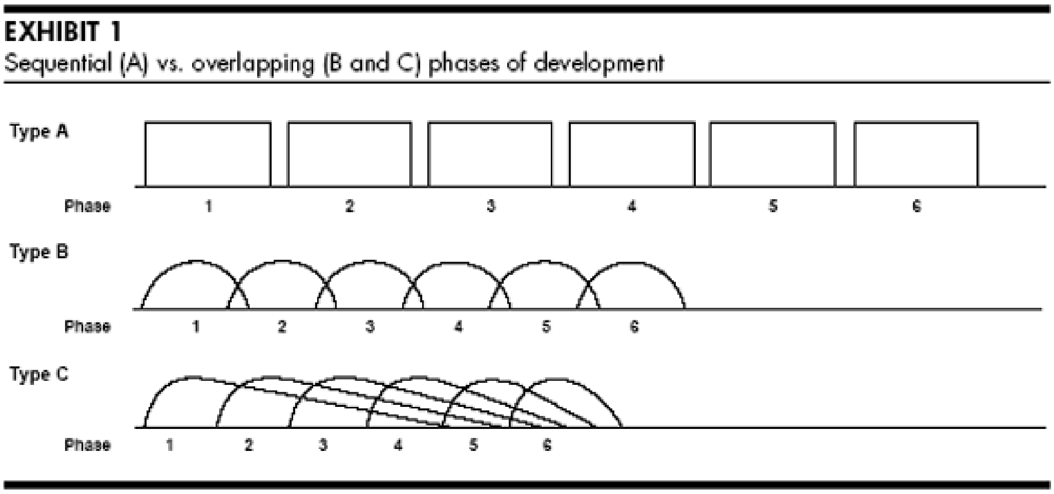


Figure 10. Sequential vs. overlapping projects (Takeuchi and Nonaka 1986).

Communication amongst NPD team members is another important factor that can directly influence the success of a NPD project. With the creation of a core team with extended members in a product development project, brings to the table new problems. In global organisations these core teams and extended team members can be located at different offices within the same site or at different sites around the globe, with the additional complication of having different time zones which further complicate peoples' availability, which only emphasise the fact that team members need to stay on top of communication and control it.

Communication in project management comes in many shapes and forms, such as oral communication, meetings, telephone calls, emails, instant messenger systems, teleconference calls, and video conference calls (Roy 2008). Communication plays a crucial role in knowledge sharing and the social dynamics of a team. Without adequate communication channels, a team would fail to produce new innovative ideas that could be transformed into new products (Leenders, van Engelen et al. 2003, Crawford and Nahmias 2010). Therefore, the combination of effective communication, project management and knowledge management are critical to the success of NPD projects.

3.3 Product Testing and Validation in NPD

Testing is an essential part of the PD process and is one of the major time consuming processes within the PD lifecycle. Product testing for NPD can be divided into two main sections: Design Validation and Product Validation. The difference between the two is significant. During design validation, a new design idea is tested as a verification of that idea so that it can be implemented into the product design. During product validation, the product design is almost concluded and the purpose of the testing is to validate the design as a whole and to check that the product fulfils the product specifications. Product validation is also used to certify products to safety norms, such as Underwriters Laboratories (UL), European Conformity (CE) and Technical Inspection Association (TUV). Certifications enable the checking of if the product is safe for use by end customers. The verification and validation of engineering designs are of critical importance, as they dictate product performance, functionality and customer perception (Maropoulos and Ceglarek 2010).

The literature search on product validation and testing processes did not give many results. This lack of literature indicates that there is a significant gap in development testing processes which are of high value and, although the testing process is repetitive, the nature of the projects are one-offs, which could be the reason why this subject area is overlooked.

Maropoulos and Ceglarek (2010) analysed product verification and validation in the context of engineering design. They looked at the PD process as a whole from product conceptualisation to the digital design and its digital validation, utilizing CAE tools, and finally the physical product testing to validate the initial digital validation analysis. Their work highlighted the complexity involved in the product lifecycle and how important CAE tools are in accelerating design validation, making a time saving, cost cutting and resource usage saving for NPD a high industrial priority. CAD and CAE tools do have a place in a testing facility as these tools can be used as a simulation tool, enabling specific installation planning or test rig design preparation before the physical product is made available; therefore, contributing to time saving within the NPD cycle.

Dickinson and Wilby (1997) investigated the importance of concept testing as a means of early screening of new product ideas and how these new product concepts would be perceived by potential customers. Their study investigated whether or not concept tests, involving both product positioning and trial, will evoke different responses than those that involve only exposure to the product concept. The study mainly consisted of two groups of subjects; the first group tried the product prototype, while the second group only received the information about the product. The researchers concluded that the subjects trying the prototype gave greater feedback which could be incorporated into the design, but that a product trail run was only effective for completely new products. This study highlighted the importance of involving the customer in development testing mainly because the customer is the only user that has a significant amount of hours using the product, as a result, tapping into that knowledge can contribute to better understanding in the development of user friendly products.

Kleyner and Sandborn (2008) developed a methodology to minimise the life cycle costs of a product by developing an optimal product validation plan. Their framework considered the costs involved in future repairs and warranties in relation to the costs involved in development testing. In other words, if the predicted repair costs are low, minimal validation testing is required and, therefore, shortening the testing plan would result in a time and resource saving. The developed model was validated by an automotive electronics application. The results of their work provided application-specific optimal product validation plans and evaluation of the efficiency of a product validation program from a life cycle cost point of view. Maravelias and Grossmann (2004) looked at optimising PD testing plans for pharmaceutical companies. They developed an algorithm which predicted the optimal testing schedule with the real life constraints - that of availability of resources and the actual cost, such as the cost implications involved in testing is accelerated due to consideration of the resources availability.

Lu et al. (2000) argued that to shorten time to market, the PD process needs to change its way of working from the classical ‘wait and react’ to ‘anticipate and prevent' as early as possible in the development process. In order to do so, they examined the concept of accelerated stress testing for NPD as shown below in Figure 11. Accelerated stress testing is a classical solution for the implementation of tests where product failures need to be activated faster and cheaper in a well-controlled environment at the early stage of the PD. Their research demonstrated that these accelerated test strategies are mainly based on generic lists of failure mechanisms and have only limited relation with the actual failure rate curve of products. Currently available accelerated stress testing strategies do not take into account the four-phase roller coaster failure rate curve, but only the constant failure rate. Systematic strategies for testing all the phases of the failure rate curve can be derived based on maturity index on reliability analysis, the knowledge of the four-phased roller coaster curve and the stress-susceptibility concept.

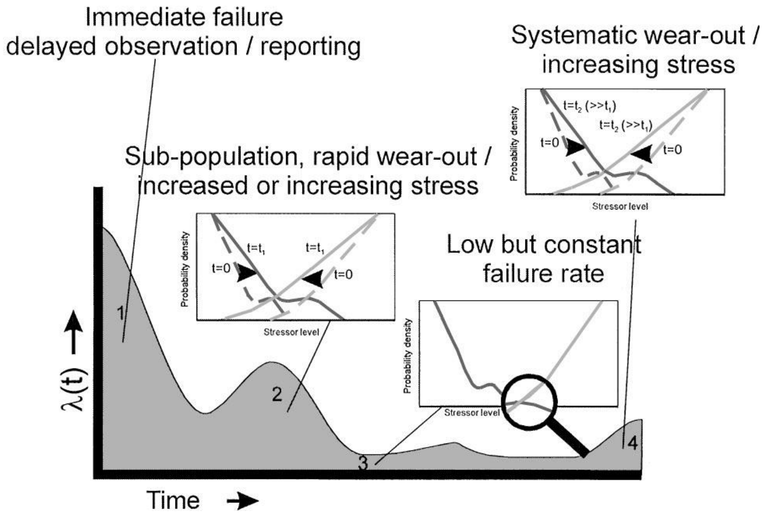


Figure 11. Four-phase roller coaster failure rate. (Lu, Loh et al. 2000)

In summary, it has been highlighted by previous researchers that the use of CAD tools to aid and accelerate product development testing, the use of end customer knowledge during product development testing as a means to improve the usability of the product. The testing plan intensity was also examined from a study which analysed the testing costs in relation to the financial repercussions of product failures and from the point of view of the availability of resources.

3.4 Data, Information and Knowledge

3.4.1 Definitions of Data, Information and Knowledge

Data is a set of discrete, objective facts about events (Drejer 2002). In an organisation, data is most usefully described as structured records of transactions. For a testing / validation facility, the data will consists of voltages, currents, temperatures, stresses, stains and noise measurements to name a few. Data on its own does not explain why the equipment under test was running and what the main scope behind the test was. Drucker (2011), a popular author on management techniques, stated that "information is data endowed with reliance and purpose. Converting data into information thus requires Knowledge", which of course suggests that data by itself has little relevance or purpose.

Information can be described as a message, usually in the form of a document or another form of communication (Davenport and Prusak 2000). As with any message it has a sender and a receiver. Information is meant to change the way the receiver perceives something, to have an impact on his judgement and behaviour. Data becomes information when its creator adds meaning to it. Most people have an intuitive sense that knowledge is broader, deeper and richer than data or information. Knowledge is a fluid mix of experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the mind of knowers. In organisations, it often becomes embedded, not only in documents or repositories, but also in organisational routines, processes, practices and norms.

The European Union Committee of standardisation came up with a more simplified definition of knowledge which is similar to Davenport and Prusak's (2000) statement – "knowledge is the combination of data and information, to which is added expert opinion, skills and experience, to result in a valuable asset which can be used to aid decision making." From an organisational point of view, Tsoukas and Vladimirou (2001) developed an alternative definition that introduces the concept of collective understanding derived from historical experiences. “Organisational knowledge is the capability of members in an organisation have developed to draw distinctions in the process of carrying out their work, in particular concrete contexts, by enacting sets of generalizations whose applications depends on historically evolved collective understandings”. Knowledge is derived from information, as information is derived from data. If information is to become knowledge a knowledgeable person must interpret the information and transform it into knowledge by:

- Comparison – deciding how information about this situation compares with other situations that he has known.
- Consequences – deciding what implications the information has.
- Connecting – deciding how this bit of information relates to another.
- Conversation – finding out what other people think about this information (Drejer 2002).

There is no simple or clear way to obtain knowledge. A process of understanding the information or data at hand and making informed and educated interpretations is required in order to create new and innovative knowledge. Innovative knowledge can lead to measurable efficiencies in product development and in manufacturing production lines it can be used to make wiser decisions about strategy, competitors, customer requirements and product life cycles. Knowledge develops over time through experience that includes what a person absorbs from courses, books and mentors, as well as informal learning in our everyday lives.

3.4.2 Types of Knowledge

Knowledge can be classified into two categories: Explicit and Tacit. Explicit knowledge can be expressed in formal methods or natural languages. It can be shared and exchanged as formal data, formulae or in documentation. Tacit knowledge is normally not expressed or cannot even be expressed, emphasising personal skills and understanding, and is very difficult to share and exchange by formal and systematic methods. This kind of knowledge is the opinion, experience and action based skills of employees (Miller 1998).

Knowledge embedded in an individual is multidimensional and includes explicit knowledge – knowledge that can be laid out in procedures, steps and standards, and tacit knowledge – knowledge that is stored in an individual's mind but cannot be fully explicated (Burrows 2001, Polanyi and Sen 2009). Explicit knowledge can be copied and used by a firm's competitors and thus, is unlikely to sustain the company's competitiveness. In contrast, tacit knowledge is derived from a person's lifetime of experience, practice, perception, and learning (Polanyi and Sen 2009). This type of knowledge is highly abstract and closely relates to know-how (Grant 1996). Therefore, one may acquire tacit knowledge in one context and apply and stimulate this knowledge in another context (Burrows 2001, Nonaka 2003).

3.4.3 Knowledge Management

Knowledge Management can be defined as "the ability to harness and build upon an organisation's intellectual capital"(Drucker 2011). With today's turbulent economic climate, companies need to judge what they already know and must use that knowledge effectively; the size and dispersion of many of them make it especially difficult to locate existing knowledge and get it to where it is needed. According to Davenport and Prusak (2000), the maximum size of an organisation in which people know one another well enough to have a reliable grasp of collective organisational knowledge is 200. The vast amount of knowledge found in a global enterprise, which has offices and plants spread out around the globe, is enormous but taping into that pool of knowledge is a problem due to the sheer size of it. Corporate knowledge only becomes of value if people in that organisation can gain access to it and use it. If there isn't a KM system available, employees will make do with what they already know or the explicit knowledge already available. This knowledge could be of good quality, but in today's market sometimes good quality is not good enough (Ramesh and Tiwana 1999, Shani, Sena et al. 2003).

A lot of companies can argue that KM systems cost a lot of money and a lot of effort is required to setup and maintain, but knowledge can provide a sustainable advantage to a company. Eventually, competitors can almost always match the quality and price of a market leader's current product or service. By the time this happens, the knowledge rich company will have moved on to a new level of quality, creativity, and/or efficiency. The knowledge advantage is sustainable because it generates increasing returns and continuing advantages (Davenport and Prusak 2000). Good KM systems pay for themselves by creating new innovative ideas which are transformed into products and sales for the company.

Another key point highlighted by Briggs (2006) was the movement of employees. Some employees move from one department to another while others move from one company to another. Both these situations have considerable impact on companies; the latter more than the former. Employees from time to time do move, either to progress their career or to move to another position to improve their income; this employee movement cannot be stopped, which is why KM is a necessary business function for business process improvement and for maintaining competitive capability when enterprises lose their key personnel (Briggs 2006). This has a significant influence on cost, time, quality and the success of a company.

Nonaka and Takeuchi (1995) proposed that a continuous knowledge conversion process is required in order to have an effective KM system. According to them, an effective KM system needs a social process between individuals and not confined by one person. They identified four different modes of knowledge conversion method which have been integrated and is shown in Figure 12.

- Externalization (tacit to explicit) is the process of conversion of tacit into explicit knowledge, transforming process experiences into guidelines.

- Combination (explicit to explicit) is the process of enriching the available explicit knowledge to produce new bodies of knowledge, and organisational knowledge into a decision support system.

- Internalization (explicit to tacit) is the process of individual learning by repeatedly executing an activity while applying some type of explicit knowledge, and absorbing the relationship between actions and results as new personal tacit knowledge.

- Socialization (tacit to tacit) is the process of learning by sharing experiences that creates tacit knowledge as shared mental models and professional skills.

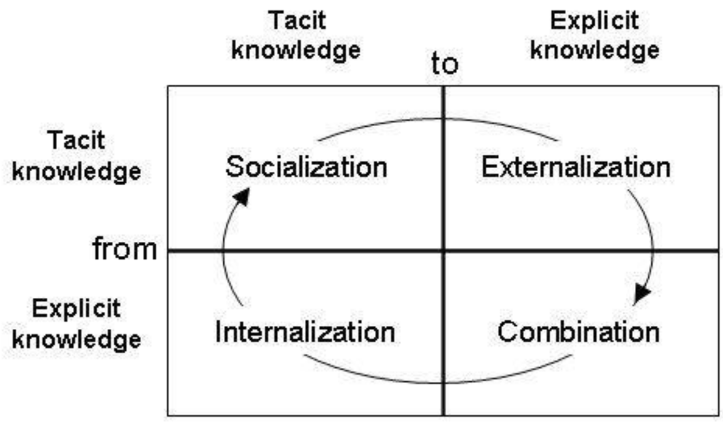


Figure 12. The knowledge conversion processes in a knowledge creating organisation(Nonaka and Takeuchi 1995)

A knowledge management system is made up of several actives which influences its success. These critical activities are; Knowledge Strategy, Knowledge Identification, Knowledge Storage, and Knowledge Sharing. A Knowledge Strategy outlines what knowledge at present is required and what knowledge will be needed in the future. Knowledge Identification consists of guidelines for the user of identifying valuable knowledge and categorizing it. Once knowledge is captured and categorized the next natural step is storing it for future use, which creates the final step of Knowledge Sharing. Once the knowledge has been correctly categorised and stored, users can access the knowledge enabling its re-use.

Akhavan, Jafari et al. (2006) proposed a framework, which consists of three main layers. The interior layer includes their main concepts which is the backbone and makes the ideal KM system. It is composed of knowledge architecture, knowledge strategy, knowledge sharing, knowledge storage and knowledge identification. Knowledge architecture has been demonstrated as a system integrator. It also links between the other main factors. The middle layer consists of some factors that are necessary for success. In other words these factors can guarantee the success of KM systems and can facilitate it in an organisation. The outer layer shows factors that are more general in comparison to the other factors. These elements are necessary for the successful establishment of every system in organisations. This framework explains both the raw mechanics required for a KM system to be successful but also includes the interactions the system needs to have in order for it to be used successfully.

3.5 Knowledge in NPD

3.5.1 Knowledge Sharing

Organisational competitiveness is rooted in the mobility of knowledge that is realized through knowledge sharing and transfer, allowing individuals, teams and organisations with the opportunity to improve the work performance as well as create new ideas and innovations (Cummings 2004). In any company, knowledge is shared on a daily basis, whether the knowledge process is managed or not. This occurs each time an individual aske a colleague for help, making it an unofficial knowledge transfer. These knowledge transfers are part of organisational life, however, they are often local and fragmented. In general, problems are discussed with local colleagues due to convenience, but this does not guarantee that the best person has been consulted on the subject (Davenport and Prusak 2000, Bhatt 2001).

Spontaneous and unstructured knowledge sharing is an important aspect of everyday life in a company, but a structured knowledge management system enables, encourages and promotes the spontaneous creation of this knowledge. Tacit knowledge is hard to transfer from one individual to another, unless they spend a considerable amount of time together and the expert of the two is willing to share his/her knowledge; this mentoring experience within a company is not always possible due to costs involved.

A definition of knowledge sharing, provided by Yang (2004), explained that knowledge sharing is the dissemination of information and knowledge within a community. Hislop (2002) proposed that knowledge can be transferred by means of explicit knowledge sharing which has been translated by the sender for the receiver. The receiver then needs to interpret the information into knowledge.

Nonaka and Takeuchi (1995) argued that tacit knowledge is difficult to capture and share due to the personal understanding of the subject matter. They stated that only tacit knowledge that can be transformed into explicit knowledge can be successfully shared with others. Hislop (2002) suggested that tacit knowledge can be shared through 'direct communication among individuals' and provides three examples from the literature as to how this may be achieved. These were stories, observing others and learning by doing within a community. Therefore, one can argue that if you can capture a person's knowledge and experiences using one of these three techniques, tacit knowledge can be captured and documented in order to be shared with others. This will be further explored in the next section.

3.5.2 Knowledge Capture

Traditional KM systems are generally document based where processes, procedures, product information and other information are captured and transcribed into a written document which includes? Text and diagrams to explain the information or knowledge it is intending to share but this system is limited to explicit knowledge only.

It has been mentioned previously that tacit knowledge is difficult to capture and share, only tacit knowledge that can be transformed into explicit knowledge can be successfully shared with others. As suggested by Hislop (2002), tacit knowledge can be captured and shared by 'direct communication among individuals' by means of stories, observing others and learning by doing within a community. But in today's market, the accelerated PD timelines to develop products and bring them to the market place in the shortest time possible is critical for product success. This generally means that a company's human resources are stretched to the limit, with technical staff having limited time available to share their own knowledge or train younger staff (Mueller 2014).

This situation has prompted several attempts from researchers to explore new ways as to how tacit knowledge can be captured in such a way that reduces the need for a technical expert to spend their time to share their own knowledge or to train younger staff, especially when dispersed global PD teams are involved. Universities worldwide have tried and tested eLearning successfully using web-based technologies to create a student centric learning environment, where students create the critical and cognitive skills higher education aims to develop (Jonassen, Mayes et al. 1993, Moron-Garcia 2002).

All of these technologies have been used extensively to capture and share knowledge in an academic setting. The academic staff capture and prepare this knowledge using web-based materials and rich media tools are considered as experts in their field of study and in the use of these eLearning technologies. This project aims to use the same principles as e-Learning to capture and share knowledge, with the difference that industrial experts will be used to capture the knowledge required. One can argue that an industrial expert will not have the same level of education as an academic, and therefore will not be able to develop the structure required within the knowledge contribution for an effective knowledge transfer and will not be able to use the eLearning technologies effectively.

At the moment, however, these industrial experts are used for knowledge transfer using the traditional direct communication and face-to-face method, therefore they are already transferring knowledge effectively in an informal way. As for the eLearning technology, most of this technology is already being used on a daily basis, when we browse the internet and when we use our smart phones. Therefore, it is the researcher’s opinion that these industrial experts are the ideal people to capture the knowledge as 1) they are the experts in their field and 2) if user friendly tools are used they will not have any problems to capture the knowledge required.

3.5.3 Knowledge Classification and Tagging

Collecting and storing knowledge in an electronic format inside a database has been well established throughout this literature review showing that it is of great benefit to any organisation. But, it would be pointless if you are able to store the captured knowledge but not be able to retrieve the knowledge in the shortest time possible on demand when it is needed, bringing us to the subject of knowledge classification. In essence, the process of classification simply means the grouping together of like things to some common characteristic (Hunter 2009).

Traditional knowledge classifications consist of classification structures using general terminology, in order to facilitate the easy search and access of documents using terms like subject area, year, author and other classification features. The process of knowledge classification can be used in a formative way and is thus useful during the preliminary stages of enquiry as an investigative tool in discovering, analysing, and theorizing (Davies 1989) the available knowledge management systems.

With the dawn of the digital age, traditional libraries were replaced with electronic databases increasing both the accessibility and the amount of information to classify the stored knowledge called metadata. Metadata aids the identification, description, management and location of information resources in both digital and non-digital environments. With the digital environment, the use of metadata to enhance resource discovery continues to be indispensable, particularly within specific communities of practice such as digital libraries or repositories (Macgregor and McCulloch 2006).

To facilitate retrieval by subject, information resources were manually given a subject heading according to their content or, to use cataloguing parlance “aboutness”. Such subject descriptors are commonly known as index terms and these are derived from a larger set of index terms known as an indexing language providing a controlled structured index using highly controlled vocabularies. Although this system yielded many results, the problem of controlling the indexed terms used for the searches, a new system was developed that of collaborative tagging. Collaborative tagging emerged as a means of organising information resources on the Web and is contradictory to the ethos of controlled vocabularies (Macgregor and McCulloch 2006).

Tagging typically describes the voluntary activity of users who annotate resources with terms – so-called “tags” – freely chosen from an unbounded and uncontrolled vocabulary (Golder and Huberman 2006). Tagging is a mechanism that has become wildly popular in recent Web 2.0 applications, partly in response to the difficulty of discovering highly relevant results using traditional search engines. Macaskill and Owen (2006) defined Web 2.0 as a ‘web-based platform which allows users to gain access, contribute, describe, harvest, tag, annotate and bookmark Web mediated contents in various formats, such as text, video, audio, pictures and graphs. Evans (2014) provided a more precise definition of Web 2.0, stating that it is web sites which people can share content on. Web 2.0 is a vast improvement from Web 1.0 which only conveyed static information. With Web 1.0, only web programmers were able to modify and post content. In contrast, with Web 2.0, anybody with minimal ICT skills can contribute and share their information (Evans, Gao et al. 2014). With the power of high speed computer systems, more complex search algorithms are being developed by most of the KM software companies by not only looking at the index or the metadata and tags of the files stored on the database, but also looking at the file content at each and every word on multiple file formats, systems like google search engines, Dassault EXALEAD OnePart and many others.

3.5.4 Knowledge Management Models and Frameworks

Any KM system implementation requires either a model or a framework that is structured around the concept of processes it is aimed to cater for or in the context of the developed KM system (Sensuse, Sucahyo et al. 2014). The terms ‘model’ or ‘framework’ can create some confusion, because both terms represent two different things.

A model is an abstract representation of reality, useful for its explanatory and predictive power providing a highly formalized and visual system, yet simplified representation of a phenomenon and its interactions (Durant-Law 2006), that can simulate processes or systems in order to analyse and understand the proposed improvements (Kim, Lim et al. 2008). KM models are generally easily understood and can be replicated, although there are still many shortcomings, such as the lack of detail on how the KM model should be implemented, as well as the absence of a quantitative evaluation of the structure of both research and practice (Prat 2011).

On the other hand, a framework provides various perspectives such as organised ideas and concepts that can be easily communicated to others. It can be regarded as a representation of concepts and practices of a project. According to Davenport (2011), the cognitive structure of the framework is used to organise our thinking about a particular domain of interest which are usually used as a visual or conceptual tool set, in draft lines, to show the context of the specific approach.

In summary, a model describes or explains the inner workings of a conceptual idea, while a framework describes the empirical relationship between each aspect needed for consideration, providing a general direction and limitations of a theory or research. Therefore, a framework can be made from theories and models of KM (Sensuse, Sucahyo et al. 2014).

The *Knowledge Category Model* proposed by Boisot (1987) considered knowledge as either codified or uncodified and as diffused or undiffused within an organisation, as shown in Figure 13. The top right quadrant of the model covers public knowledge which consists of codified knowledge that is diffused. The model suggests that there is a spread or diffusion of knowledge across an organisation as reflected in the horizontal dimension of the model. However, the codified and uncodified categories in the model are discrete categories of knowledge. In addition, the concept of diffused knowledge is rather general and lack clarity if it includes gathering knowledge within the organisation or the idea of spreading it (Haslinda and Sarinah 2009).

	Undiffused	Diffused
Codified	Propriety Knowledge	Public Knowledge
Uncodified	Personal Knowledge	Common Sense

Figure 13. Boisot's Knowledge Category Model

The *Knowledge Management Model* developed by Nonaka and Takeuchi (1995) assumes that knowledge is divided into tacit and explicit elements. In this aspect, tacit knowledge is defined as non-verbalised, intuitive and unarticulated, whilst, explicit knowledge is articulated and can be specified in writing, drawings, computer programming text *inter alia*. The model shows that a form of knowledge either being tacit or explicit can change by means of one of the below mentioned methods that of socialization, externalization, internalization or a combination of them (Sensuse, Sucahyo et al. 2014).

The *Intellectual Capital Model* developed by a Swedish company named Skandia in 1997, proposed an approach for measuring its intellectual capital. The model consisted in measuring the different elements that make up knowledge within a company that of human resources, customers, KM flow structures and the ability to control these elements. It was suggested that this model assumes a scientific approach to knowledge and assumes that intellectual capital can be transformed into commodities or assets of knowledge management (Lank 1997). The intellectual capital model assumed that intellectual capital is a vital asset in an organisation and should be managed efficiently for a company to succeed (Haslinda and Sarinah 2009).

The *Adaptive Knowledge Management Model* proposed by Bennett's (2004) suggested that an organisation can be considered as a system in a symbiotic relationship with its surrounding environment, changing in size and its content depending on its circumstances. The Intelligent Complex Adaptive Systems theory sees an organisation as an adaptive and complex system. Their model contains a series of functions which ensures the viability of any living system in general and in organisations. The key elements of their model are understanding, creation of new ideas, problem solving, decision taking and following actions to obtain desired results (Schwartz 2005). It views the organisation much like a living entity concerned with independent existence and survival (Dalkir 2013).

The *Knowledge Management Enabler Model* was developed by Girard (2005) to help the Canadian government to better manage the knowledge at their disposal. The model shown in Figure 14 resembles a human shaped figure made up of pilled stones which was a traditional Canadian system used as a navigational aid. The model consists of key enablers extracted from existing KM models, in highly visual and symbolic fashion to depict key importance areas.

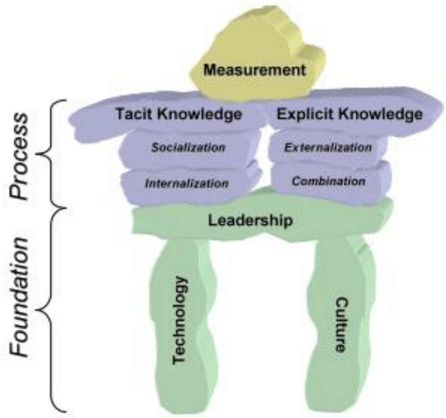


Figure 14. The Inukshuk: A Canadian KM model (Girard 2005).

The *Intangible Assets Framework* suggested by (Erik Sveiby 1997) consists of a combination of individual competences, including knowledge organisation that consists of five interdependent elements (explicit knowledge, skills, experience, value judgments and social network); internal structure (patents, concepts, models and computer and administrative systems) and external structure (relationships with customers and suppliers). It encompasses brand names, trademarks and the company's reputation or image (Sensuse, Sucahyo et al. 2014).

The *Knowledge Management Cycle Framework* proposed by Wiig, de Hoog et al. (1997) presents a model of how organisational knowledge assets are used. The framework is designed as a process that can affect both internal and external stakeholders in the organisation. These processes are review, conceptualization, reflect, act, development, distribution, consolidation and combination (Schwartz 2005).

The *Holistic Knowledge Asset Framework* was developed by Knowledge Associated Ltd in 2002. Their framework puts the knowledge customer in a central position, with the main elements covering operational issues, task execution and also the inter-relationships so that the resulting knowledge would be an integrated company effort. The objective of this framework is to provide a list and analysis of all elements that will be tested by method and relationship, facilitating a derivative of high level of user needs and provide guidance on the development of the next method. Their framework includes process knowledge, content knowledge, knowledge flow and knowledge capital with five types of practical knowledge (knowledge creation, knowledge access, knowledge assets, knowledge repositories and knowledge environment) (Sensuse, Sucahyo et al. 2014).

The *Knowledge Flow Framework* proposed by Newman (2003) consists of agent elements (individual, and collective agents) and knowledge artefacts (documents, memories, norms, values and other things that represent the inputs to and outputs of the knowledge-enabled activities of agents). This refers to some representations (cognitive knowledge and physical knowledge artefacts) and is divided into three classifications (explicit, implicit and tacit knowledge artefacts). This stream is undergoing a transformation in behaviour between agents to produce artefacts which are then divided into four general categories (knowledge creation, knowledge retention, knowledge transfer and knowledge utilization) (Davenport, Holsapple et al. 2011).

Mostert and Snyman (2007) developed the *Knowledge Management Process Framework*, which classifies knowledge into a matrix as a set of processes based on four functions: planning, organizing, leading and controlling, to form part of the organisational knowledge.

Their framework includes first process (planning: KM) which affects the goals and objectives of the plan and strategy of the organisation and is related to planning, organising, leading and controlling; the second process (organising: KM) effects organisational structure that was built to ensure responsible planning, organising, leading and controlling; the third process (leading: KM) effects leadership in planning, organising and controlling, in the process of organisational knowledge. The final process (controlling: KM) effects performance monitoring and the detection and repair of plan activity level of performance in planning, organising and controlling of the application of leadership.

3.5.5 Limitations of Knowledge Capture and Sharing

Several issues can hinder knowledge sharing; these inhibitors are generally called 'frictions' because they slow or prevent the sharing of knowledge and are likely to erode some of the knowledge as it tries to move throughout the organisation. Davenport and Prusak (2000) came up with a list of examples of these frictions and the possible solutions to counter them; these are listed in Figure 15.

Friction	Possible Solutions
Lack of Trust	Build relationships and trust through face to face meetings
Different cultures, vocabularies frames of	Create common ground through education, discussion, publications, teamingm job
Lack of time and meeting places; narrow idea of	Establish times and places for knowledge transfer; fairs, talk rooms, conference
Status and rewards go to knowledge owners	Evaluate performance and provide incentives based on sharing
Lack of absorptive capacity in recipients	Educate employees for flexibility; provide time for learning; hire for openness to ideas
Belief that knowledge is prerogative of particular groups, not in vented here	Encourage nonhierarchical approach to knowledge; quality of ideas more important than status of source
Intolerance for mistakes or need for help	Accept and reqard creative errors and collaboration; no loss of status from not knowing everything

Figure 15. Knowledge sharing frictions (Davenport and Prusak 2000)

Most of the issues listed can be considered as social interaction factors but technological factors could also cause a hindrance to knowledge sharing. As stated previously, product development needs good communication between the different team members of a PD team (McDonough, Kahn et al. 1999). Knowledge sharing suffers from the same attributes similar to those found in communication in PD. If communication between the people sharing knowledge is not adequate, knowledge sharing barriers will be encountered. Chow and Chan (2008) also found that social interactions and networks are one of the factors impacting organisational knowledge sharing.

Knowledge sharing limitations can be classified into two categories: 1) issues encountered due to interdepartmental issues and 2) issues that are caused due to geographical distance. For Category 1, the different departments have different areas of expertise, educational level and goals and, therefore, these differences will change the interpretation and understanding of the information / knowledge they are sharing. This information may or may not be relevant to other job functions and therefore can or cannot be useful knowledge (Sole and Applegate 2000). Another issue of knowledge sharing barriers may arise when employees make knowledge sharing conditional depending on what information they will receive in return, so people distinguish who and with whom they share information (Schmitz 2011), making the knowledge at their disposal a bargaining commodity.

The second barrier category of knowledge sharing is due to the geographical distance that exists within a global enterprise. This can occur when certain expertise is located in one location and therefore the company would be suffering from an imbalance of the distribution of expert knowledge. Apart from the time, cultural and language differences, this type of knowledge sharing limitation also suffers from a lack of face to face knowledge sharing (Sole and Applegate 2000) which reduces the effect on the quality of knowledge transfer between the sender and the receiver.

Companies today often face the problem of knowledge sharing/capturing activities not usually being a part of the official job description and, therefore, no time resources are allocated for this type of activity (Mueller 2014). Furthermore, project teams suffer from time pressures to reach their actual project goals let alone have free time to pursue knowledge capture/sharing activities. Resultant factors on the other hand, deal with specific problems and can be regarded more like the symptoms rather than the disease (Frost 2014). Some of the failure factors highlighted by Frost (2014) are lack of performance indicators and measurable benefits, inadequate management support, improper skill of knowledge managers and workers, problems with organisational culture and lack of responsibility and ownership to name a few.

3.5.6 Facilitating Knowledge Capture and Sharing

There are many ways to facilitate knowledge sharing within a company. The simplest method involves an open sharing policy, by changing a company's culture to openly share knowledge amongst each other in order to aid the distribution and creation of new knowledge. People will need to dedicate their time to share and explain their own knowledge upon request. A second step would be to involve the introduction of a software database tool which enables knowledge sharing electronically, making this method more labour intensive to start off with in order to populate the knowledge database. An alternative method is to use online social network / communities, allowing users to search and collect information from either internal or external expertise. The social networking and virtual communities have been gradually increasing in popularity and are considered a very important platform for knowledge sharing (Chen and Hung 2010, Chang and Chuang 2011).

Some people will argue that you do not need technology to implement a KM programme. To some extent they are right. KM is fundamentally about people, not technology, but there is absolutely no way that you can share knowledge effectively within an organisation – even a small one, never mind a large geographically dispersed one, without using some sought of technology (Gurteen 1999). There still exist sceptics to this hypothesis because if people are not willing to share knowledge at their own accord, no software will ever manage to change this attitude. Therefore, both methods are required if you want an effective KM system.

There are several off the shelf software tools for KM but none of them will cater 100% for a specific company's requirements, due to each company having different knowledge requirements and therefore any system should be modified to a certain extent to cater for those requirements. The collecting of knowledge for the sake of collecting does not result in knowledge being shared or used by others. Any knowledge collected for storage should be purposely selected for the use by the company and/or its employees.

The main challenges for knowledge management initiatives are finding solutions to people-centric problems, such as motivation and personality factors and creating organisational antecedents to ensure a smooth knowledge flow (Von Krogh and Roos 1996). Corporate culture can also explain why different initiatives succeed or fail because it discovers patterns in organisational behaviour (Denison 1990). Sackmann (2002) defined this corporate culture as the basic beliefs commonly-held and learned by a group, that govern the group member's perception, thoughts, feelings and actions and that are typical for the group as a whole. Consequently, KM initiatives are only successful if they are in accordance with the company's cultural perception influencing if and how knowledge is shared (Davenport, De Long et al. 1998).

3.6 Critical Literature Review of Key Topic Areas

In this section, a selection of papers which are particularly relevant to this research area are examined in more detail highlighting the contribution and short comings of each particular paper. The criteria of the selected papers are dependent on the number of citations and the subject area they contribute towards in relation to knowledge management.

3.6.1 E-Learning

E-Learning can be defined as instructions delivered on a digital device such as a computer or mobile device that is intended to support learning (Clark and Mayer 2011). Over the last decade, e-learning has moved from an experimental procedure used to teach technical subjects within computer companies to a mainstream staple teaching everything from life-saving medical procedures to spiritual vision (Horton 2011).

The study presented by *Özdemir (2008)* investigates current literature relating to e-Learning. They state that e-learners are able to gain both tacit and explicit knowledge in e-learning environments due to the negative premise that knowledge creation and transfer is not possible if face-to-face interactions is missing during e-learning activities. The researcher concludes that in 2008, technology was not adequate for appropriate tacit-knowledge and that a new generation of students will suffer from this shortage. They highlight that further development is required if e-learning as a teaching tool is to further be used as a replacement of traditional lectures.

The shortfall of this research is that it only explores the theoretical studies dating back in some case considerable amount of time and ignores new advancements in Web 2.0 technologies, which would aid and stimulate better e-learning environments.

Chen and Hsiang (2007) presented an empirical study carried out by means of qualitative research of learning organisations on knowledge community based e-learning. The aim of their research was driven on the premise that industry is constantly under pressure to develop fast-paced innovation and knowledge transfer in order to remain sustainable and competitive. Therefore, in order to implement a knowledge management policy, the development of a knowledge community is critical in order to achieve this. The focus of this study moves away from teaching individuals but takes into consideration the collective learning of the community so that the company as a whole can benefit from the knowledge transfer.

Another study on the impact E-learning has on the educational system was conducted by Shehabat and Mahdi (2009). Their research explored if knowledge management and e-learning can be integrated effectively in Universities in Jordan. The scope of the project was purely university based and was aimed at addressing the design issues of e-learning courses that can be used to capture the teachers knowledge so that when and if the teaching staff decided to leave or retire from the university the knowledge that the staff has developed during the years of service is not lost when the person leaves.

The researchers continue their analysis with first-hand experiences in a Jordanian University and provide recommendations / requirements that

Universities in the middle-east should follow if they are to successfully implement e-learning techniques in this part of the world. While the study provides some insight into learning methods used for different cultures, it lacks a proper framework that can be utilized to implement new e-learning and also there is not data that substantiates the recommendations provided (Shehabat and Mahdi 2009).

The interactions between a knowledge expert and novices, and knowledge is transferred between these groups was conducted by Wilkesmann and Wilkesmann (2011). Their research presented the results of a six year qualitative investigation into knowledge management and e-learning activities at Lufthansa, a German airline company. The investigation looked at the processes and system that enable both sides of knowledge transfer, obtaining and providing knowledge, between the expert and novice employees within the company.

The identified approached used by the German company offers support for both knowledge creation and transfer by allowing employees organisational leeway that provides the expert to create knowledge and for novices to absorb the knowledge available. The second point was the convergence of e-learning and knowledge management in the form of rapid e-learning so that novices can absorb the information quickly and efficiently and finally with the introduction of knowledge transfer methodologies.

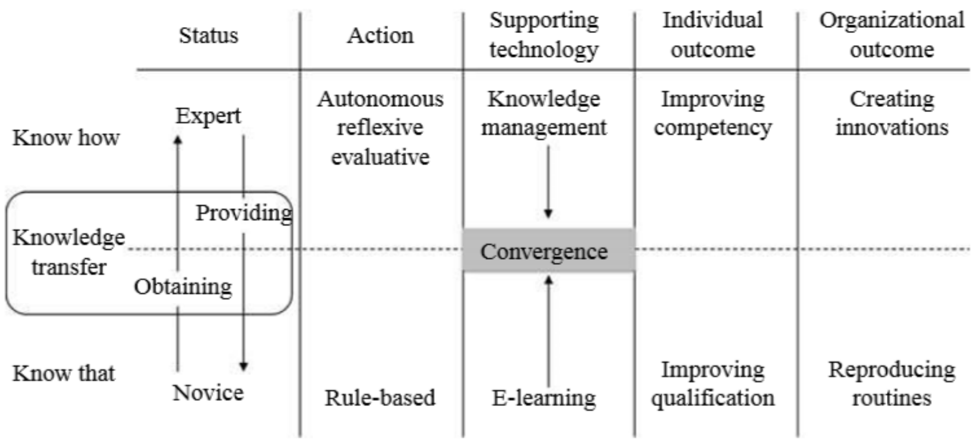


Figure 16. Knowledge transfer as an interaction between expert and novice (Wilkesmann and Wilkesmann 2011).

The researcher concludes that the developed knowledge transfer methodology creates the right environment, since every employee is considered an expert in a certain field of knowledge and also a novice in other fields of knowledge, knowledge transfer becomes a reciprocal process. In this regards, a positive change in the learning culture of the company takes place.

Regarding the research shortfalls, it only offers a high level view of the KM system used by Lufthansa. The research does not cover how the knowledge is created and, therefore, does not provide a picture of the effort required to create knowledge and keep the created knowledge up to date with the latest technology shifts in industry (Wilkesmann and Wilkesmann 2011).

3.6.2 Storytelling

Stories provide the ideal medium to explain in an ordered and logical way past experiences and ideas that need to be communicated to others. Stories provide a bridge between the tacit and the explicit form of knowledge as stories conveys the speaker's moral attitude (Linde 2001). Storytelling has been touted as the best way to make the leap from information to knowledge, and as the best way to capture and transfer tacit knowledge (Reamy 2002).

Storytelling, as a means to improve communication for Small to Medium Enterprises (SME) knowledge transfer, was carried out by Martin-Niemi and Greatbanks (2009). Their research looked at different techniques to facilitate communication and collaboration that SMEs use in order to transition into a larger organisational structure. The researchers explored utilizing storytelling with new generation Web 2.0 technologies which provide an individualised and customisable user experience including virtual social interactions, shared collaborative portals and communications tools.

Their proposed framework aimed at capturing and sharing knowledge by means of storytelling within the firm as means of knowledge transfer and for communicating the common practices and organisational standards referred to as the 'company way'. They proposed that a service-orientated company, whose main assets and resources are contained within the skills and abilities of its employees to convert their individual knowledge into organisational knowledge, benefits the whole company. Unfortunately, the framework was based on theoretical theory and no validation studies were conducted to quantify the effectiveness of the proposed framework.

Another study which used storytelling for the purpose of transferring knowledge was conducted by Kalid and Mahmood (2011) who developed it into a framework (see Figure 17). Storytelling in a knowledge management context is seen as an effective tool to communicate knowledge, particularly tacit knowledge. While face to face interactions are considered the ideal for knowledge transfer, this process is unstructured and replicable due to the inconsistences of the person conveying the story / knowledge, meaning that from one instance to the next the person conveying the story / knowledge can change the message which can have a different effect on the knowledge receiver; this can result in a loss of knowledge value. Therefore, the proposed framework involves the capturing of knowledge and encapsulating it into a structured and narrative form.

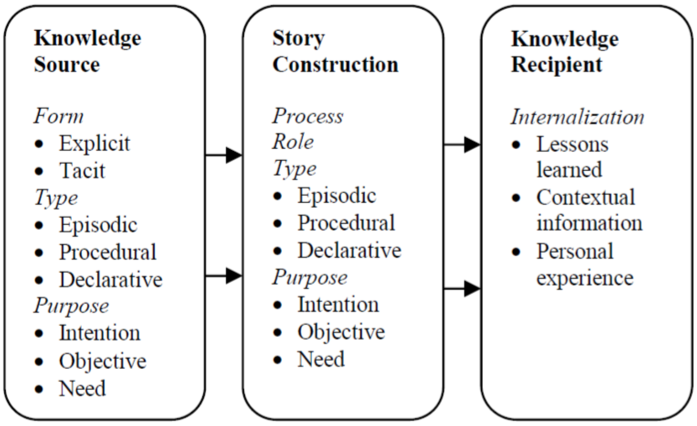


Figure 17. Knowledge story construction process framework (Kalid and Mahmood 2011).

This is achieved by constructing the knowledge story by identifying key items such as factors, concepts or time and writing the subplots of events to reflect these items. These ideas are than processed through the developed model which consists of 4 steps: articulating knowledge source, the organisation of ideas and concepts, write story and revise story. This framework was only tested by means of workshops to create knowledge stories. Unfortunately, the research did not cover the quality and effectiveness of the knowledge story to transfer knowledge to third party users.

In the construction industry, the use of storytelling as a knowledge transfer mechanism was examined by Leung and Fong (2010). Their study looked at the capturing and sharing of project member's tacit knowledge. Construction projects are generally classified as fast paced, complex with limited time and resources, with team members generally changing from one project to the next. Therefore, vital knowledge in experienced personnel might not be available on a particular project due to capacity issues. Their study aimed to explore storytelling as a knowledge transfer mechanism that could be applied in construction project environments. Their analysis is primarily carried out by means of in-depth literature review of the use of storytelling as means for knowledge transfer and formalize insight into the role for this type of knowledge transfer mechanism. Unfortunately, the study didn't carry any real life research to provide validation to the presented assumptions.

The effectiveness of storytelling to transfer different types of knowledge as a teaching tool was explored by Katušcăkovă and Katušcăk (2013), who stated that if knowledge is captured in a properly constructed story, it will represent an effective and important knowledge management tool for motivation, persuasion, communication, interpretation and education, as well as sharing tacit knowledge and visualise the invisible. Their framework was case studied at the University of Zilina in the Slovak Republic on undergrad students reading knowledge management courses. The knowledge capture by means of storytelling was carried out by the students participating in the project which were then used for the actual knowledge transfer analysis.

The knowledge transfer research was carried out with two student groups. The first group received the classical knowledge transfer method, using lectures, while the second group received prepared constructed stories, while the content of the knowledge transfer was identical for both groups of students. The students' knowledge retention was measured by means of 3 tests: 1) a pre-test to measure knowledge before the knowledge transfer took place, 2) after the test to measure how much knowledge was absorbed and 3) post-test to measure how much knowledge was retained by the student at a later stage.

It was found that storytelling provided students with an in-depth understanding of the subject area because the process gave them the opportunity to associate the knowledge with a real life situation. The only short coming in this research was that the knowledge contributors were not considered as experts in the subject area and, therefore, they were limited in real life experience content, and were predominantly based on theoretical knowledge obtained from publications. If the material would have been created by real experienced and knowledgeable personnel it would have given the study additional substance and validity.

3.6.3 Social Media

According to the OxfordDictionary.com (2015), social media is defined as “Websites and applications that enable users to create and share content or to participate in social networking. With the explosion of social media, with the fast passed advancement of information and communication technology (ICT) in the last decade, social media tools have been inundated with information and knowledge. Research by Schirru (2010) proposed a topic based recommendation tool for Web 2.0 social media sharing platform. The intention of the system was to identify the knowledge workers short-term and long-term topics detection and tracking and generate recommendations of what knowledge content is required by the user.

The recommendations are developed from identifying the knowledge workers topics of interest by applying textual data mining techniques on the metadata of their computer account profile. This data is then applied through an item-based collaborative filtering algorithm, which compares the results obtained from other users in order to increase the accuracy of the recommendation. The preliminary results of this study showed that the users were able to associate the recommended topics with the real topics of interest, thus showing that the method is likely to capture reasonable user interest topics. Further, it was pointed out that the users widely agreed that they would appreciate resource recommendations for the identified topics.

The main limitations of this study were that the case study was limited to eight users and, therefore, provided only a small test environment. Also, the social media platform used was not a main, readily available system that can be easily applied to the masses allowing the possibility of a larger test environment. Finally, the system relied on data mining of appropriately labelled knowledge contributions, which reduced the effectiveness of the tool.

Similar to the work of Schirru, Zhong, Fan et al. (2012) looked at multiple social media platforms, such as Facebook and Twitter in order to increase the accuracy to predict user behaviour by examining their activities across multiple social media platforms. Their study was primarily directed towards social marketing by the personalization and recommendations of ads that come up during internet browsing.

This gives the opportunity to leverage the knowledge of user behaviour on different networks, in order to alleviate the data sparsity problem in order to enhance the predictive performance of user modelling. This cross platform data mining analysis brings its own challenges to the research due to the difference in the source code of the different platforms which required the researchers to develop a composite network knowledge transfer before any algorithm could be applied to the big data from which specific user topics are identified.

The main contribution of this study was that it exploited user-topic distributions to generate social relations between users. The proposed model is flexible enough that it can be applied to a number of social media networks providing a more accurate picture of user behaviour patterns. While the intension was to use main stream social media tools, this was not carried out in the study and instead the researchers opted for less known social media tools. From the outset, the study was directed towards social marketing. This might be a useful tool if used as a recommendation tool for user knowledge requirements and current interests.

Cao, Guo et al. (2011) explored the influence that social media has on employees' work performance and the underlying mechanism social media can create value in the work place. The research proposed that social media can promote work performance by stimulating trust among employees and offer a communication channel where explicit an implicit knowledge can be effectively transferred. The study was conducted by means of surveying software professionals on their current practices.

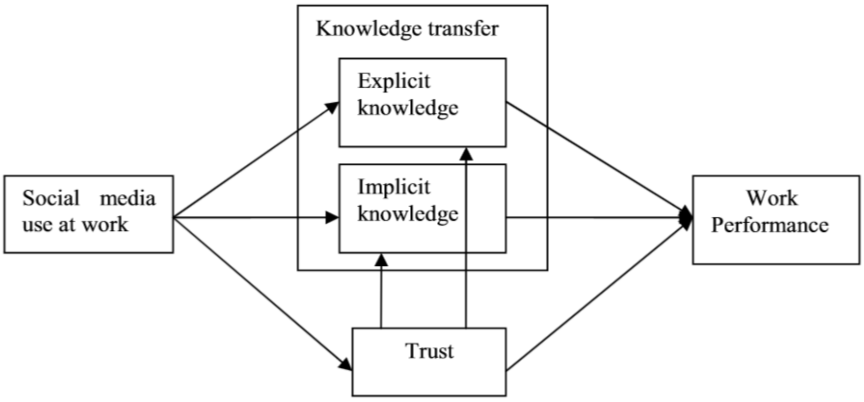


Figure 18. Understanding the influence of social media research model (Cao, Guo et al. 2011).

The findings of the research revealed that social media can enhance trust amongst employees but they found that it did not enhance knowledge transfer (Harden 2012). Even though the researchers stated that building a relationship of trust amongst your employees is the first building block to improve communication, they did not follow up the research if this newly built trust improved knowledge transfer later on if the experiment might have been extended to a longer period of time. Due to the complexity of building new employee relationships, one cannot expect significant behavioural changes in a short period of time; this would require nurturing and attention and the proper environment in order to produce results (Cao, Guo et al. 2011).

3.6.4 Video Sharing

Video Sharing consists of people sharing video content over the internet by means of a hosting website. The most well know video sharing website is called YouTube which is owned by Google Inc., which hosts a large variety of video content. Clifton and Mann (2011) investigated the use of YouTube, a video sharing tool, to enhance student learning by conducting a case study based on undergrad nursing students at the University of Nottingham. Their work consisted in exploring the use of new technologies in the classroom to enhance the delivery of teaching material and student learning. In their study, they used YouTube as a learning resource to supplement and enhance classroom learning. With its popularity, YouTube is a well-recognised and established social media tool which is widely used by individuals and organisations, such as universities, who are creating their own YouTube channels to provide a wider access to their institutional learning material. Due to this tool's popularity, the study relied on teaching material which is readily available on the YouTube database. From their study, the researcher found that the video sharing website increased student engagement, critical awareness and facilitated deep learning, Furthermore, the videos used allowed students to access them at any time of the day and from any place to suit student needs, providing extra flexibility and repeatability.

The main shortcoming of this research was the lack of quality control that currently exists on YouTube. Due to YouTube being populated with material both from individuals and/or organisations, there is no control on the quality of the material uploaded and, therefore, users need to evaluate material content before accepting it as new knowledge. The study encouraged the use of video sharing websites but did not explore the time and effort a knowledge contributor would need to create a knowledge video.

Another similar medically-based study was carried out by Akgun, Karabay et al. (2014) who examined the usefulness of YouTube video content for learning purposes of electrocardiogram material. They examined the material quality and the content available on the video sharing website. The researchers of medical background searched the YouTube database for electrocardiogram video materials and selected 119 video for in depth quality and content analysis. Their analysis found that more than half of the uploaded material was submitted by individuals, only 21.8% and 8.4% were uploaded from health website and universities / hospitals respectively. When they classified the usefulness of the selected material, they found that 90% of the material uploaded by universities /

hospitals was classified as very useful while 45% of uploads done by individuals was classified as misleading.

This study highlighted the lack of quality control in the material available in an open system like YouTube, and the importance to be selective with the videos available. Similar to the previous paper, this research is limited to readily available material uploaded by others. It is also limited due to the subjective nature of the classification method used to categorize the selected video material, and only provides a quality snap shot of when the study was carried out (Akgun, Karabay et al. 2014).

Due to its popularity and its accessibility, the third video sharing study being reviewed also used YouTube as the video sharing database. Lee and Lehto (2013) proposed a conceptual framework for user acceptance behaviour of video sharing content for procedural learning, which was conducted amongst 432 respondents. Procedural learning is an integral part of common activities which are characterized as psychomotor skill acquisition of “how-to-do something” through step-by-step procedural instructions. The proposed framework is founded on the Technology Acceptance Model (TAM) which is based on the perceived usefulness as a form of extrinsic motivation.

The research hypothesis of the study was based on the user perception of the shown material on the criteria of user satisfaction, perceived usefulness and perceived ease of use. From the proposed criteria, the researchers found that only user satisfaction and perceived usefulness resulted as key elements that motivate people to use and accept video sharing content and stated that video sharing may augment its function as a common channel for procedural learning.

One of the main shortcomings was the duration of the study. The data collected was a snapshot of people’s perception of video content; it would be interesting to explore peoples’ perception when they visit a video sharing website for a second, third and fourth time, to see if they have the same perception from the first time or if they have increased or decreased their perception towards video sharing websites. A secondary limitation to the study was the targeted audience. While having a response rate of 432, which is quite an achievement, the broad selection process used was not focused to a specific topic area and, therefore, with people having different interest areas, this limited the cohesion and the usefulness of the material shown to the participants.

Torres-Ramírez, García-Domingo et al. (2014) presented a study conducted at the University of Jaén for undergrad and postgraduate engineering students on the use of video-sharing as an educational tool. In an ideal world, engineering students would greatly benefit from visits to industrial plants to observe first-hand real engineering in practice, but due to financial limitations and in some cases lack of industrial support, this cannot always be provided for students. Therefore, the researchers proposed to use video sharing material on renewable energy, based on video cast techniques, to show different ways of obtaining thermal energy and electricity from renewable resources with the aim to bring engineering technology closer to the student and, therefore, provide a richer learning environment. The developed tool was used for both face-to-face learning and distance learning environments.

The study found that the students which used the video sharing tool obtained a high degree of general satisfaction, improved the understanding of the theoretical concepts previously studied in a traditional way and the facility to access the video content when the student felt like it were considered as the main benefits of the project.

The conducted study was of high quality and provided insight into video sharing in relation to engineering knowledge transfer. It would have been interesting to explore if this tool could be used in an industrial environment where the users are not there only to learn an engineering subject but have their day to day working tasks not solely in a class room to learn a specific subject.

3.7 Summary of Identified Research Gaps

The literature survey has identified several research gaps listed below;

I. There is a lack of enabling tools and methods to support the improvement of testing operations, as an integrated activity in the whole product development process;

II. There is significant research representing knowledge and information for PD design, manufacturing and management, but there is a lack of research and methods in the capturing, representation and analysis of PD testing related knowledge for the easy reuse and share for new PD;

III. There is a lack of tools to manage tacit knowledge;

IV. Social media and Web technologies have been widely used for social networking and communication. However, these technologies have not been used for complex engineering applications. The potential of social media technologies to address the social aspects of knowledge management in engineering applications should be explored;

V. Several research papers have looked at specific sections of knowledge transfer through video sharing, but it seems the literature lacks a complete examination of a fully integrated process from capturing to sharing the knowledge, up to building/creating new knowledge;

VI. The idea to use rich multimedia and video sharing content as a means for knowledge transfer has already been used by universities to some degree as a method to supplement the student learning processes (Clifton and Mann 2011). However, it seems that universities generally rely either on professional media agencies to develop the knowledge content or rely on readily available content found on the Web. There is a gap in the literature on knowledge content created by the actual knowledge experts.

These research gaps will be explored through the creation and implementation of a knowledge sharing framework. With the proposed solution using main stream everyday technologies, which are also used by universities to some extent to deliver subject content to its students. These proposed tools include technologies like video sharing, storytelling, social media and E-learning. These topics have been covered in the above critical literature review, which highlighted several issues that require further research before any framework can be developed.

In the next Chapter, the carried out industrial investigation and findings are explained and analysed, identifying the industrial requirements.

Chapter 4: Industrial Investigation and Findings

An extensive industrial investigation has been conducted to gain a greater understanding of the current processes and problems being faced by the collaborating company and capture industrial requirement. This investigation is mainly divided into three sections: 1) Physical Observations, 2) Utilization Metric Monitoring, and 3) Questionnaire Studies. The main issues that have been identified during the industrial investigation are discussed and analysed. The analysis is divided into five sections: 1) the observation period, 2) utilization metrics, 3) pilot study questionnaire, 4) site visits and 5) KM end user questionnaire. The investigative methods used in this research are also described.

4.1. The Investigation Carried Out

The first objective of the industrial investigation was to understand the company's organisational structure and establish the company research project requirements. The interest in the organisational structure is in regard to the departments which are in direct contact with the testing facility and contributing to the development testing of power generation units.

This investigation was divided into three tasks, i.e., observations and process modelling, utilization metrics, and investigative questionnaire studies. The observations and process modelling task allows for a better understanding of the company's current status. The utilization metrics task, allows for operational measurement of the current testing facility and, at the same time, highlights problem areas that need to be addressed to improve efficiency. The applied utilization metrics can also provide a dimensional measure of improvement at a later stage when the implemented framework will have matured enough that it will provide a tangible improvement in the operation of the testing facility. The third task of investigation consisted of a number of investigative questionnaire studies carried out at different stages of the project, exploring the opinions and knowhow of the people working in the testing facility and their collaborators / stakeholders in other departments. The initial questionnaires highlighted real issues faced by the product development team in a real industrial setting and provided the project with basic requirements and direction to improve the capture and sharing of employee knowledge and communication dissemination. The three tasks are further described below.

4.1.1. Observations and Process Modelling

Remenyi (1998) described this research method as *"making first hand observations of activities and interactions, sometimes engaging personally in those activities as a participant-observer".* The observations research technique provides first-hand information, and hands on experience into the research area, providing a greater insight and understanding, rather than simply depending on user input which tries to describe the situations or processes.

It was obvious that a period of physical observations was required to provide a better understanding of the operations and the product development cycle which affects the testing facility. The main reasons behind this was to experience first-hand the day to day interactions amongst the different members within the testing facility team and their counter parts in other departments. It also served as a learning experience of the day to day operations, which was crucial in providing a better understanding of the processes which should be modelled and documented as part of this research project.

Another aspect of the physical observation period was to understand the extensive product range which is manufactured by the company both on site in Kent and at other sites in the UK and the US. A number of research trips were made in both countries, providing the personal opportunity to grow as an engineer by being exposed to different testing technologies which were not available at the Kent site, but also meeting different employees from different cultural backgrounds. The most crucial part of this investigation was to learn what core values and beliefs are promoted by the company as best practice and normal operating procedure. Without this, the research would have been too generalized, which could have not met company requirements from the start of the project.

4.1.2. Utilization Metrics

Operational performance or facility utilization monitoring is an important activity which keeps management informed of how the facilities are operating and can easily highlight when a problem arises. According to Neely (2002), “a performance measurement system is the set of metrics used to quantify the efficiency and effectiveness of past actions” and “it enables informed decisions to be made and actions to be taken because it quantifies the efficiency and effectiveness of past actions through the acquisition, collation, sorting, analysis and interpretation of appropriate information”.

Several commercially-available monitoring tools can be used for this task, such as RealTime™ Production Monitoring from IQMS or VIMANA by System Insights. These software solutions monitor and manage engineering equipment productivity, but due to financial restraints on the project, a more cost effective system had to be developed by the researcher. The developed utilization system had to be able to record testing cell usage and categorize and quantify any down time. It also needed to provide historical operational data presented in a graphical manner giving a clear picture on a monthly basis of test cell usage and quantifiable and categorised down time.

At the beginning of the project, the testing facility only recorded an approximate amount of hours that the testing cells were actually used to run tests. Figure 19 shows how the data collection evolved in the first 6 months of the project. Initially, prior to January 2013, utilization data was collected on a weekly basis during a team meeting held at the end of each week. Most of the run time data was recorded from what the testing technician recalled from memory during the past week, without any formal documentation procedure to accurately record test cell running time.

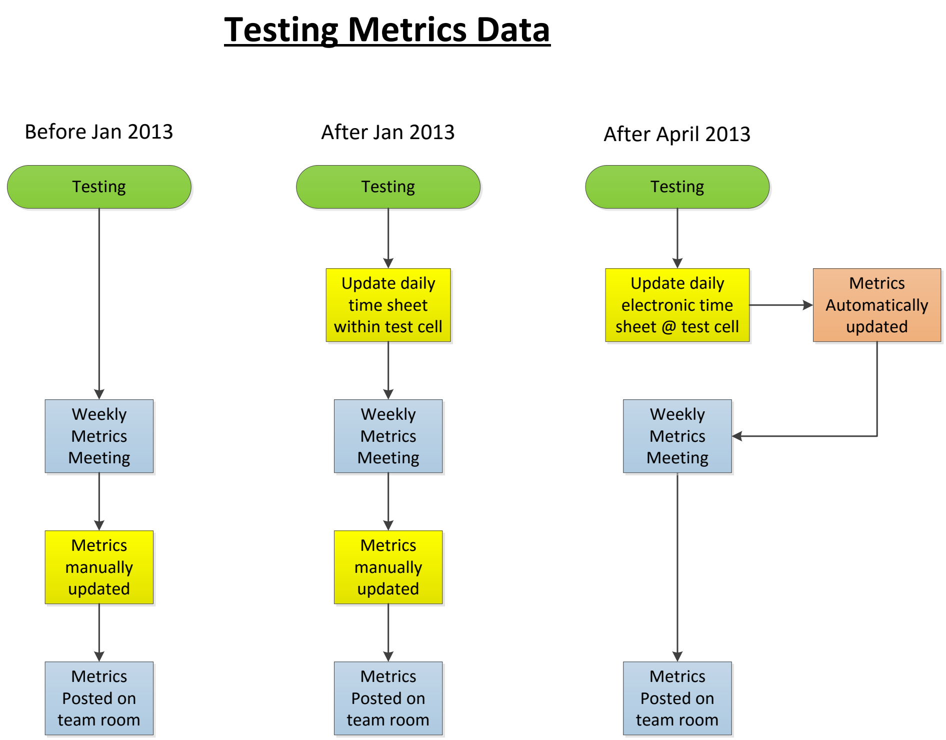


Figure 19. Utilization data collection evolution

Unfortunately, this method was not very accurate, mainly due to the data only being as accurate as the technician's recollection and several tasks were being missed out. Therefore, this method only provided a rough idea of actual running time of the test cells. Wasted time, such as down time and setup time was not being documented or categorized in order to highlight any reoccurring issues or problems in the test cell or testing procedure.

This issue was also highlighted in a 6-sigma utilization project which was running at the time during the start of the investigation. Therefore, in collaboration with the 6-sigma project team leader, a new simplified method of collecting this data was created and implemented in this project. The new addition to collection method was to attach a time sheet in each of the test cells which would be filled in by the technician responsible for running that cell. The developed time sheets divided the day into 30 minute slots and each slot had to be filled in by hand on regular intervals during the course of the day, resulting in more accurate data. Another issue addressed regarding the developed time sheets was the quantification of wasted time. The developed system only quantified the time that the test cell was either running a test or down time, which did not explain the reasons for down time.

In order to obtain a better picture of what the down time consisted of and identify the major waste detractors inside the testing facility, a list of waste categories had to be developed and agreed upon with the testing technicians. Due to the different interpretations that a group of people will provide to the same situation, careful thought was required to create the list of waste detractor categories in order to avoid misinterpretations and mistakes. A draft list of waste detractor issues was created from a brain storming session with a number of testing technicians. The initial list, shown in Appendix P: Figure 180, incorporated the time sheet consisting of 23 activities which a technician in a test cell needed to complete, quantifying and categorizing the number of hours the usage of the test cell had.

This data was collected on a weekly basis and converted into an electronic format for further processing and manual population of the monthly utilization chart. This manual utilization time sheet carried on for a total of 6 weeks. The main purpose of the manual time sheet was to demonstrate the benefit of having data available of the waste detractors in any of the test cells and also to establish the stability of the developed list of waste detractors. The list was further developed into a list of 31 activities, shown in Appendix P: Figure 181, which include the activities grouped into 8 main detractors.

The final improvement Metrics Utilization Monitoring Systems (MUMS) in the data collection method was implemented in April 2013. The new version developed in principle was very similar to the manual time sheet shown in Appendix P: Figure 180, with the main difference being that the initial time sheets in which the technician needs to input the utilization data was transferred into an electronic format in Microsoft Excel. Once the information of the test cell activity was inserted to its corresponding time slot the Excel sheet automatically calculated the various activities throughout the month and populated the monthly utilization chart; this time sheet digitization eliminated the two manual tasks of transferring the weekly utilization into an electronic format and the calculation of the different activities into a graphical format shown in Appendix P: Figure 182.

The digitization of the time sheet provided the opportunity to simplify and, at the same time, increase the accuracy of data entry by introducing techniques such as colour coding for the different activities. Apart from distinguishing the difference between detractors, this simple method also highlighted any missing information. This data is then automatically counted and calculated up in a secondary table, shown in Appendix P: Figure 183 and Figure 184, in which all the different activities in a single day are added together and a logical check verifies that the quantity inserted equates to the actual hours worked. This calculation is utilized to populate several customized graphical charts required by management.

The developed software checks that the right amount of hours are entered and distinguishes between normal working hours and over time. This is an important step because it is easy to improve utilization by doing extra overtime but this comes at an expensive cost. Therefore, by distinguishing the different hours, this will give a real value of normal working hours and overtime.

The data being captured provides an improved picture of the day to day operations in the testing facility, resulting in a system that can quickly pin point any problem areas, which in turn can be addressed in the quickest and most concise manner. This utilization metrics data collection system can be further improved by categorizing the data into further detailed information. For example, if the running time or set up time data is collected against the type of unit or a type of test, this information could be used for a live database that is able to provide the average running time for a particular test on a particular size Genset. With this information, the test planning process would be more accurate and, based on real hard data, rather than an assumption and gut feeling of test durations.

4.1.3. Questionnaire – Studies

Throughout this investigation a number of questionnaire studies were conducted to determine requirements at different stages of the project. The first questionnaire was used during a pilot study. A pilot study questionnaire is defined as a preliminary piece of research conducted before a complete survey to test the effectiveness of a research methodology (Stopher 2012). This was followed with a second questionnaire conducted during site visits both in the UK and US, aimed at highlighting differences in processes and available equipment at the different sites. The final questionnaire was conducted after the project requirements were identified and focused on determining employee attitudes towards knowledge sharing and their use of social media. In the following sections explores the contents and rational of the conducted studies.

4.1.4. Pilot Study Questionnaire

The aim of the pilot study was to obtain a general feel of three main topic areas: 1) Communication, 2) Processes and 3) Knowledge Management. The intended target audience was testing facility staff and their counterparts with whom they have constant contact with, in relation to product development at the Kent site. From the gathered feedback, a more focused questionnaire would have been developed later on in the project. However, the quality of the responses received from the pilot study gave the researcher excellent quality of data, more than anticipated. Consequently, the pilot study was never developed into a full questionnaire study. Instead, it was decided to extend the targeted audience of the pilot study and add participants from off-site locations. These included key people that have an influence on testing processes and product validation outside the Kent site, due to their senior management position or technical expertise.

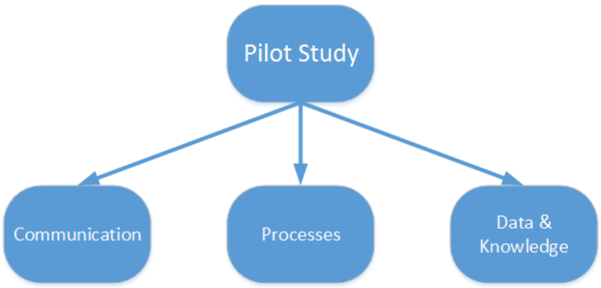


Figure 20. Pilot study structure

The pilot study consisted of 24 questions divided into three categories, communication, processes and data & knowledge. The intention of each question was to obtain the interviewee's personal opinion on the different people involved in the product testing and development cycle. The questions varied from simple closed questioning providing a 'yes' or 'no' response, to open ended opinion based answers, such as:

- How can the company improve communication between colleagues during the product development process?

- What do you think of the existing planning process of human and equipment resources?

- When a problem is encountered during product development do you find adequate support from other department?
  Yes ☐ , No ☐

- Do you feel that you send significant amount of time searching for information, data and/or knowledge, any quantitative indicator?

A copy of the questionnaire used during this study can be found in Appendix C.

The pilot study questionnaire was conducted using three methods: email, face to face interviews and telephone interviews. These were conducted at different stages of the investigation, depending upon the response of the participants. The questionnaire was first issued by email following a presentation given to participants. Respondents were given six weeks to hand in their response. Following this period, eight face to face interviews were organized with onsite personnel that failed to respond to the questionnaire. Additional telephone interviews were organized with participants which were off site. These interviews resulted in more fruitful responses because more detailed answers were received and further discussions on topics close to the heart of the interviewee. This result was an unintended from both the researcher and the topics targeted by the questionnaire. One interviewee summed up this as having the chance to “*have a bit of a moan*” on the particular subject.

4.1.4.1. Other UK and US Industrial Site Visits Questionnaire

In order to obtain a standard and structured collection of information from the different site visits, an investigative questionnaire was developed. The intention of the questionnaire was to highlight different capabilities at different sites and to highlight the commonality between them in anticipation that the developed knowledge capture and sharing framework would be relevant and compatible with these different sites. Obviously, Cummins have more testing facilities sites spread out around the globe but, due to financial limitations, this investigation was limited to the UK and US main testing sites. The questionnaire used during the industrial site visits consisted of 24 questions divided into three categories: Test site capabilities, documentation and software tools and testing facility waste detractors.

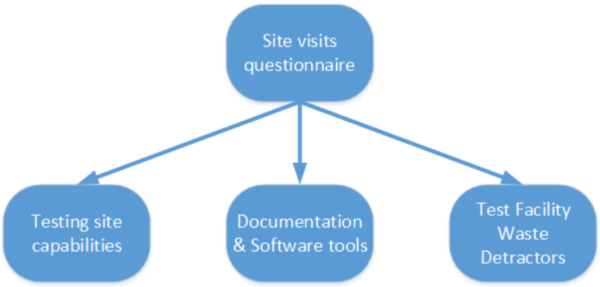


Figure 21. Site Visits questionnaire

The questions varied from simple closed questions to open ended opinion based answers, such as:

- What types of tests are carried out at this site?
- What is the current testing capacity? Supply demand of test requests
- How is documentation controlled and stored? Do you use any kind of CMS tools to store and control documents? Could you please show me & send me a screen shot?
- Are the test schedules static or dynamic to changes? If the plan schedule is software based is it reactive to changes?
- Genset rig time – do you use any techniques to reduce time. Pre – rigging prep work, CAD simulations, or any form of planning?

A copy of the questionnaire used can be found in appendix E.

4.1.4.2. Proposed Framework Requirements Investigative Questionnaire

Once the industrial requirements were established and the proposed knowledge framework outlined, an investigative study on the tools to be used and the learning and sharing user preferences was required in order to formulize the optimal strategy to full fill the industrial requirements. The aim of this questionnaire was to obtain user input on three topic areas: employee use of social media, learning preferences and knowledge sharing preferences. Similar to the pilot study questionnaire, the same target audience was used for this study.

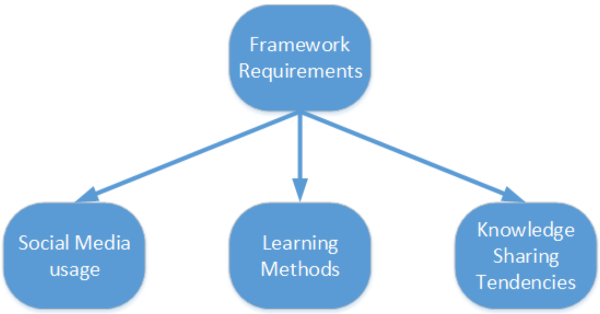


Figure 22. Framework requirements investigative questionnaire structure

The questionnaire consisted of 10 questions divided into three categories: social media usage, learning methods and knowledge sharing tendencies. The intention of the questions was to obtain an understanding of the eventual developed system user's opinion and tendencies on the three topic areas. The structure of the questionnaire consisted of multiple choice questions; the reasoning behind this format was to provide a form of structure to the answers provided by the participants which simplified the analysis of the results obtained. The selected format provided an increased completeness of the questionnaire. During the pilot study questionnaire, it was noted that some participants skipped difficult questions in order to avoid writing lengthy answers to explain their opinion on the particular subject. Another reason for the selected format was to minimize the amount of work disruption of participant's time to complete the questionnaire. Example questions included in the questionnaire are shown below:

- How much of a social media user do you consider you're self to be? *Select answer from:* I hardly use it, I use it from time to time, I use it daily, I'm a heavy user, and I cannot live without it.

- Do you consider yourself as a passive user (only read / follow what others are writing / posting) or an active user (you write/post things yourself) of social media tools? (twitter, Facebook, LinkedIn, YouTube, online forums, blogs, etc.)

  Passive user, ❑

  Active user, ❑

- How do you feel about sharing with others the knowledge that you have acquired during your time at Cummins?
  Select answer from: I don't like sharing, I only share when it's to my benefit, I share when I am asked to, I share with others, and I openly share with other because it makes my life easier.

- What kind of incentive would trigger or improve your participation to share your knowledge?
  Select answer from: No incentive needed I share knowledge willingly, Recognition – status, Career advancement, Gift compensation, (tickets for shows or events, etc.) and Monetary compensation.

A copy of the questionnaire can be found attached in appendix G. The framework requirements questionnaire was conducted using the collaborating company's official survey tool over a period of 3 weeks.

4.2. Observations and Process Modelling Findings

One of the most important process modelling tasks was to document the current situation of the testing facility at the start of the project. This was completed by going through the Value Package Introduction (VPI process) process flows, conducting discussions with company staff and by observing and reporting the actual processes. The information captured is illustrated in the process flow chart shown in Figure 23. One of the first noted points is that the VPI process is not observed to the letter. This could be due to the rigidity of the processes which, according to comments received during the observation period, the VPI process is a one size fits all solution for a variety of other Cummins businesses, which would explain the rigidity of the process.

It was also noted that several unofficial communications are conducted during the initial stages of the project testing cycle. It is good practice that projects are communicated at a very early stages as a sort of 'heads up' notice. But this could result in problems occurring when actual discussions are conducted and not captured in the documentation. This could also lead to, in the worst case, misunderstandings or the bypassing of the documentation process which is important not only for the sake of documentation purposes, but also as it provides a historical reference point when validation problems reoccur up to 6-

12 months down the track and people are simply recalling events from memory. Another documentation issue is regarding the Design Verification Plan and Report (DVP&R) approval process. The DVP&R is a document which states the required tests to be performed on a testing prototype. In the past, the approval process step was overlooked mainly because the process required the responsible engineer to run around the company asking for signatures on a paper document which was scanned once all signatures had been collected and stored on to the system in an electronic format.

Omitting this approval step automatically eliminates the possibility of management questioning or challenging the requirements of a specific test. A 6-sigma project was being implemented as an intermediate solution to force the approval process by coupling it with the company's email system, but unfortunately this ran into IT development issues.

The intermediate solution was to send out emails to the chosen approval personnel so that immediate action could be taken and then documented in an electronic format; thus saving a lot of time seeking colleagues for their signatures. The changeover approval process, when the DVP&R document is submitted to testing facility shown in Figure 24, is also not functioning as it should be. Another issue when the testing facility receive a DVP&R is that the information has to be transferred manually into another document called a work request; this work request has its validity as a document, but often feels more like a duplicating and transferring exercise, adding the information into a different format without gaining anything of extra value.

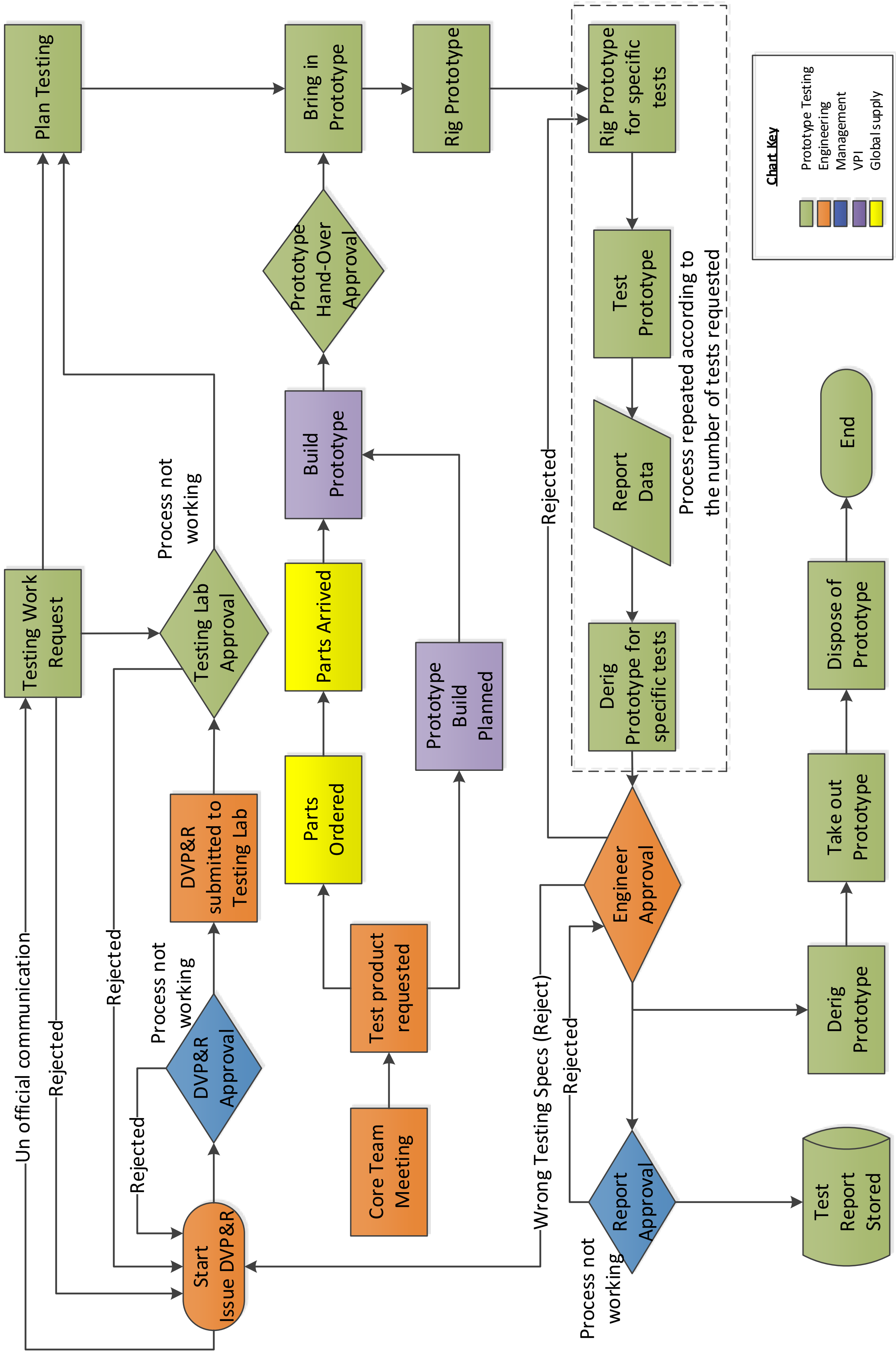


Figure 23. Testing Facility Process Flow

Concurrently at this stage, the testing prototype is being built by the VPI team. Upon completion a testing prototype hand-over meeting is conducted marking the changeover of responsibility for the testing prototype. A lot of positive feedback was received about this step. Testing staff find this meeting very beneficial and a lot of valid and important information is transferred at this stage that has been encountered during the prototype build.

Once the prototype is ready for testing it is moved in to one of the test cells to be rigged and prepared for testing. The initial rigging consumes a lot of time, which will be quantified later on in the metrics sections. It is the opinion of the researcher that this time could be drastically reduced by implementing several measures, such as planning before testing prototype installation operations by using CAD tools to run simulations of different scenarios which could arise during installation. Specific equipment could also be prepared or ordered from the CAD interface measurements between the prototype and the test cell which it will be installed in. Ducts and other objects could be pre-fabricated, avoiding the need to keep the cell offline to build them on site around the prototype being tested. The CAD models for the prototypes are readily available from Engineering and drawing up an exact model of the Test Cells is a one-time job and, therefore, it would not require a lot of time or financial investment to implement such a measure.

Other measures that could be explored include: pre rigging the testing prototype before it enters the test Cell or maybe rigging sensors on different components when they are being built in the VPI area. An exercise to identify these different rigging items needs to be conducted in order to reduce the rigging time.

Another solution could be to decouple the testing time from the rigging time. At present, the normal operating hours of the testing facility are from 7 am till 4 pm and both test systems and testing technicians work together to get a testing prototype rigged and ready for testing, resulting on utilization losses. If these two are decoupled, either by rigging using longer shifts or flexi time, there could be the possibility of keeping 37.5 hours of testing without rigging having an effect on the utilization.

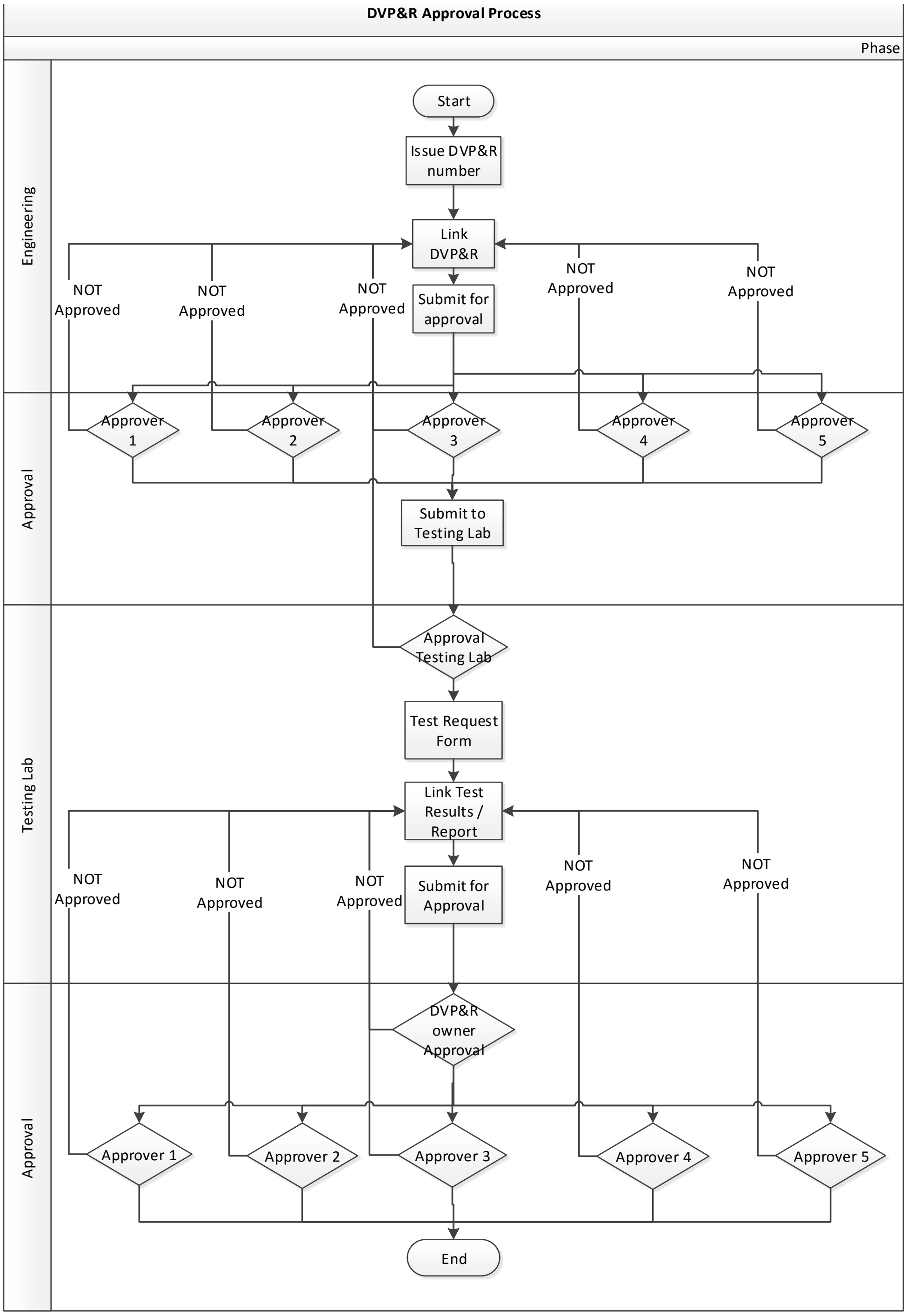


Figure 24. DVP&R and Testing Report Approval Process

Other measures exist but would involve extensive investment, such as introducing a testing Kanban system where a testing prototype would be sitting on a movable tray system from where it can be easily brought out of the Test Cell without the requirement of heavy lifting machinery and a new waiting prototype would be brought in to replace it, for example, when a failure occurs in order to maximise running hours. The rigging could also be conducted in a preparation area and the installation systems would be simplified in such a way as a plug and play system, similar to the lean manufacturing processes of Single Minute Exchange of Die (SMED), which is done for body panel stamping tools, extremely huge dies which are changed in a matter of minutes (Dave and Sohani 2012).

Going back to the testing facility process flow, the next step in our process flow map is to run the actual tests. This step can be repeated several times depending on the amount of tests requested for the particular prototype. Once a test or all tests are completed the information is sent to the engineer for his examination and approval. Several issues have been noticed at this testing stage. One noted is that there are no safe guards set up to show the testing technician whether the testing being conducted is a failure at an early stage. A test can go through its whole process without anyone questioning its correctness or validity, which can result in a wastage in time and resources. Safe guards, such as running criteria or ranges, could be stipulated by engineers in order to avoid having such scenarios occur. Also, more responsibility and ownership needs to be entrusted in the testing technician and more support needs to be provided from the design engineering team who should participate and witness the testing with the hope of spotting and identifying bad test results at an earlier stage and, therefore, avoid a wastage in time and resources.

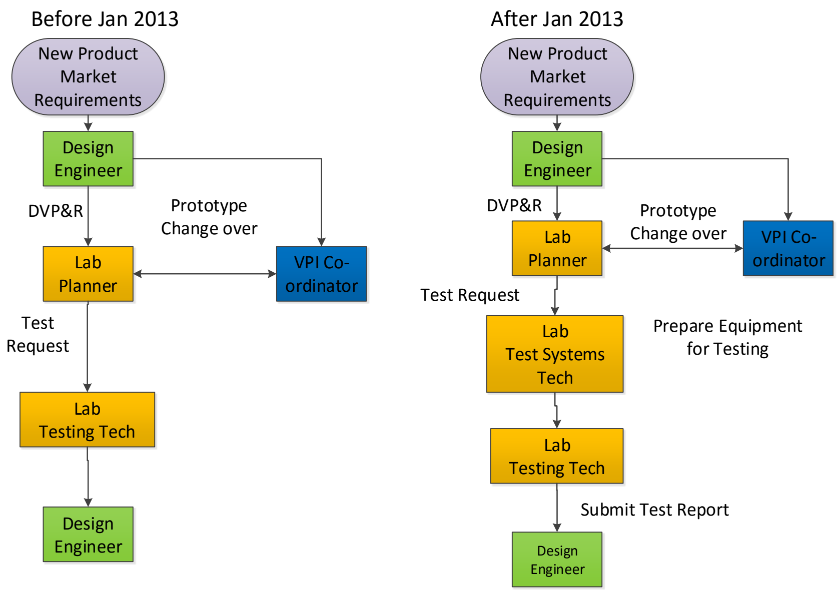


Figure 25. Testing Facility Testing Requests

Once tests are completed the results are compiled into a testing report which requires approval and another round of signatures. Similar to the DVP&R approval process, this task is also inefficient and is intended to be improved with the implementations of the intermediate solution mentioned above. The chart shown in Figure 24 illustrates the approval process of the DVP&R and test report process.

Another process that has been examined is the testing documentation flow. This has already been mentioned above in the testing facility process map, but the diagram in Figure 26 goes into more detail on the actual documentation process and how it is stored. The process starts off with the creation of the DVP&R document; this document is controlled by a DVP&R number which is a sequential unique number that identifies the validation testing process of a specific project. This number is stored on an open server so if two number requests are processed at the same time by different people this number can be duplicated. Furthermore, due to the openness and lack of control, numbers can be reserved and then later not used, thus creating gaps in the numbering sequence. Once the DVP&R is completed with its corresponding number it is stored on an open server which is unsecured and easily accessible by unauthorised personnel, which unintentionally could be deleted, moved or damaged.

Once the document is submitted to the testing facility, the document is duplicated and stored in a different database called Lotus notes. Consequently, the same file is stored in two different locations. This step can result in several negative implications to the integrity of the data. One of the main reasons behind the secondary file storage location from the testing facility is to guarantee a time stamped testing requirements document which was agreed upon submission. This was in reaction to problems that occurred in the past where testing specs changed during the actual running of tests without the testing facility being informed, making the tests obsolete. Still, however, the fact that two live documents exist simultaneously can lead to a misinformation disaster.

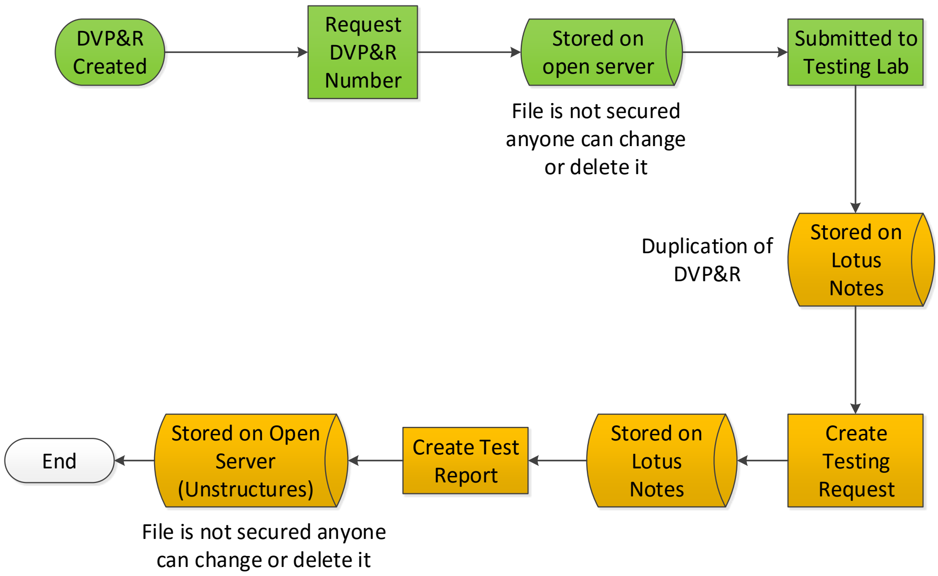


Figure 26. Testing Documentation Flow

Once the testing report has been completed, it is submitted for approval (this process has been described above) and is stored on an open server, without any kind of structure or link with its DVP&R document; this can result in an impossible task to locate such information six months down the line or for people who are not familiar with the project, making locating this information a time consuming and sometimes impossible task.

In summary, the lack of storage structure, security, file duplication and time stamp monitoring and modification tracking, and revision control are all areas that need significant overhaul and improvements. Such changes will reflect a significant improvement on the overall product development, knowledge searching, sharing and its re-use, and also aid in saving time and money.

4.3. Utilization Metrics

Utilization metrics is a critical tool which allows companies to monitor the performance of equipment that they are interested in. The level of monitoring detail depends on the requirements you set out to monitor and your capabilities to capture this data. You can capture large amounts of information but if you don't have automated processes to compile the data into usable information, the task can become very difficult and cumbersome, changing the task into a real challenge (Neely, Adams et al. 2002, Cocca and Alberti 2010).

The methods used to collect this information, as described in Section 4.1.2, were heavily dependent on manual input and data compiling. New methods have been introduced but there still remains scope for improvement in this area.

The data used for this analysis consist of 3 sets: historical data, which was collected from the monthly utilization charts. The second data set was collected from the developed Metrics Utilization Monitoring Systems (MUMS) and finally, a snapshot of the utilization 1.5 years after its introduction is presented to provide insight on any improvements that the monitoring system had on the testing facility.

4.3.1. Historical Data

As mentioned in section 4.1.2, the historical data was collected on a weekly basis during weekly meeting. Each week the team goes through the tests performed day by day from memory. This collection method had many drawbacks. For example, the data is as accurate as a person's memory and, after a week, it is hard to believe that a person can recall the whole eight hours of five days ago, so the data has to be taken on face value.

The first chart, shown in Figure 27, represents the utilization for Cells A, B & C over a six month period from July 2012 to December 2012. Utilization is worked out on the total amount of hours running tests divided by the total amount of hours available in a week (24 hrs x 7days). With the current shift pattern, that of a five day a week morning shift, this equates to 37.5hrs. The utilization figure on normal working hours cannot achieve more than 22% if the test cells are running at 100% testing during the whole working week. To achieve more than this overtime a second shift is required. However, these figures are highly unlikely to occur because each testing cycle will consume some form of wasted time; this could be in the form of prototype failures or rigging the prototype for a particular test.

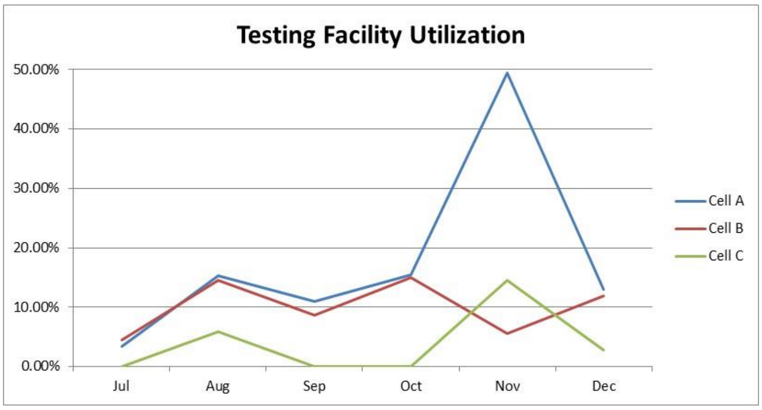


Figure 27. Historical utilization data

Figure 27 shows a high spike in cell A during the month of November where the utilization went up to almost 49%. This was a one off case due to an endurance run on a specific prototype which was being operated constantly around the clock 7 days a week during the period. Even with these kinds of running conditions, 100% utilization was not achievable due to certain categories of wasted time which is part of the testing process but is not considered as a form of running time.

On average, the utilization achieved is approx. 10 – 15%, whereas the set target is 18%. The testing facility are still off from this target. To figure out why, the data need to be further examined and analyse how the time is being consumed this brings us to the next chart, that of the same period of time, but this time looking at the running time vs. wasted time.

Figure 28 clearly shows that on average, when operating under normal development testing conditions, the amount of time wasted is about the same as the time needed to test a prototype. However, when you look at the composition of this wasted time, the highest hitter is setup time. The process of setting up comprises the initial rigging when a prototype enters the test cell and rigging for a specific test halfway through the development testing cycle. This was taken into consideration in the new monitoring system which divides these different types of rigging processes.

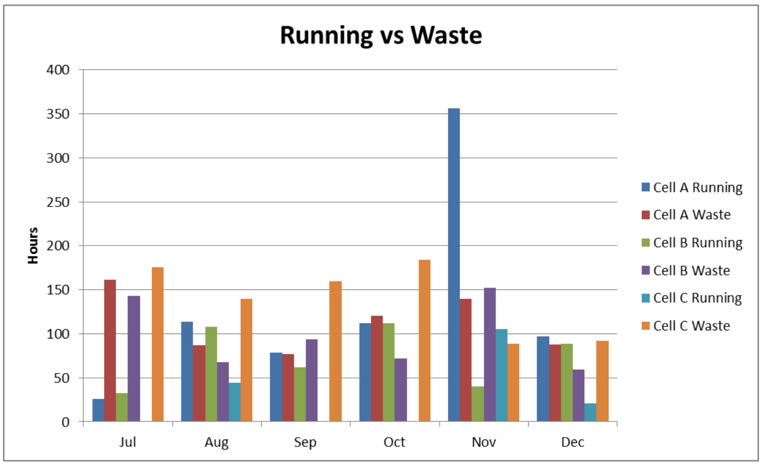


Figure 28. Historical running time vs. wasted time

Figure 29 shows that major wastage is consumed by doing setups which is always consistent because setup is a crucial part of the testing cycle. Other main waste detractors are infrastructure and prototype issues. These two are accidental occurrences, but still significant and, if reduced, great utilization gains will be achieved.

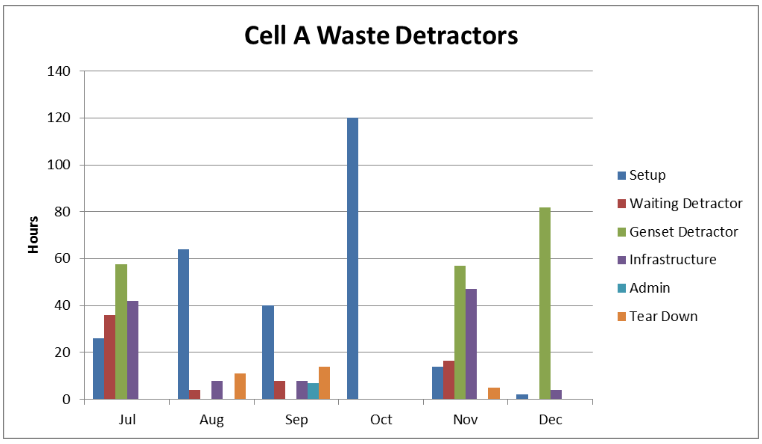


Figure 29. Cell A waste detractor

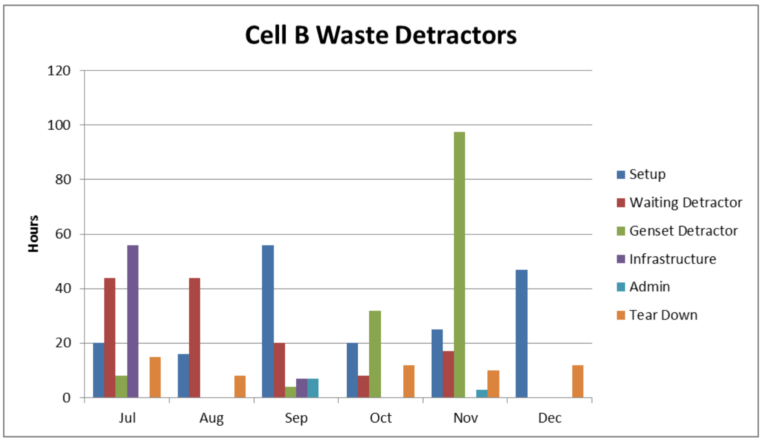


Figure 30. Cell B waste detractor

4.3.2. 6-sigma Project Data

Initially, a 6-Sigma monitoring project was started in February 2013 and planned to run for a four-week period. In those four weeks, however, a lot of problems with the prototype being tested and/or infrastructure issues hampered getting normal operating data, which was unrepresentative when these four weeks are compared with any other four-week period during the previous year. After a quick analysis of the data, the researcher suggested that the 6-Sigma project leader extend the study by another four weeks so that proper data could be obtained. Figure 31 shows the utilization data for the seven-week period. As you can see the utilization data is all over the place due to abnormal stoppages.

The same trends are shown in the running vs. waste chart in Figure 32, where the same kind of results occurred, except for week seven where things started to return to normal. All in all, it is felt that the data is inconclusive, but does show that unforeseen problems do arise and adequate procedures need to be put in place to tackle situations more efficiently and promptly, to avoid having a negative impact on the utilization of the test cells.

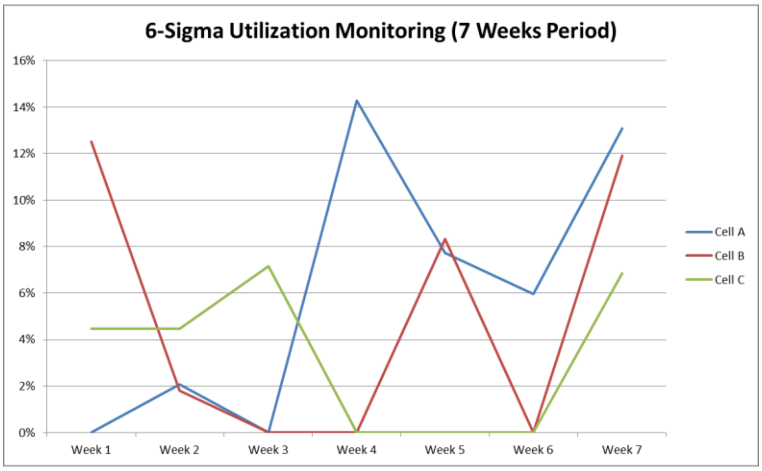


Figure 31. 6-Sigma utilization chart

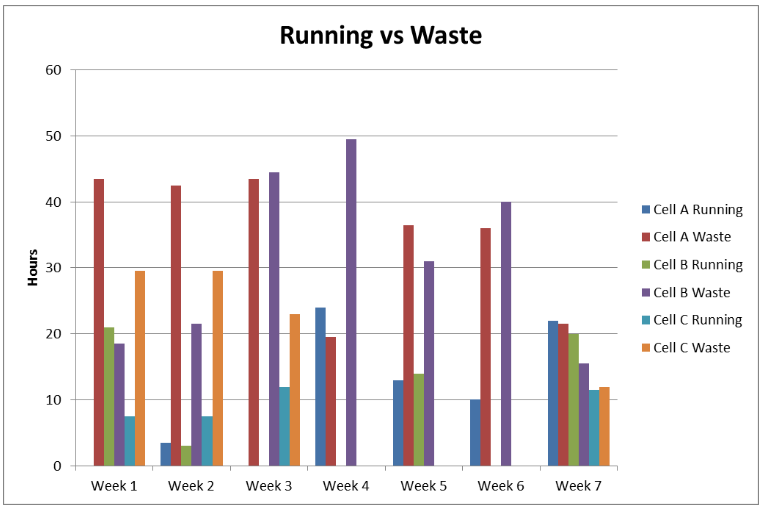


Figure 32. 6-Sigma running vs. waste chart.

In conclusion, both data sets cannot be used out right to make drastic comments or statements. In the case of the first data set it is due to the accuracy not being 100%, while the second data set was plagued with abnormal problems which have not been seen in normal operations. Therefore, prudency is required in quoting and using this information. In the following section, new information has been collected from the developed MUMS which had been running for a period of six months following implementation.

4.3.3. New Metrics System Data

As mentioned in Section 4.1.2, the developed MUMS was introduced in April 2013. Feedback received show that the system was positive and only minor updates to the software were required. Mainly distinguishing the difference between normal operating hours and over time, the intention of the sheet was to be filled in, in real-time as the day goes on but testing technicians generally update it with a couple of hours' delay, but still an improvement compared to data collected on a weekly basis from memory.

Figure 33 represents the utilization for Cells A, & B over a six month period between April 2013 and September 2013. Cell C has been omitted from this analysis because the test cell was taken out of action for maintenance for a number of months and, therefore, a large amount of data was not available making it irrelevant for this analysis. As in the historical utilization data section, the utilization is worked out on the total amount of hours running tests divided by the total amount of hours available in a week. Therefore, with the shift patterns, that of a five-day week morning shift, which adds up to 37.5hrs, the utilization figure cannot achieve more than 22% if the test cells are running at 100% capacity during the whole week. To get more than this overtime, a second shift is required, but these figures are highly unlikely to occur because each testing cycle consumes some form of wasted time. This could be in the form of prototype failure or rigging the prototype for a particular test.

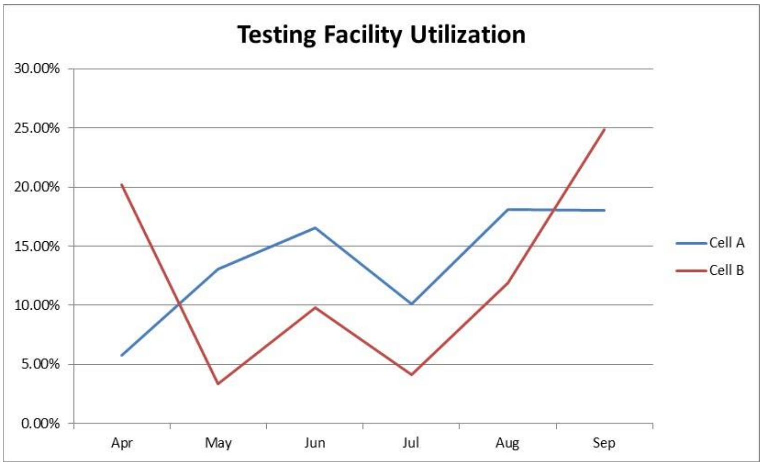


Figure 33. Post implementation utilization data

When the average utilization for Cell A & B is calculated, it results in 13.6% and 12.38% respectively. Cell A has performed relatively balanced with the only low value resulting in the month of April, while in Cell B, April and September resulted in the highest utilization percentage but the performance in the middle of the period was way below at 10%, dragging down the overall performance of the cell. To better understand both these performance issues further exploration into the running time vs. wasted time, as done in previous sections, was required.

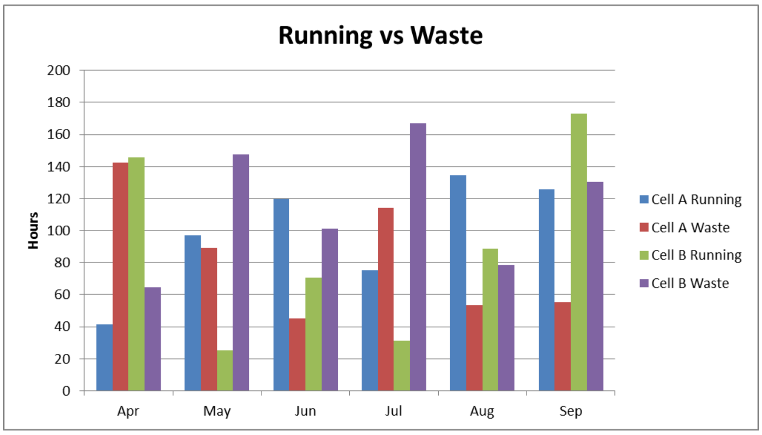


Figure 34. Post implementation running time vs. wasted time

Figure 34 shows both the running time and wasted time. By analysing the data, the obvious ideal situation would be that the running time would be considerably higher than the wasted time. This tells us that the test cells are running tests most of the operating time. This chart explains the low utilization shown in the previous diagram, for example the utilization in Cell A in April was 5.76%; when you look at the same month in the Current Running time vs. Wasted Time chart, you see that the company had 41.5hrs running time and 142.5 hrs wasted time. It also indicates high overtime, if the utilization for Cell B is 24.86% which is considerably good when compared to the 18%, but this is broken down into 173hrs running time and 130.5hrs wasted time coming to a total over time of 137 working hours, which is not an ideal situation. Unfortunately, as previously discussed, not all of the wasted time is unavoidable, as some of the wasted time is required in order to perform specific tests, such as rigging and setup. In the next chart, the wasted time is examined by breaking it in to different components.

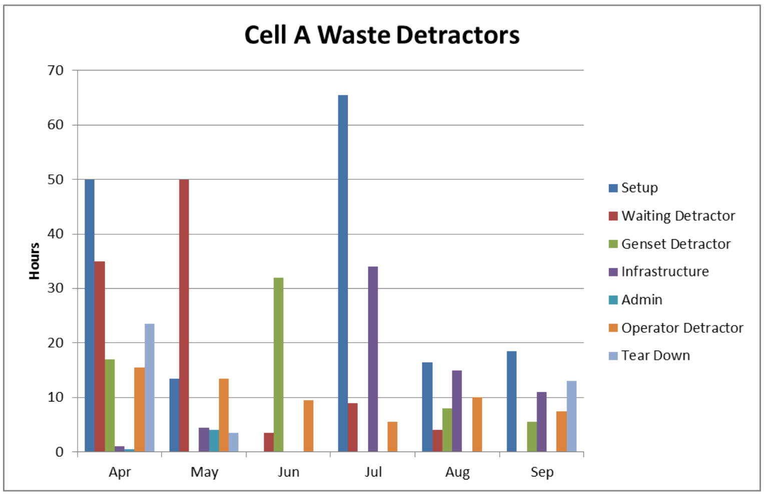


Figure 35. Post implementation Cell A waste detractors

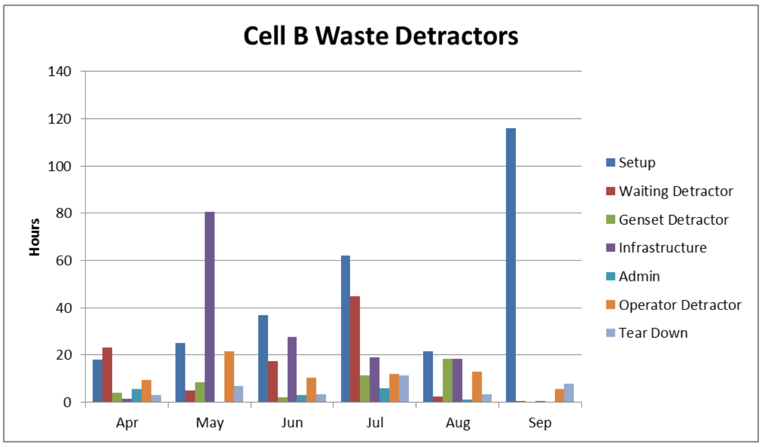


Figure 36. Post implementation Cell B waste detractors

The above figures, similar to the historical data, clearly show that the major waste is consumed doing setups which is always consistent due to setup being a crucial part of the testing cycle. Other main waste detractors include infrastructure and testing prototype issues. These two are accidental occurrences, but still significant and, if reduced, great utilization gains will be achieved. These charts only increase the importance of improving the setup time and decoupling it from the test cell by either taking the prototype out of the test cell and completing the setup outside or introducing flexi hours, so that setting up a prototype and running a prototype are not done on the same shift and, therefore, do not affect the testing hours.

4.3.4. New Metrics System Data +1.5 Year

As indicated in the previous section, the developed metrics system provides an insight in to the operational running efficiency of the testing facility. The system has been running for more than 1.5 years and, from interviews with staff, it has been indicated that the metrics have improved both in terms of awareness and visibility of any kind of stoppages that will affect the efficiency at the end of the month. It has also been highlighted several times that reoccurring issues exist that have been identified and tackled through a number of 6-sigma projects to improve operations.

Figure 37 shows the updated facility operational utilization for a six-month period between October 2014 and April 2015 (excluding December). It also shows historical operational utilization data for a six-month period between April 2013 and September 2013, as indicated by the dashed lines. The facility utilization, as shown, has improved significantly and the average utilization for Cell A and Cell B have increased by 2% and 6% respectively.

Unfortunately, no concrete data exists to substantiate the claim that the metric utilization monitoring system has actually improved the facilities efficiency but, from discussions with the facility manager and other technical staff, it is strongly believed that the system has contributed to highlighting issues and increasing awareness.

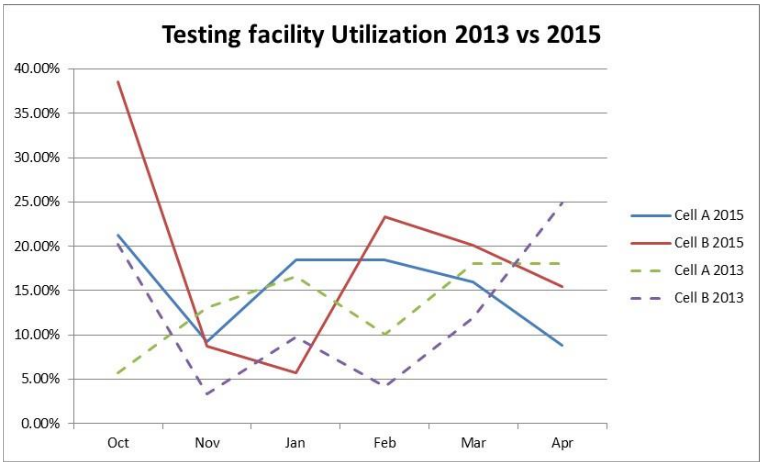


Figure 37. Current utilization data

As a validation tool for the developed knowledge sharing framework, the researcher believes that if followed carefully, the metric system should provide an improvement indication but, due to time and financial restrictions to the project, this has become out of scope of the project.

4.4. Questionnaire – Pilot Study Findings

The pilot study questionnaire was originally submitted only to employees at the Kent site but, due to the quality of the responses received, it was extended to key people at other sites in the collaborating company. The questionnaire was initially sent out by email, resulting in a 60% response rate. In research a 60% response rate is considered as relatively successful (Baruch and Holtom 2008), in an analysis carried out by (Nulty (2008)) he found that the most of online surveys achieved an average response rates of 33% while paper-based ones averaged 56%. Nonetheless, it was decided to persist and carry on with the study until a higher response rate was obtained. Another reason to continue with the study was to get a broader view from participants. Following this phase, the remaining participants were contacted in order to carry out the questionnaire in the form of an interview, which was carried out face to face or over the telephone, depending on the location of the participant. Figure 38 shows those people selected for this study.

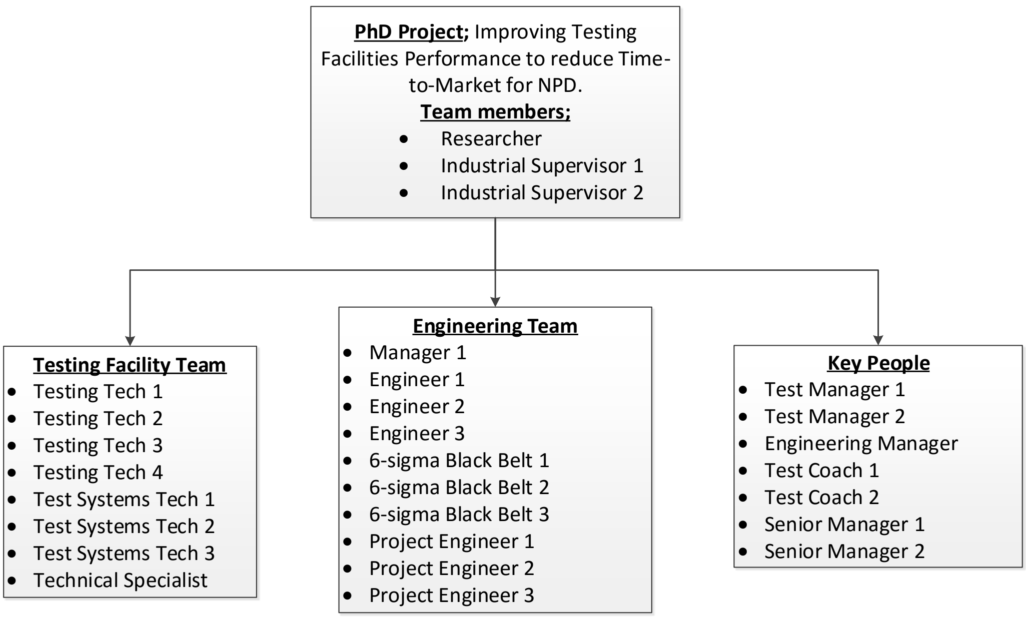


Figure 38. Main stakeholders @ collaborating company selected for study

The pilot study was structured into three sections: Communication, Processes and Knowledge. The analysis that follows will be done in the same order.

4.4.1. Social Communication Response

The first questions asked of participants were how they communicate with on & off site colleagues. This gave us an indication of what are the preferred communication tools used by the company and also highlighted if there are any trends surrounding certain functional departments using different communication mediums. However, this resulted in a consensus that all staff at a variety of functions and levels all use the same communication tools supplied, that of email, Sametime (web-based chat), telephone calls and meetings.

When asked how can collaboration between staff be improved it was commonly agreed that more work needed to be done by the company to improve communications and make it more focused to the relevant people and their job role. Another important issue noted was the increase of face-time, emails and text based communication which made people lack the feeling of being part of the team and impersonal. Additionally, information sharing, which is again focused to the relevant people was mentioned. Staff complained that they felt that they are kept in the dark and that vital information for their job function was not readily available.

> *"I have to collaborate in order to complete work function I find it vital to talk to people involved ideally face to face on a daily basis in order to make sure that people understand what I need from them and to get the job done."*

The researcher also experienced this during the observation period. An example of this is the strategy of company software. Information that specific software was being phased out was accidentally encountered during a conversation, but what will replace it and the timeframe within which it will be replaced was not available to employees. In such situations, certain decisions cannot be taken as such issues need to be addressed beforehand. In addition, some employees felt the need for the removal of departmental barriers, the US and THEM mentality.

> *"Some people's mentality is the problem, with a "Them & Us" attitude instead of sometimes trying to work as a team; it's easier to just blame others. A day working with each other now and then might break down barriers."*

This mentality is not a company policy, but the fact is that employees perceive this is a problem that can hinder teamwork and ultimately the achievement of the project goals.

When asked how communication could be improved, a clear consensus was evident. Employees stated that better tools were needed to keep all relevant parties informed on the project about what is actually happening. Once again, more face time communication arose and the need/want to feel more involved. Another issue noted was to have a more defined framework for structured communication between project milestones. It was felt that people will not report updates unless they are obligated to, due to the information gate which results in relaying information too late in the game whereas if done earlier it would have been more beneficial. Complaints regarding the rigidity of the workflow process and that people used it to their advantage to hide behind were also noted.

> *"Break down the silos that still exist between functions, this includes within Engineering. Need more transparency, still a lot of them and us mentality at all levels of the organisation. There are many tools available such as the eWiki site, but people are reluctant to use them effectively, partly because there are so many tools: QSi, PLM, eWiki, MyCummins, Notes dBases etc. Which do you trust?"*

> *"Email is heavily used as a defence mechanism. Realistic deadlines and getting the whole team on board with the project. And prioritizing the delivery of product, to the end customer."*

When asked in what shape and form a new communication framework should be, the issue of face time was raised once again. The importance of putting a face to a voice / email was observed as very important. This is only natural because from an email or a telephone call, a person can easily deceive a person to make him/her think something that they want. Being that this is internal communication, it is important that communication is transparent and honest, and provide the ability to see a person's face and their body language / non-verbal communication can help you deduct if one is being truthful or not in his statements.

> *"Anything that promotes more face to face discussions and more regular reporting."*

Participants also mentioned the importance of having a forum-based system which is able to capture dialogue during the product development cycle which is time stamped and reaches all relevant people. This can be a sort of development diary, which a person new to the project or who has even worked on it, but needs to refresh their memory, can go to and easily understand the development process and the rationale behind decisions that were taken at any point in time.

> *"Written communication is authenticated with time stamps, face to face bridge short comings. Important for engineers is to educate themselves about what is involved to conduct specific tests and that they should from time to time participate at the testing facility with the testing in order to better understand what is involved."*

As for training on communication software, the majority of respondents were confident that they could quickly get to grips with new software following a quick introduction tutorial which would mean no expensive learning course is required.

In summary, this portion of questionnaire unfortunately highlighted several issues regarding inter-department communications and distrust between colleagues in different departments.

4.4.2. Process Response

When asked of the current processes, testing staff had both positive and negative feedback, whereas engineering and management personnel seemed to have a more pessimistic view. The positive comments received by testing regarded weekly internal meetings, prototype build and hand over meetings, VPI workflow which clearly defines the responsibilities of job functions. On the other hand, negative feedback came from both groups and ranged from complaints regarding colleague personalities, to the lack of training / knowledge in areas such as H&S. Engineering also highlighted the rigidity of the VPI workflow and that it is not agile enough to respond to customer needs and the lack of following the system due to stringent timelines and unrealistic deadlines.

> *"At the moment not all of the info is readily available when the project is transferred to testing. Several times project milestones are changed which can have a significant impact on the facility. Still testing try to be as flexible as possible to these changes if this changes are minimized the testing facility performance would be greatly improved."*

When asked how processes could be improved, several issues were mentioned. Proper and smarter planning of tests and having a proactive rather than a reactive response was highlighted. Complaints regarding the documentation structure was also pointed out to improve the accessibility of information. Testing would like more time to work on prototype performance and avoid rushing tests to deliver to a deadline. Obviously, this would be a nice commodity but unfortunately in today's market, time is always against product development projects. Customers want their products yesterday and subsequently at present, it is not envisaged that this could be improved. Another issue highlighted by testing was to change the mentality of not implementing lessons learned during testing in the products. This issue was also noted by the researcher who believes that it is a lost opportunity that lessons learned are not filtering through to new products.

> *"More testing bays to improve utilization, apart from having more test cells the need for preparations areas would greatly help the testing team to improve their facility utilization. Each test cell should have a prep area where a prototype can be pull on to for servicing or maintenance."*

Issues relating to planning within the testing facility engineering included little buffer time is allocated especially when the testing requirements are vague. Unfortunately, this statement is very troubling because the testing requirements are set up in the first place by the engineer. In the current economic climate, one cannot rely on vague specifications and expect other people downstream to make good from vagueness. Another issue pointed out by engineering was the lack of testing ownership from testing staff. This was also noted by the researcher but, as they say, it takes two to tango; more ownership needs to be given from both sides. During observations, it was noticed that some tests could have been avoided if either the engineer was witnessing the test or the testing technician questioned the test or data. It is imperative to get this right the first time round. An interesting point was that better testing duration time data needs to be captured, so that it can be used for better planning in future. This point is quite simple and can easily be implemented by means of a proper utilization database which could result in dividends in time.

> *"I think the intentions are good and training and guidance is also good. However, there is often little buffer time allowed and things often go awry once a vague requirement cannot be met."*

> *"Planning is very reactive which puts us in a catch up position."*

In terms of planning from engineering and management point of view, the majority of testing personnel agreed that better planning from management is required and realistic deadlines should be given. This problem was highlighted by both groups, but testing saw it as engineering management who were causing the problem, but from engineering management, it is a reflection of market requirements which are coming from sales. A further improvement request from testing is to enhance the supply chain of parts to be tested. Parts need to be on site at the appropriate time and having spares on hand would avoid lengthy stoppages due to failures. Obviously, it would be impossible to have all the spares on hand but a list of critical spares could be determined beforehand depending on risk; seconds could be purchased in order to avoid such problems.

The questionnaire then went on to ask about participant's perception of the support they receive from other departments when problems arise; the responses was mixed. The bar chart, shown in Figure 39, shows a positive response from testing personnel, but this result is not accurate.

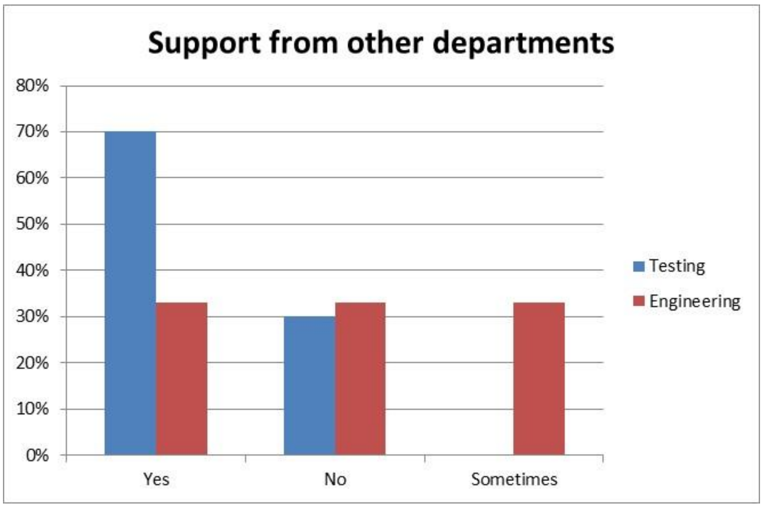


Figure 39. Support from other departments.

At present, when a problem arises, the testing technician asks the planning / supervisor for help, this is promptly given mainly because it's an internal request within the testing facility. However, the channel to ask for help outside of the testing facility comes through the supervisor and, therefore, the testing technicians are buffered by the supervisor and, as a result, they do not face support problems directly. From an engineering group's perspective, the response is balanced between yes, no and sometimes, which when quantified would result in a 50-50 response which is a good indicator of ineffective teamwork.

Suggestions made by the testing team to improve current processes include: better communication mediums, better response time and timely action from TPL's are required. Engineering noted that communication should be the main driver to improve any of the current processes. They also pointed out that more team building exercises are required to improve team work to achieve project targets. Another interesting point was to introduce remote access of current testing and provide the ability for engineers to review on-going work rather than wait for final reports.

> *"Clear and timely communication is required, more robust planning to be made for every project with a project leader will be able to build trust and show evidence that the project is holding to the plan. Implementation of preventive measures rather than being reactive to problems encountered during testing. One of the items could be having more parts to save guard against breakdowns."*

> *"People have to understand that everyone should have the same goal that of getting the product delivered to the customer at the given date. A lot of attention is given to team budgets and who's being charge for a specific job. People's energy should be focused on the product rather than the department's expenses."*

As for training, both groups agreed that more training is required in several areas, but the most interesting point was that people should be more aware what work is involved so that they can better understand other people's job functions, requirements and time to carry out tasks.

4.4.3. Data and Knowledge

In this sections of the questionnaire it starts off by quantifying how much time is wasted searching for data and knowledge. The responses received are shown in Figure 40. The response is quite apparent that proper structure and simplification to search for data and knowledge need to be improved. More than 60% of responses was that they feel they wasted a lot of time looking for information that could have easily been found if it was filed in a structured way that could be easily searched. This issue can have significant repercussions', because the company data and knowledge is a very expensive company resource and if this knowledge is not reused the company may end up re-inventing the same thing over and over and have to pay for each iteration.

> *"Gaps exist everywhere. Testing requirements are not filled in properly and testing should be given the right data from the beginning."*
> *"Too much time trying to find information in the vast amount of systems / databases. Non-Value added activities when information should be readily available."*

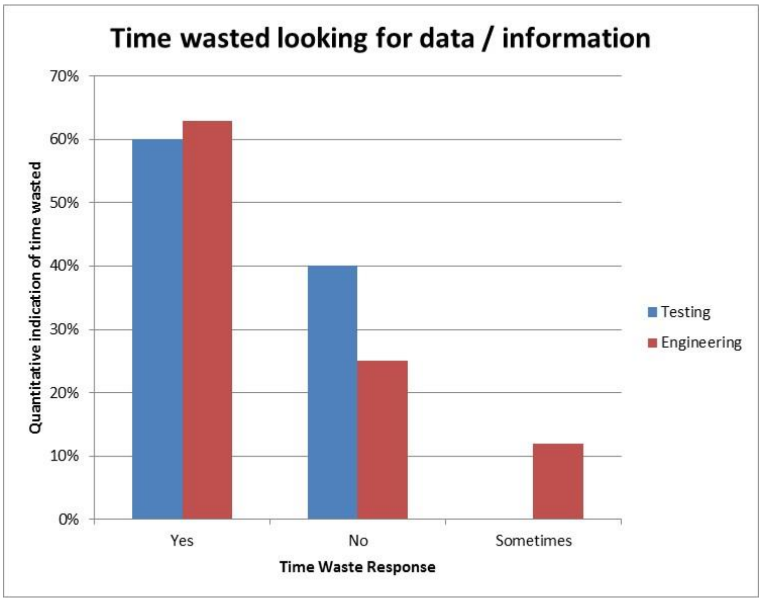


Figure 40. Time wasted looking for data / information

As an improvement recommendation, a consensus was that Cummins should provide better databases to get all the information required from one source, rather than having to interrogate multiple systems. Another point highlighted was regarding the capturing and documenting of people's knowledge so that this information could be shared. The company should be interested in investing further into this because once that specific employee leaves the company, all their information leaves with them, which will result in loosing that knowledge forever.

> *"Data & Knowledge are not properly stored and it's not managed properly. Also test reports are not properly filled in and not securely stored."*

Testing pointed out that they would find it beneficial if they spent time following and observing colleagues job functions and, in turn, other people outside of testing should spend time in the test cells to gain a greater understanding of what it takes to prepare and conduct product tests. By having a broader view of the whole product life cycle, the different people involved could be more sensitive to the requirements of other job functions, which can result in better teamwork.

> *"People should spend time in other departments to get a broader view of different job functions."*

There is a general agreement that new tools and processes for knowledge capture need to be implemented onsite and globally at Cummins.

> *"we need better storage & sharing of knowledge to avoid repetition / future errors A transparent approach for all to share / communicate best practice etc"*

When asked about training requirements, a similar response was received. The majority of interviewees were confident that they would quickly pick it up following a quick introduction tutorial, so no major training expenses would be necessary.

Regarding how to keep people informed, several ideas emerged, such as project progress meetings, publishing live data via electronic boards or web portal/dashboards, a large Andon board and many others. Figure 41 shows a proposed example of an information board which could be published on a web portal or a large screen strategically located for maximum impact to keep staff informed of testing facility current status.

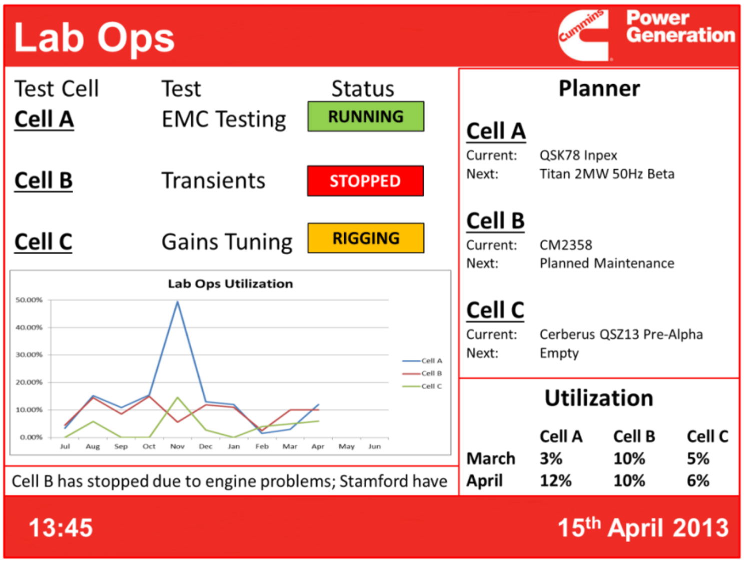


Figure 41. Proposed mock-up of an information board

4.5. Site Visits Findings

The collaborating company forms part of a global organisation spread over 190 countries. There are 88 manufacturing facilities in total, producing a vast range of products from engines, alternators, filtration system, turbo systems and control systems to name a few. The company in Kent designs and manufactures high horse power electrical generators forming part of the power generation business unit (Cummins 2015).

The purpose of the site visits in the US was to gain an understanding and to highlight the difference in capabilities at different sites and to highlight the commonality between them in anticipation that the developed knowledge capturing and sharing framework would be relevant and compatible with these different sites. Obviously, Cummins have more testing facilities sites spread out around the globe but, due to financial limitations, this investigation was limited to the UK and US facilities.

The site visit questionnaire consisted of 24 questions, divided into 3 sections: testing site, documentation & software tools, and testing facility waste detractors. In the next section the differences between the testing facilities that fall under the same business unit - power generation are analysed. It was decided that only testing facilities that test similar products, like for like, would make sense as a comparison.

4.5.1. Testing Sites

The site in Kent and the main development sites in Fridley (USA) conduct similar product development testing from equipment trials, tunings, transients, max power runs, vibration, fuel consumption, and noise emissions, while the site in Columbus (USA) concentrate on calibration development, gas blending and development testing of running gas engines on waste gasses from landfills. The development testing site in Columbus is focused more on validating new modifications rather than development testing on new products.

As for the product range being tested, all sites visited tested similar sized products, except from the Fridley plant. Apart from the high horse power generators, they also tested smaller units mainly used in the domestic and recreational market, including mini generators used for small domestic dwellings or recreational vehicles (RVs). While the prototype building process at each site has different build facilities available and procedures, the Fridley site is fully vertically integrated, having dedicated facilities within the testing facility to build their prototypes from the ground up. This situation is similar in Columbus, with the only general difference being that they test modifications, therefore, prototypes are not built from scratch but modified from current production units. The situation in Kent is completely different. Prototypes are built by a separate department (VPI) and once completed, they are handed over to the testing facility. This method has various shortcomings, such as the lack of control of the prototype build or the lost opportunity of the testing facility staff to have direct involvement during the prototype build to start learning and experiencing the product at first hand before they start development testing. It is also a lost opportunity to start pre rigging the prototype during the build stage. One of the major waste detractors, as indicated from the utilization metrics, is product rigging before testing. Apart from attaching sensors while the units are being built, they avoid disassembly of the prototype during the rigging time to attach sensors in places which are not reachable when the prototype is completely assembled.

There is a large difference in the size of the testing facilities across the different sites. The facility in Fridley has a considerable amount of test cells, while the site in Columbus is relatively the same size of facility and considerably smaller than the Fridley site.

4.5.2. Documentation and Software Tools

The generation of documentation across the sites is generally managed through Lotus databases or networked drives. These solutions are not the ideal situation for information storage and sharing because the system structures are open and, therefore, do not have any traceability for versioning control. This can result in costly mistakes or outdated information being acted upon. This situation is being investigated with the introduction of several company-wide systems, such as PLM, and Global Lab Information Management System (GLIMS). These tools provide security and traceability across the company and greatly improve information sharing, storage and collaboration.

Data acquisition in the US use a dedicated data acquisition software which not only controls the test cells, but also monitors the data being produced from the products being tested. This integrated solution, named Cyflex, provides improved data acquisition capabilities and, at the same time, reduces the risk of matches in the acquired testing data. The situation in Kent is dissimilar. Whilst the intention is to use a fully integrated data acquisition system in Kent, at present there is still a reliance on a number of separate systems to collect data and then the testing technician must compile all the data together which can be prone to mistakes or errors.

While all of the visited testing facilities run a fluid and dynamic operation, because testing outcomes are very unpredictable due to failures and stoppages, all sites rely on static planning completed using a simple spreadsheet. If changes happen in the testing facility, including stoppages or failures due to the static planning techniques used, the planning process is slow to react. In fact, one of the interviewed engine sites reported that instead of using spreadsheets for planning, they rely on a cardboard sheet completed with post it notes so that if a prototype test is cancelled or fails, they can quickly move about the post it notes to rearrange the test plan. An electronic solution should be developed to cater for these kinds of situation in a quick and dynamic manner which can identify the consequences of the proposed changes.

4.5.3. Testing Facility Waste Detractors

When waste detractors are considered, Kent and Fridley indicated that waiting and testing teardown are the major waste detractors that affect the testing facility, while the site in Columbus indicated that setup and infrastructure problems are the main waste contributors. The infrastructure could be a contributing factor, due to the age of the buildings at the Columbus site. While it is interesting to see that both Kent and Fridley indicate similar waste detractors, waiting detractors can be addressed with improvements in planning and the communication of information to get decisions taken in a shorter amount of time, whilst waste in tear down is because after any test a prototype needs to be decoupled from the testing equipment and any ancillary equipment used to run the generator set. This issue could be addressed by adopting production techniques, such as quick release and/or plug and play methods. In simple terms, the company could develop quick release solution that enable a prototype to be unplugged and pulled out of the testing facility. This would allow for the prototype to be teared down in another area, avoiding the redundant product occupying the testing cells.

These plug and play and quick release techniques have already been adopted in a small part at the Fridley site but more development needs to be done and any lessons learned should be filtered through to other sites as best practice.

4.6. KM Framework End User Questionnaires Findings

The KM framework end user questionnaires were an exploratory study used to gain an understanding of end user requirements and tendencies in using social media, preferred learning methods and their inclination to share their own knowledge. Unlike the pilot study, this investigation was only submitted to staff at the collaborating company's site based in Kent. The main reason behind narrowing the participants to the Kent site was primarily that the prototype KM framework would be developed and tested at that site only. The second reason was due to the lack of time and financial resources to extend the study to other sites and, at the same time, avoid disruptions at other sites. The questionnaire was sent out electronically using the collaborating company's official survey tool to 40 participants, which resulted in a 95% response rate. The pilot study was structured into three sections: 1) The usage of social media, 2) Preferred learning methods and 3) Knowledge sharing tendencies. In the following sections the responses obtained from this study are analysed.

4.6.1. Social Media

In this section, the questions were to get an indication of the knowledge sharing framework end-users and their usage of social media tools. As shown in Figure 42, 78% of those interviewed use social media in one form or another.

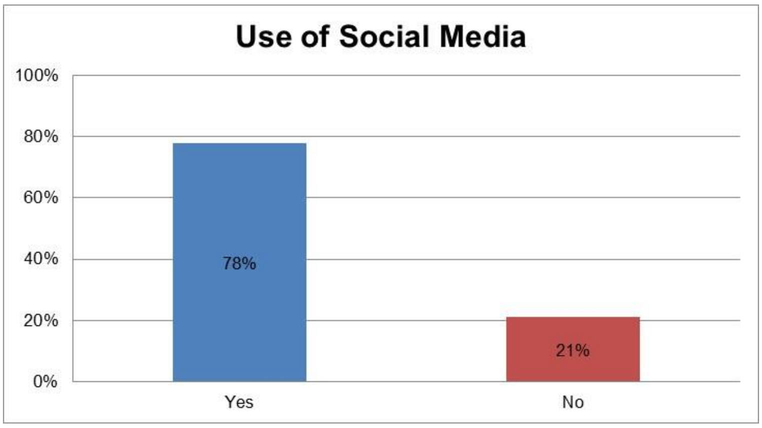


Figure 42. End-user usage of social media tools.

As for the duration of usage of social media tools used, as can be seen in Figure 43, 45% of participants use them on a daily basis, using Facebook, twitter, YouTube, etc. While 35% stated that they use social media from time to time. The remaining 20% stated that they do not use social media tools.

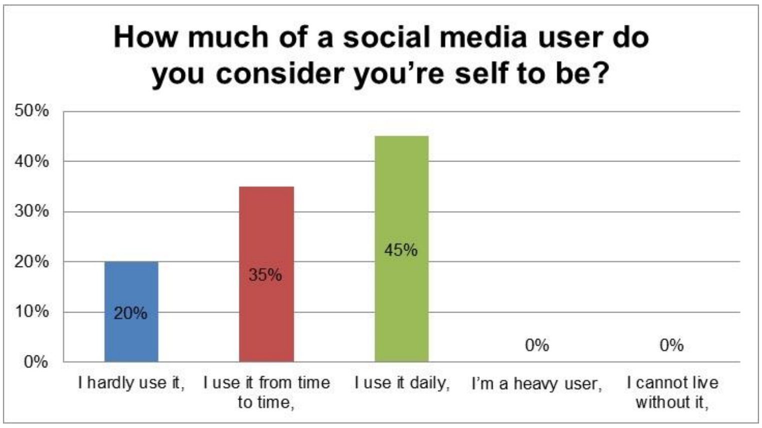


Figure 43. End-user, quantity of usage of social media

With regard to the type of contribution towards social media tools, the majority of interviewees (74%) considered themselves as passive users, while 26% considered themselves as active users, as indicated in Figure 44.

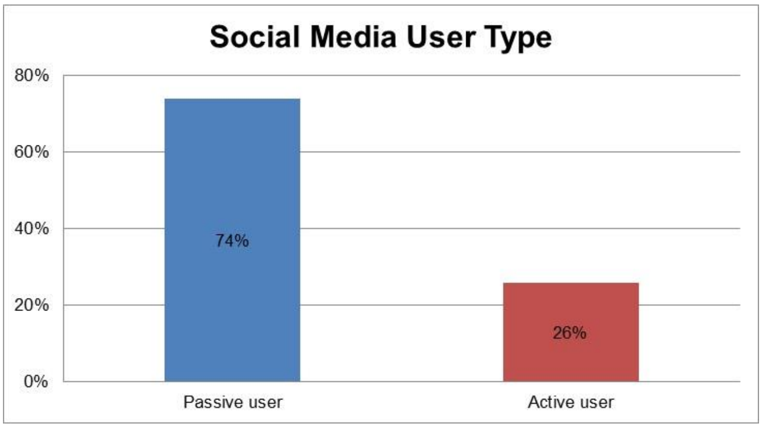


Figure 44. End-user social media user type

The fact that 78% of end-users that participated in the study use social media on a regular basis is encouraging and shows that the developed knowledge sharing framework, if exploiting social media tools as a means to share the capture knowledge by means of video sharing and providing a platform to discuss the knowledge stored in the system should be successful. While 74% of participants considered themselves as passive users of social media, this is discouraging, because with a figure so high it is anticipated that at least at the beginning of the project there will not be enough participation in the knowledge discussions which are expected to result from the captured knowledge that will be shared. It is hoped, however, that the 26% of users will contribute at the beginning from whom the others will follow suit after a period of system adoption.

4.6.2. Learning Methods

In this section the first question relates to Figure 45, the learning pyramid. The pyramid provides the order of the different learning mediums and their effectiveness in delivering the knowledge being conveyed (National Training Laboratories (NTL) for Applied Behavioral Science 1960). As anticipated, passive techniques such as lectures and reading are not as effective as discussing a topic or teaching a topic to your peers, because passive learning for it to affective the student needs to engage with the material, otherwise he/she will not gain anything from the lecture or the book they are reading. While with active learning, if students need to teach a topic to his/her peers, they will make an extra effort to understand the subject matter in order for them to convey what they have learned.

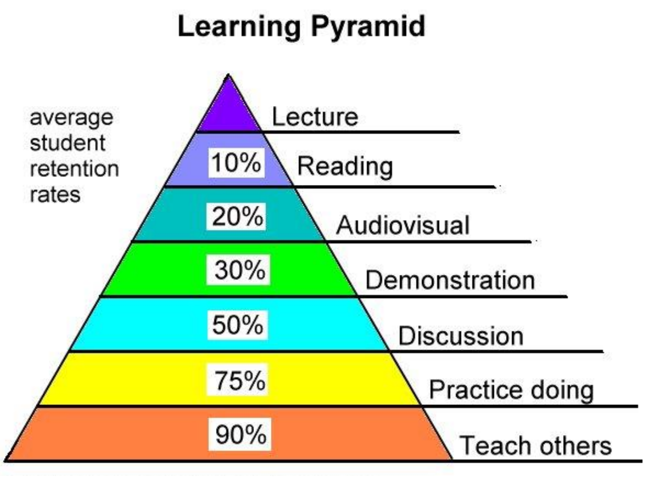


Figure 45. Learning Pyramid (National Training Laboratories (NTL) for Applied Behavioral Science 1960)

Figure 46 shows the preferred learning methods chosen by the end-users. As can be seen, the preferred method was practice by doing, with 45% of the participants selecting this method of learning things, with demonstrations coming in as the second preferred learning method followed by teaching others, audio-visual and discussions, all of which are active learning methods. These selections of learning methods have all been taken into account during the development of the knowledge sharing framework. The audio-visual element, demonstrations and teaching others are all critical components of the developed knowledge capturing procedure, while all of the selected learning methods form part of the knowledge sharing process through the video sharing medium and social media tools for knowledge discussion.

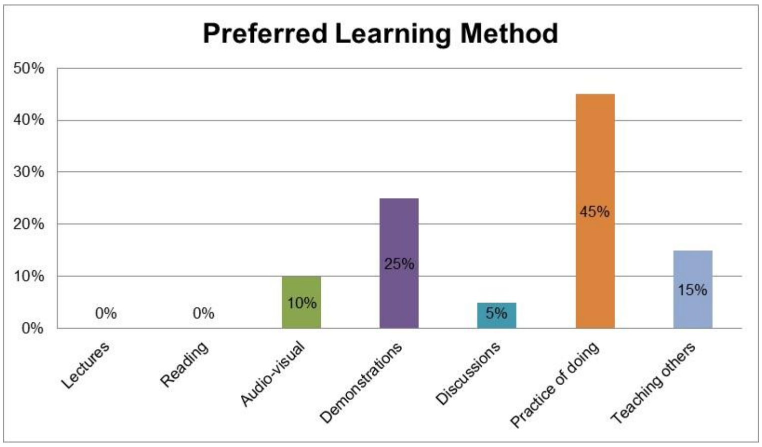


Figure 46. End-user preferred learning method

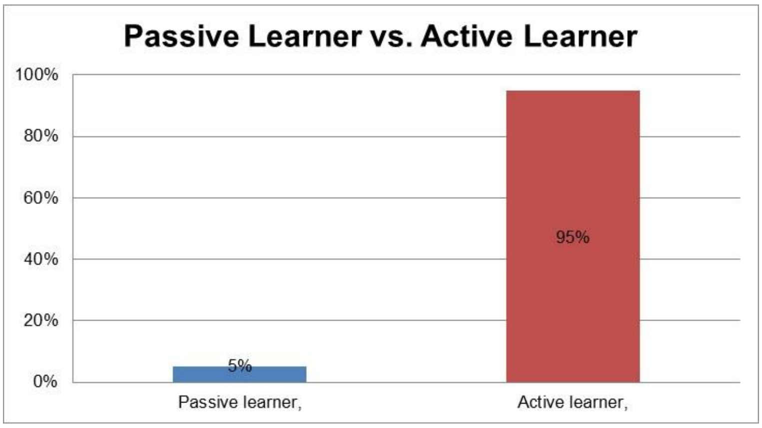


Figure 47. End-users - Passive learner vs. Active learner

When asked if participants considered themselves as either passive or active learners, their responses correlated with the learning methods they previously selected, that of active learning. Due to the proposed video sharing medium to capture and share knowledge, the end-users were asked their preferred length of audio-visual demonstrative knowledge sharing media. The end-users were split in their result, between short video presentations of 5 – 10 mints and medium length videos that of 15 – 25 mints, as shown in Figure 48. In order to avoid user's rejection in capturing knowledge and losing interest during knowledge sharing, it was decided that knowledge contributed by media would be captured in short segments of 5 -10 minutes. This should guarantee that knowledge contributors will not find the task to onerous and impossible to accomplish, while knowledge sharing would be quick and straight to the point.

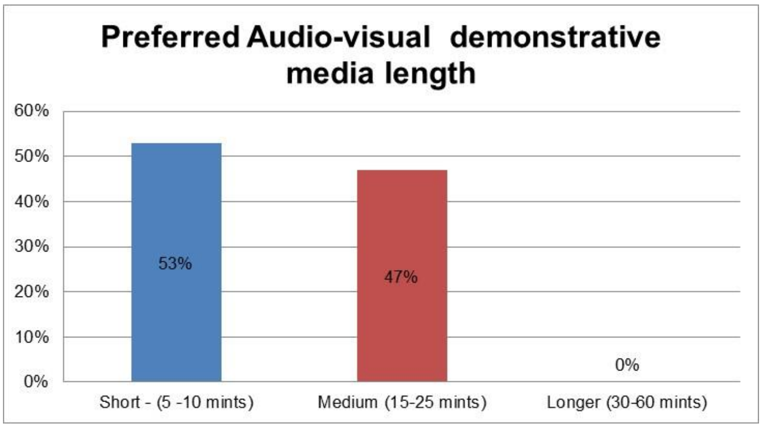


Figure 48. End-users preferred audio-visual demonstrative media length

4.6.3. Knowledge Sharing Tendencies

The last section of the questionnaire explored end-user's tendencies to share knowledge. Participants responded on how they feel sharing their own knowledge that they have acquired during their years of service. The questions produced a strong response of 55% that are prepared to openly share all the knowledge they have acquired because it makes their job easier. While 40% were open to share and if they were asked to, as shown in Figure 49.

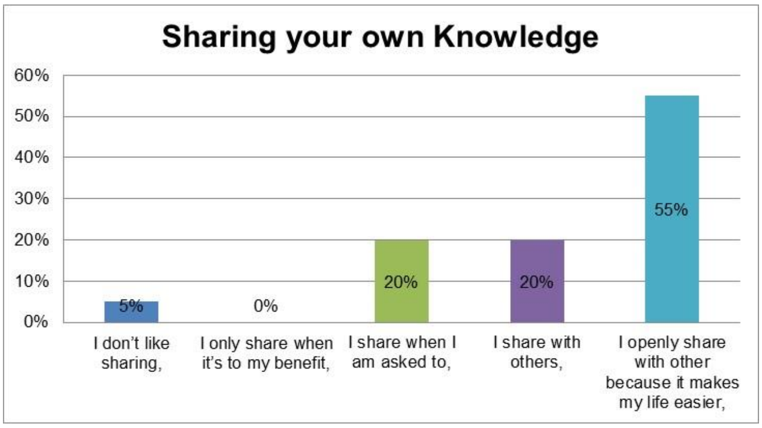


Figure 49. End-user knowledge sharing tendencies

With regard to what could incentivise them to share knowledge, 75% responded that they do not require any kind of incentive in order for them to share their knowledge. Only 20% mentioned 'recognition' and 'career advancement', which are not selfish requests.

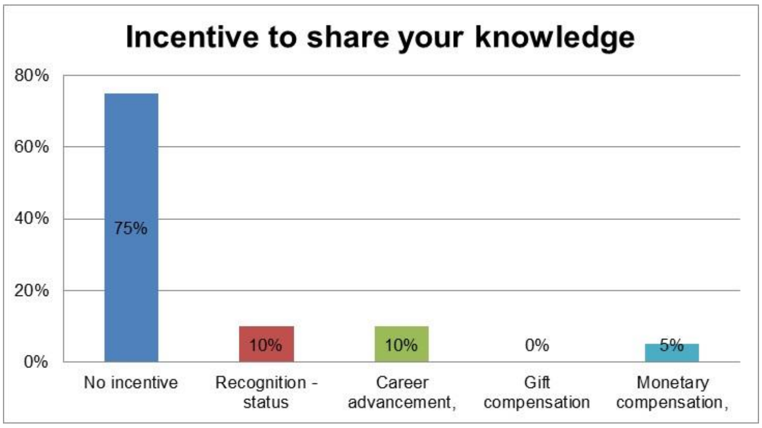


Figure 50. End-users knowledge sharing tendencies

These results are not surprising, because during the observation period, the researcher noted that the corporate culture, especially within the testing facility, is that of openness, sharing and helping one another, which is reflected in the responses provided in the questionnaire, as shown in Figure 50. This kind of attitude towards sharing increases the eventual possibility for a full implementation of the knowledge sharing framework after the completion of this project.

4.7. Overall Summary of the Industrial Investigation

When combined together and analysed, the following requirements were identified as the critical points that need refining in order to improve the product development and collaboration within the test facility and its main stakeholders. These requirements are:

1. Development of a design verification plan and report (DVP&R) framework to improve documentation control and document security. Giving better access and traceability;

2. Development of an archive database for test reports, providing engineers access to test results of the different sub-assemblies which make up product;

3. Development of a communication framework which will aid to keep all the relative people involved in a project informed with the latest information

providing all so historical documentation of all the communications throughout the project lifetime;

4. Further development of an automated metrics system providing simplified monitoring and report generation with additional ability to feed live information to a web based dashboards or electronic boards testing facility operational performance; and

5. Development of a knowledge capture and sharing framework in order to improve staff understanding of testing processes and improve personal development of employees.

From the highlighted points listed above, the development of a knowledge capture and sharing framework was selected by the management of the collaborating company as the research area worth exploring. The remaining issues highlighted during the investigation have been addressed internally by the collaborating company by a number of 6-sigma projects and other corporate process improvement projects arising from the corporate headquarters in the US.

The identification of the above listed industrial requirements from the PD testing facility is one of the set deliverable of this project. Since the literature review has not reported any in-depth investigation to bring out real industrial requirements in the PD testing context.

From the investigation and the requirements of the company it was decided to develop methodologies for capture and share testing related knowledge to address the special nature and application context of the integrated PD and testing operations. Using social media and Web 2.0 tools to meet the requirements of the social aspects of communication and knowledge management and also using video sharing and storytelling technologies to represent the tacit knowledge which is a major challenge in the PD testing application for knowledge capture and transfer. It has been identified that there is a strong need to improve communication and knowledge capture within the

NPD process in order to capture complex engineering knowledge for training purposes or to share past testing experiences, or to highlight possible improvements or corrections to products being tested. Many of the communication and knowledge management systems currently used within the collaborating company are designed for use by the whole global organisation using a one size fits all approach, without systematically analysing the needs and requirements of the different business units and departments a new innovative way of working with knowledge is required to improve this situation. This project carries out a comprehensive analysis of the nature of the knowledge and relationships in the testing operations environment.

The potential benefit of this research is aimed towards PD testing/validation facilities and the developed methodology should facilitate improved communication and the capturing and sharing of knowledge amongst PD teams, which will ultimately reduce the new product validation cycle and, therefore, improve the time to market. This project will provide the possibility to capture company knowledge which is limited to single employees and remove knowledge bottle necks that can result from these situations. It will also offer the possibility to reduce training burdens for new staff by providing the knowledge in an accessible knowledge repository while will provide the capability for cross-training. This project is not limited to this section of engineering and could be adapted to any dispersed PD team that needs to communicate and share knowledge more effectively.

In the next Chapter, the concepts of the proposed knowledge sharing framework are explained, while also providing the development work carried out to develop the software tools to enable the proposed framework.

Chapter 5: The Proposed Knowledge Framework and its Implementation

This Chapter describes the proposed knowledge sharing framework and the methodology to support the product development team and its main stakeholders (product design), by improving the operation of a product validation testing facility. The requirements of the method will be defined, and related industrial challenges and research gaps will be identified.

The methodology developed consists of the knowledge capturing and sharing framework, the method for knowledge experts to capture and document their knowledge, and the tools used for the implementation of the knowledge sharing framework and discussions.

5.1 Introduction

From the industrial investigation, five main topic areas were identified as possible project directions offering improvement opportunities to the overall operational, collaboration and knowledge sharing within the PD testing facility at the collaborating company. The topic area selected was justified by the literature survey and also approved by the management of the company was to explore and develop a cost effective knowledge sharing tool that allows for the capture of existing company knowledge and for it to be disseminated throughout the entire engineering team, in order to improve employee understanding of in-house engineering practices and avoid reinventing the wheel when knowledge is already available but not properly documented and ready for reuse.

The knowledge framework consists of a set of novel methods and tools that provide users with the opportunity to easily capture and document the knowledge that they have acquired during their years of employment. With the complexity of knowledge varying from simple explicit knowledge to more complex tacit knowledge content using video sharing and storytelling technologies to address this challenge. The framework should also provide the possibility to store this knowledge so that it can be easily searched, shared and disseminated both locally and globally throughout the organisation, using knowledge mediums like social media, Web 2.0 tools and video sharing that can deliver complex engineering knowledge, quickly and provide high learning impact to the knowledge receivers at the PD testing facility. The framework should also be cost effective, by reducing the amount of administrative effort required to manage the framework, and minimize the cost for knowledge capture in order to make the knowledge sharing system more attractive to a business.

Subsequently, the proposed framework facilitates the capture, sharing and discussion of knowledge within the PD environment. The tool will enable employees, at different levels, to contribute and receive knowledge while minimizing the cultural, locational and time differences that people (knowledge experts) experience in globally dispersed organisations.

The proposed framework is implemented using social media and video sharing technologies. With their extensive use and increased global popularity, these technologies will be utilized to capture user-generated knowledge content without the use of expensive media production professionals and offer good knowledge sharing opportunities by providing short and concise knowledge contributions of high learning impact. This should provide greater accessibility and user acceptance at all levels in the organisation, by using them as main stream tools. Furthermore, the knowledge sharing tool should enable employee collaboration across the global organisation, providing an easy to use intuitive platform that can be adopted to share knowledge and highlight hidden skills and know-how across the company.

In summary, the implementation of the knowledge framework should provide the following functions:

- A knowledge capture, sharing and discussion system, providing the methodology and process flow of the framework for complex engineering applications addressing PD testing knowledge;

- A KM tool, driven by the user, reducing the need for knowledge administrators that capture and document company knowledge;

- A KM tool able to easily capture different types of engineering knowledge in an electronic format using storytelling and video sharing technologies inside a database that can be shared throughout the organisation without the need of multimedia professional expertise;

- Structured knowledge content using mediums like social media, Web 2.0 tools and video sharing that can deliver complex engineering knowledge, quickly and provide high learning impact to the knowledge receivers at the PD testing facility;

- Promotion of the sharing of knowledge and its re-use so that new knowledge can be easily developed from the pre-existing pool of knowledge; and

The framework is further described in the following Sections.

5.2 Potential Benefits to Industry

The potential benefits of this research are mainly aimed at PD testing facilities and their main engineering stakeholders. The developed methodology is aimed to improve the capture and sharing of knowledge and communication amongst these users and also enable knowledge re-use which should result in reduced PD testing time. This project is not solely limited to the development of testing teams but can be adapted for other areas of engineering functions where companies wish to capture and share knowledge amongst dispersed and co-located teams.

The implementation of a structured knowledge framework will:

i. Promote the actual knowledge user to drive the KM system, avoiding the need for knowledge management personnel that try to capture and document knowledge which they know little about;

ii. Enable the capture of both explicit and tacit knowledge, so that knowledge within the company is electronically documented inside a database in a rich format that can be used by others inside the organisation at a later stage;

iii. Enable knowledge users to quickly absorb the knowledge they are looking for, resulting in a reduction of wasted time searching through lengthy written documentation;

iv. Promote the sharing of knowledge and it’s re-use so that new knowledge can be easily developed from the already existing pool of knowledge, and avoid the situation of re-inventing the wheel each time a reoccurring problem/issue is encountered; and

v. Enable dispersed experts to share their knowledge with others within the company without the need to travel across, in some cases continents to explain or show how a procedure or a system functions.

The framework will have a social impact on the PD testing facility team and their stakeholders, by improving the communication between team members and providing a more accessible knowledge transfer that will improve the understanding of different job functions, but also educate team members on other process they rely on but have little or no knowledge of.

The improved knowledge sharing and the open sharing of knowledge between team members should improve inter-department relationships which will ultimately result in an improvement on the company operations as a whole.

5.3 The Proposed Knowledge Framework

The proposed knowledge framework to support the product development team and its stakeholders is shown in Figure 51. The diagram represents the proposed knowledge cycle for capturing and sharing knowledge, and also for creating new knowledge, building up the already existing company knowledge.

The framework is made up of four main quadrants: Query, Identification, Capture and Sharing / Learning, with each quadrant divided into a further two elements. The start of the cycle begins with the knowledge query quadrant where the questions from the user are received, and answers to the questions are searched from the knowledge database. If answers are not found, the knowledge users need to go to the next quadrant, that of knowledge identification, i.e., the identification of knowledge gap. The knowledge users then stipulate the knowledge requirement they need and request it through the system for a knowledge expert to reply to.

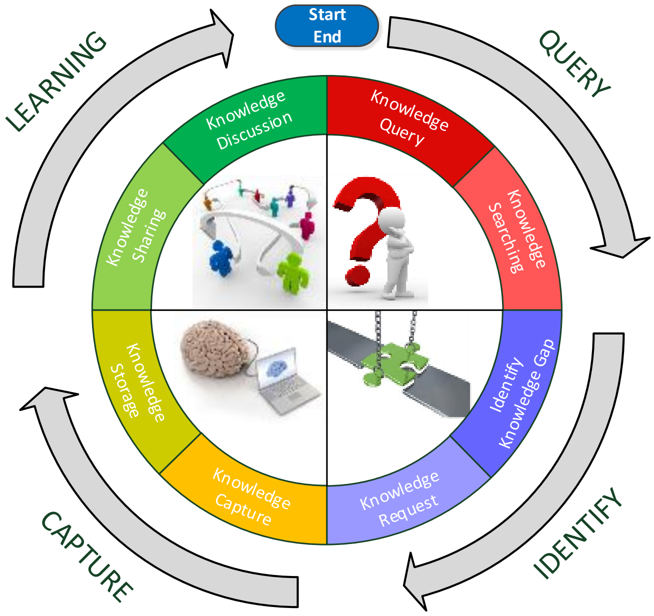


Figure 51. Knowledge framework to support the PD team.

In the third quadrant, knowledge capture, this involves the evaluation of the knowledge request and the selection of the knowledge expert to contribute towards the new knowledge contribution. There are 3 situations for the selection of knowledge expert, i.e. (1) having the perfect match between the knowledge expert and the knowledge requested, (2) a knowledge expert in a similar field to the knowledge requested, and (3) enthusiastic knowledge contributor that is willing to learn new knowledge in order to contribute towards a knowledge request. Once the knowledge is captured, it is stored in an electronic database. The last and final quadrant is that of knowledge sharing, which is divided into sharing and knowledge discussions. Knowledge sharing consists of a searchable database from which knowledge can be identified and accessed for learning, from which the user has the opportunity to question or even challenge the available knowledge through the discussion functionality. This brings back to the start of the cycle. Creating new knowledge by creating new knowledge questions that need to be addressed through a new knowledge cycle.

Each knowledge cycle is aimed at creating both the content of the knowledge database and at the same time, the autonomy of the system determining the knowledge direction depending on the end-user's interests and knowledge needs. Traditional KM systems rely on knowledge administrators to identify relevant knowledge to be captured and documented and, in some cases, also creating the content themselves or outsourcing it to third parties. While these people could be well experienced in creating documents or other media, they are not domain experts and, therefore, from a knowledge expert point of view, are not the appropriate people to capture knowledge.

The proposed framework is targeting at the actual domain knowledge experts to create the knowledge contribution, removing the need for any additional personnel / administrators to support and create the system content and, therefore, reducing the cost to manage such a system. Having said that, the role of a knowledge administrator cannot be removed in its entirety, because an administrator is still needed as a quality control checker and to distribute knowledge contribution requests, because if this is left on a voluntary basis, there is the risk of no one stepping up to fulfil the knowledge requests.

The medium selected to capture and share knowledge needs to be in a format that is easy to use, with the ability to capture complex content, quick to create during sharing, and quick to absorb and also allows for different technical levels of competence to understand and use with minimal training. The medium selected was that of social media and video sharing techniques. The main motivation in using these tools was due to their mass popularity, which in the last decade, have been exploded exponentially into everyday lives. It is also available via multiple routes, including computers, tablets and smart phones, making it an ideal tool to be adopted, while also providing a guarantee of user acceptance due to its pre-existing familiarity with end users. The social media techniques are also being used to generate knowledge discussions from the content created which it is hoped will also identify new knowledge gaps and create new knowledge and content. Some of the main benefits that this framework is likely to bring to industry are:

- People contributing to the Knowledge base will learn more about the subject, by reinforcing their own knowledge;

- Knowledge will be documented and, therefore, available for others to learn from and can also be used for training existing or new staff;

- The social discussions / comments will generate further clarifications and also generate further knowledge to both the providers and receivers;

- Generation of new ideas; and

- Social discussions will promote teamwork, with the added advantage of improving social interactions between different departments.

In the following Sections, further exploration is given to the knowledge end user process flow of the knowledge framework.

5.3.1 The Knowledge Search Process in the Proposed Framework

Collecting and storing knowledge in an electronic format has been well established throughout this research, offering great benefit to any organisation. However, it would be pointless if a company is able to store captured knowledge but not be able to retrieve it in the shortest amount of time, on demand and when it is needed. This Section describes the process that knowledge users need to follow in order to (1) search and find the knowledge they are seeking, (2) search and find the knowledge and expand it by discussing and questioning the knowledge content and (3) search and identify a knowledge gap within the knowledge base, as shown in Figure 51.

Figure 52 illustrates the entire knowledge search process flow a knowledge user needs to follow in order to identify the knowledge they are seeking. The process starts with the knowledge users having a specific knowledge question, from which they can then perform a search. The proposed repository will have five search functions, including; general search, keyword search, look up of knowledge categories, look up of specific knowledge contributors, and general system browsing.

If the users can not locate the knowledge they are searching for, they will need to identify the knowledge gap and submit a request through the system for a new knowledge contribution. On the other hand, if the knowledge is available in the database, they can absorb the knowledge content. If the content is sufficient the search stops, there.

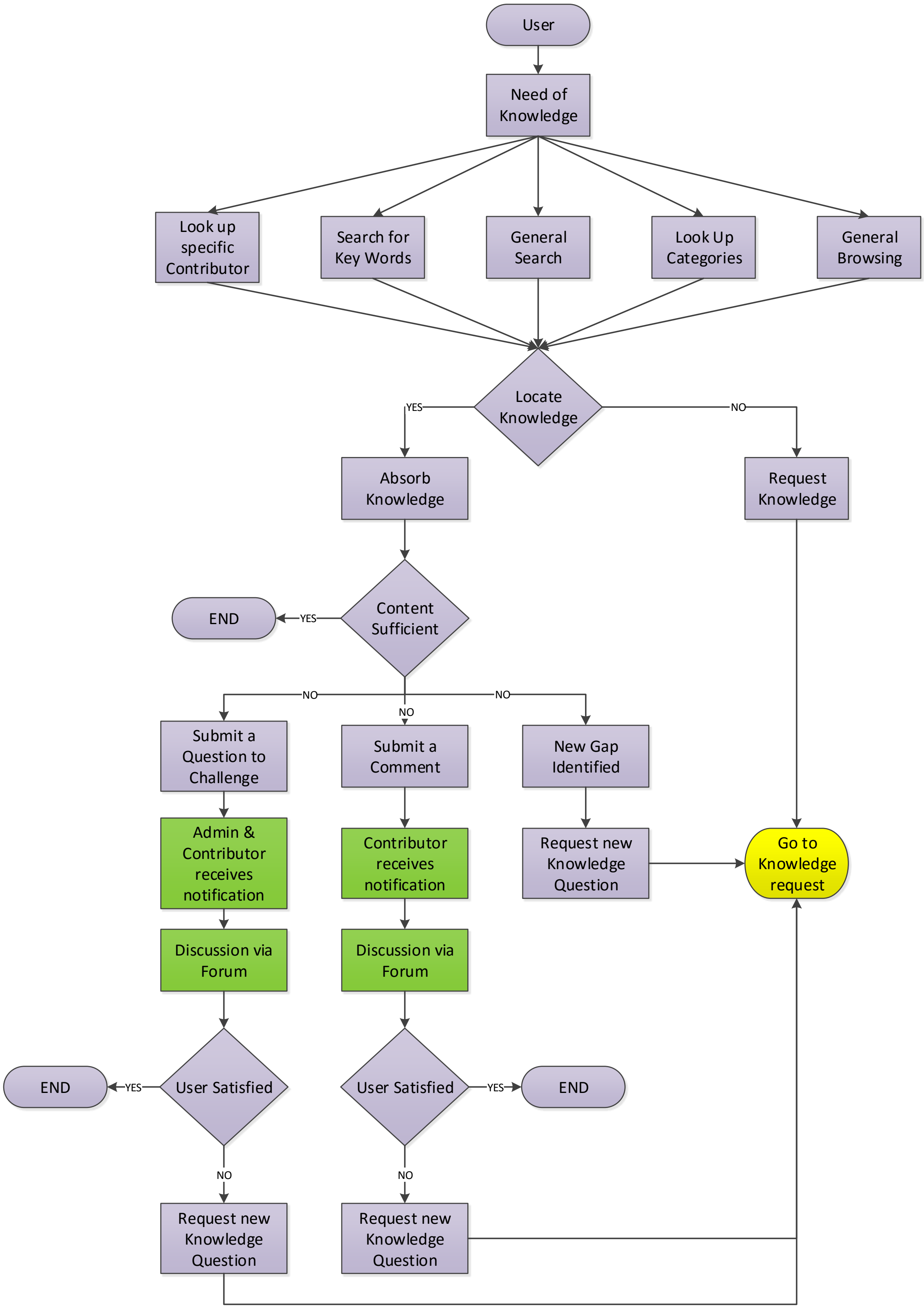


Figure 52. Proposed knowledge framework – Knowledge search flow

However, if the knowledge was not sufficient, the users have two options. They can either start a discussion with the knowledge contributors or identify a new knowledge gap, and submit a new knowledge request through the system. The knowledge discussions with the originator can be in the form of either a question to challenge the knowledge, or a comment to discuss the knowledge. In both cases, these discussions create direct interactions between the users and the providers.

The discussion forum will enable discussions to start with regard to the knowledge content while also providing a documented history of all discussions for other users to refer to, if needed. These discussions can lead to the expansion of knowledge captured by introducing different points of views from other users which may lead to new innovative ways of doing things. By challenging existing knowledge uploaded to the system, it will provide opportunities to improve content quality or even create new innovative knowledge content. If users disagree with the knowledge submitted, they have the opportunity to submit a report to the administrator and originator, stating their reasons for disagreement and how the knowledge could be improved. If their objections are approved, the knowledge content will be updated, resulting in the generation of new updated knowledge.

5.3.2 The Knowledge Request Process in the Proposed Framework

A critical component to guarantee the continuation and repetition of the proposed knowledge cycle is the knowledge request process. The aim of the process is to create a formal structure that allows users or administrators to identify and highlight potential knowledge gaps to be addressed by the system. While it was previously stated that the framework should be driven by users, it is realised that the administrator should have the ability to identify knowledge gaps as well and, at the same time, be able to initiate the initial drive needed to get the knowledge cycle started, therefore creating the initial knowledge contributions for the knowledge database. The process flows are described in more detail below, for both user and administrator knowledge requests.

5.3.2.1. Knowledge User – Knowledge Request

A knowledge request is submitted when a user identifies a gap in the knowledge database. This allows the user to obtain specific knowledge about a topic area. Alternatively, the user could identify a process that, if captured and documented, would raise awareness and would be of benefit for their colleagues and stakeholders, or simply to point out health and safety risks or procedures.

An additional reason for a knowledge request may involve highlighting product design issues or facility improvements. Sometimes, the ability to show a person what the actual issue is, is easier than trying to write it down in an e-mail or report. The impact of showing a problem speaks louder than words (Yadav, Phillips et al. 2011, Tapp 2014), with the critical part of changing dialogue into tangible action. These are only some of the reasons that the knowledge request process may target.

The process is illustrated in Figure 53 and can be generally used for all of the previously mentioned knowledge request reasons. The start of the process is when the user identifies a knowledge gap, from which the user needs to specify, in a formal structure, the reason and benefits of the identified knowledge gap. Once this information is available, a request can be submitted.

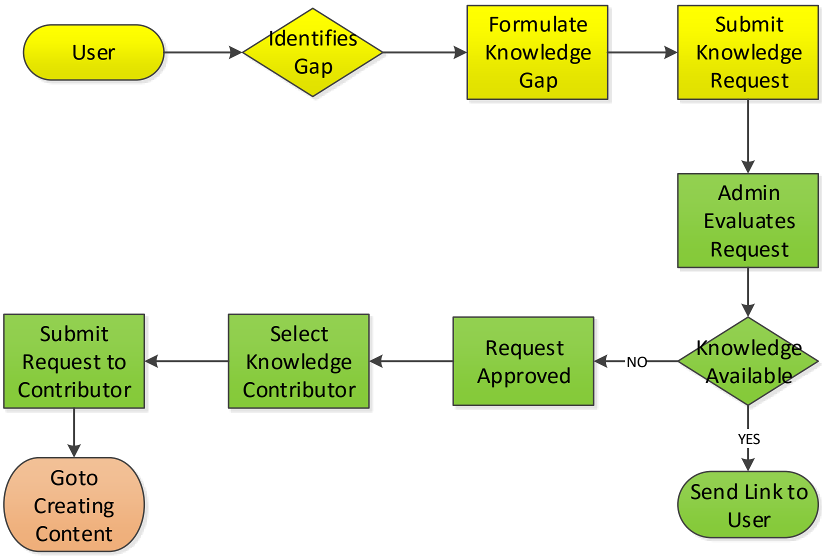


Figure 53. Knowledge user – Knowledge request process flow

Once the request is submitted, the responsibility for satisfying the request is shifted to the administrator who evaluates the knowledge request and checks if the knowledge already exists. If this is the case, the administrator will provide the user with a link to the knowledge required. On the other hand, if the knowledge is not available and the request is of benefit to the company, the administrator will approve the request, select the most appropriate person to fulfil the knowledge request, and inform the knowledge contributor to create the content.

Initially, the selection of the knowledge contributor needs to be carried out from the administrator's experience and knowledge of people's expertise. Once the knowledge sharing platform is populated with content, experts and active contributors will be highlighted and, therefore will provide an active selection pool to choose from. A rating scale will be available for users to rate the contributions in the system both for knowledge content and knowledge discussion. This will provide both the quality check instigated by the users and rating of content originators.

5.3.2.2. Knowledge Administrator – Knowledge Request

The administrator knowledge request is used when critical knowledge / process is identified by the administrator or by management, which need to be documented to provide benefit to the work force by sharing it. It can also be used to document specific knowledge topics that will be accessible and absorbed by other team members outside the Department, in order to educate and demonstrate other work functions across the organisation, thus it can also be used as introductory training material. One of the most important aspects is to reduce the risk of losing critical knowledge that keeps the department going, e.g., when people move up within the company or leave the company.

The process is illustrated in Figure 54 and can be used across all mentioned knowledge request reasons, mentioned above. The start of the process begins when the administrator identifies a knowledge gap. Once this gap has been identified, the administrator selects the appropriate person that is suited to fulfil the knowledge request and informs the knowledge contributor to create the content.

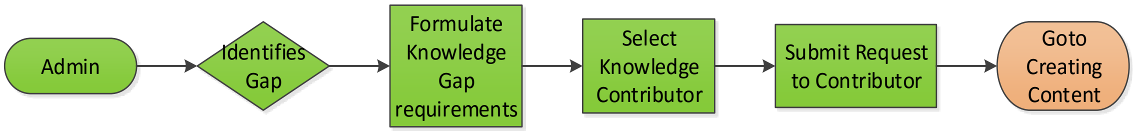


Figure 54. Knowledge admin – Knowledge request process flow

5.3.3 The Knowledge Capture Process in the Proposed Framework

Knowledge Management can be defined "as the ability to harness and build upon an organisation's intellectual capital" (Drucker 2011). While organisational competitiveness is rooted in the mobility of knowledge that is realized through knowledge sharing and transfer (Cummings 2004), knowledge capture is the critical component required in order to achieve this.

The medium selected for knowledge capture is a combination of video sharing and storytelling. Reamy (2002) suggested that storytelling is arguably the best way to transfer tacit knowledge, in that you are able to convey information and context in a form that is easily understood by most people. According to LeBlanc and Hogg (2006), stories make information meaningful, while tacit knowledge is more explicit and allows information to be organised into learnable chunks.

The proposed process to capture the desired / requested knowledge is illustrated in Figure 55. The starting point of the process begins when the knowledge contributors receive the knowledge request from the administrator, from which information the contributor needs to evaluate the requests content. If the contributor possesses the required knowledge and skills to capture the required knowledge contribution, they move on to the next step that of planning the knowledge capture. On the other hand, if they do not possess the knowledge required, they need to look it up and acquire this knowledge through means necessary (books, internet searches, equipment manuals and company procedures) and proceed to the planning stage.

Once a knowledge contribution plan is created, the user is advised to make a quick literature search to make sure that the knowledge available is up to date and relevant, before creating the knowledge contribution plan and submitting it to the administrator. This provides a quick quality check and avoids time consuming of creating knowledge contributions which are inconsistent to set out requirements.

Once the knowledge contribution plan has been reviewed and approved by the administrator, the contributor can start collecting the information in any format required to start creating the knowledge story. Once all the information is collected, it will be compiled into a single video file with additional voice over to explain the knowledge being shown. This compiled knowledge contribution is submitted for a second round of approval, as a means of a quality checking, which once approved, will be uploaded on to the knowledge sharing tool to be shared within the organisation.

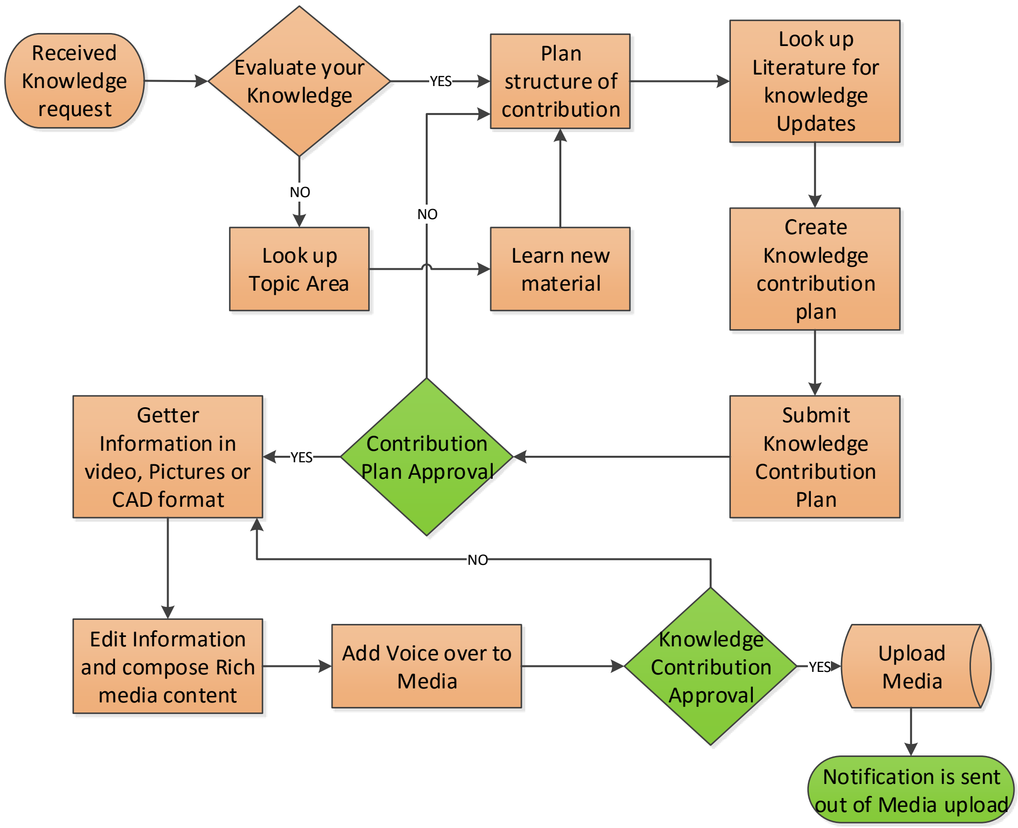


Figure 55. Knowledge contributor – Knowledge capture process flow

5.3.4 Overview of Knowledge Repository in the Proposed Framework

For any kind of knowledge to be successfully and efficiently shared and disseminated within an organisation, the knowledge needs to be stored on a system that allows for connectivity, easy access, single version of the truth, and provides a global reach in order to involve the entire global organisation. It was concluded that the tool selected to store and share knowledge in a video format should be Web 2.0-based and written in Hypertext Preprocessor (PHP) language. This provides the additional capability to create discussions linked to the knowledge media in the form of conversation threads. The reason in limiting the video sharing application to only PHP language resulted from the simplicity of the Web 2.0 programming language due to the limited programming experience of the researcher. Therefore, an Open Source PHP application will be selected as the core system which will be modified and adapted to the required needs. This will be further examined during the development section.

The core requirements for the knowledge sharing platform have been determined and are illustrated in Figure 56. The system, apart from providing a repository function, also needs to provide the functionality for knowledge search, knowledge discussions, knowledge requests and provide an index / directory of knowledge experts.

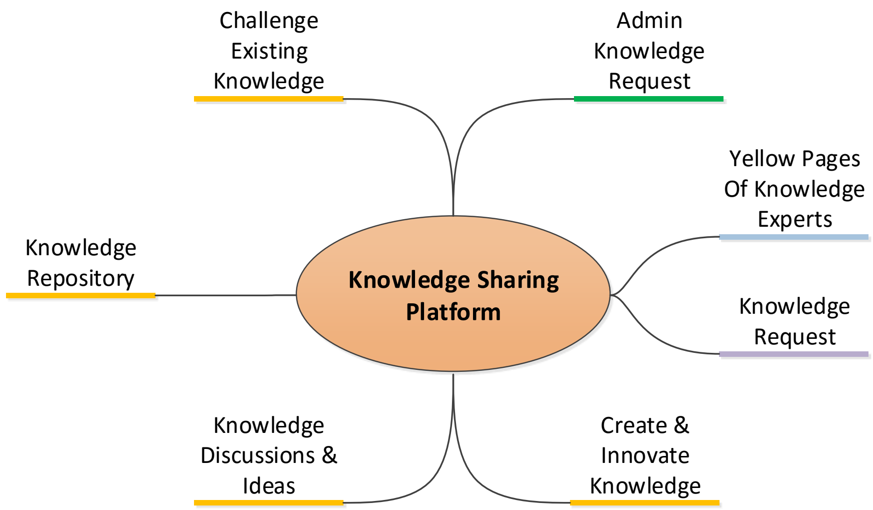


Figure 56. Knowledge sharing platform main components

Figure 57 combines the previously illustrated process flows, bringing them together, forming part of the knowledge sharing platform. The first flow process in orange summarises the knowledge search requirement, while the second and third process flows in violet and green illustrate the knowledge request process. While the last process flow highlighted in blue shows the knowledge expert yellow pages.

The ‘yellow pages’ is a simple system that highlights knowledge contributor’s speciality and expertise. Each system user will have a user profile which will be rated according to different criteria. The higher the rating in a specific field in conjunction with positive feedback from their peers, the higher their ranking will be. The rating criteria to be used are; number of contributions, rating by other users of knowledge content, the number of comments left on content, the number of content views, accepted requests submitted by the user; and from a negative side, the amount of reports sent to the administrator.

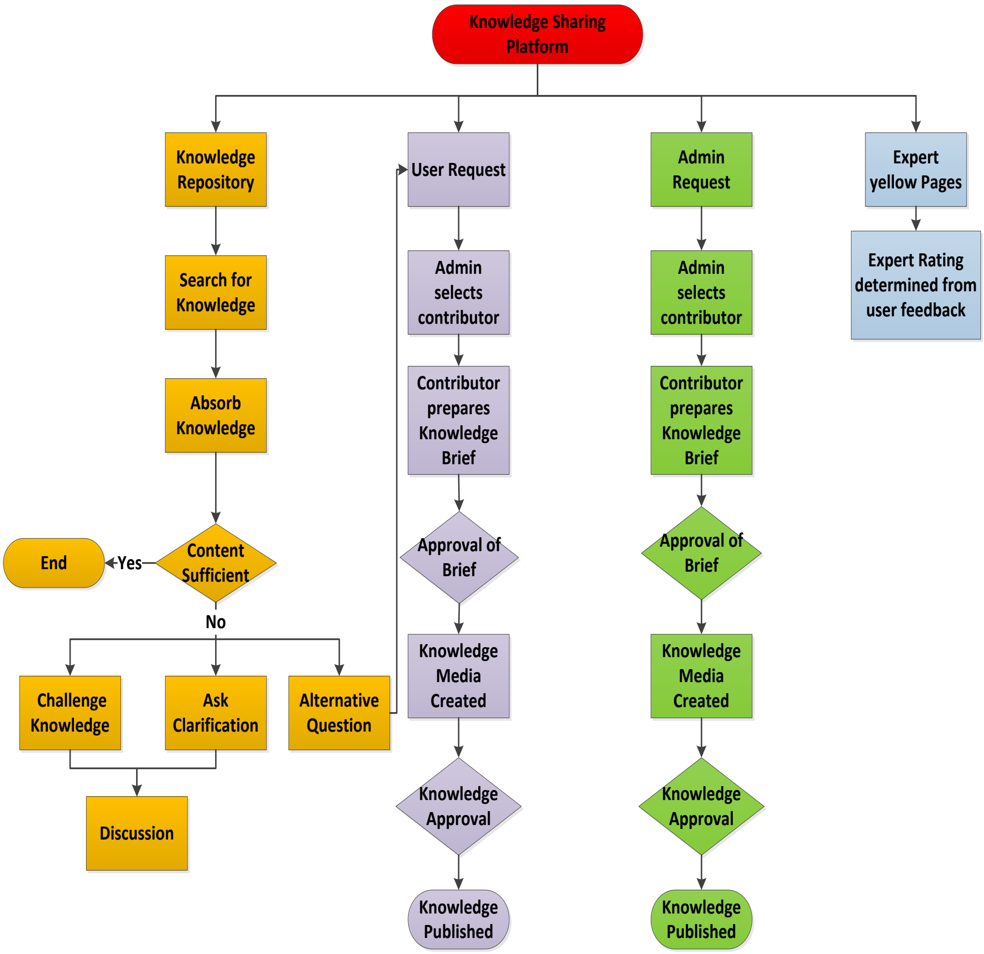


Figure 57. Knowledge sharing platform basic structure

These ratings will monitor both the usage and quality of the contributions submitted by the users.

Prior to development, the opportunity was taken to experiment and document some preliminary ideas and considerations of how the system should look; these ideas were shared with the end users for feedback and input. Some key parameters of the system were discussed below. The repository will contain all captured and uploaded knowledge which is accessible for other users to share and learn from. The information will be accessible through the following search parameters; titles, contributors, categories, tags, recently added material, most viewed material, mostly commented, and related media.

These different search parameters will enable users to interrogate the repository in different ways and enable them to access the information they are after. From this exercise, the following front page mock-ups were established as a guideline for future use during the knowledge sharing platform development.

The mock-up consisted of the knowledge media position, central to the page being the primary focus with a comments space right underneath it. While on the right hand side of the page, two categories of knowledge media are that the top being knowledge created by the person who has knowledge being viewed, and the underneath is the second category of media, which is related to the topic being shown. The rational for having these two categories was that the media created by the same knowledge contributor should provide knowledge which is related because the reason for selecting a particular user is that they are experts in their field, and related media as the title describes is self-explanatory. At the top right, a set of menus allow for users to navigate through the knowledge sharing portal.

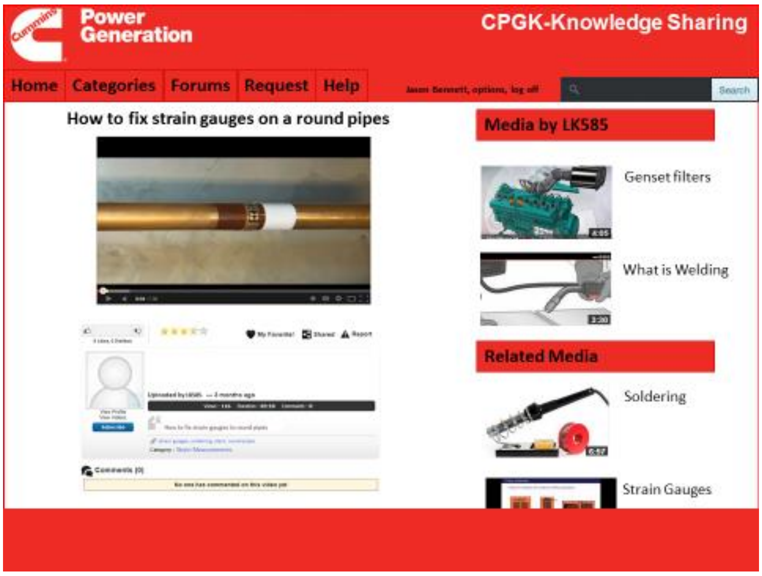


Figure 58. Mock-up of knowledge sharing repository contribution page

The second mock-up created was for the knowledge request form. One of the industrial requirements was that the developed system should be fully integrated and cater for all functionalities of the system, including knowledge sharing, knowledge discussions and knowledge requests right through to the approval and submissions to the knowledge contributors and their corresponding approvals.

The Mock-up, shown in Figure 59, includes the details of the knowledge request form, and next to each field, a system of traffic lights is included. The intention of the traffic lights are that they will be used for approval by the administrator. When a request is submitted, an administrator can approve or reject particular information and each time the knowledge request goes through iterations until the information provided is sufficient to be processed for approval and subsequent submission to a knowledge contributor.

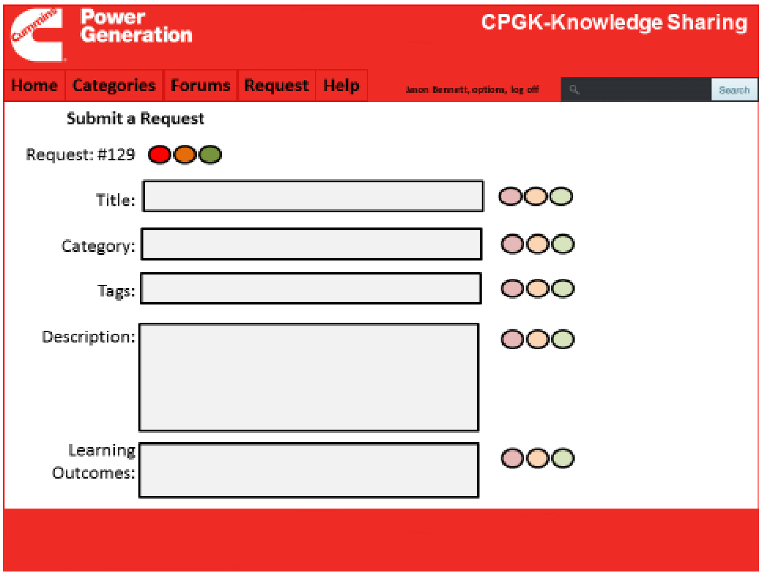


Figure 59. Mock-up of knowledge sharing repository knowledge request

5.3.5 Knowledge Repository Quality Monitoring

The quality of knowledge content is critical in order to guarantee the level of knowledge being disseminated through the organisation. Therefore, an efficient and effective monitoring system is required to evaluate the created content. System monitoring will be carried out using the following:

- From submitted requests, both administrator and user requests are critically evaluated for content and the benefits that the knowledge capture will bring to the team;
- The knowledge capture is critically evaluated for its content and its correctness;
- Media rating – this provides a peer review of content and an overview of the quality of the knowledge being captured and uploaded into the knowledge database. If a knowledge contribution is badly rated, this will be highlighted through a low rating score and, therefore, can be either removed or enhanced;
- Amount of Comments left – this highlights the quality of the media uploaded. If a lot of requests for clarifications are submitted, this will

indicate that the media content is failing to portray the knowledge which is trying to be portrayed;

- Comments – these highlight areas of interest. The greater the comment traffic is, the greater the need to focus on that particular topic area; and

- User report submissions – reporting to change or request more information.

These different indicators should provide a clear picture on the content quality and highlight any issues that arise. As mentioned, the majority of indicators are user driven, reducing the load for constant administrative monitoring.

5.4 Development of the Knowledge Sharing Platform

Further to the process flow described in section 5.2, the first step in developing a knowledge repository, using a Web 2.0 application as the system back bone, is determining the software requirements from which a software package can be short listed and selected. The essential requirements that have been determined from the investigation and the framework design are as follows:

- Store knowledge content,
- Ability to store multimedia format files,
- Cater for collaborative discussions,
- Provide a variety of search functionalities,
- Email notification functionality,
- Online help,
- Admin help request,
- Provide storage security,
- User access control,
- Software cost (for proof of concept should be relatively cheap),
- Provide extensive storage capability,
- Open source software in order to allow source code access and ability to modify it, and

- PHP language (simple to use with the researchers limited acquired knowledge).

From initial software analysis, wiki's and video sharing applications were the two software types considered for further investigation. Wiki's were considered due to their flexibility; this type of software provides adequate functionality for discussions and employee collaboration. A list of applications from these two types of software was drawn up and bench marked against specific criteria, shown in Figure 60 and Figure 61.

Wiki Name	WWW	Licese type	Hosting	Security	Blog	File attach	Embedded Video	Media Search	WYSIWYG	Email Notif	Online Help	Physical Help	Development status	Cost	Rating
MediaWiki	ww.mediawiki.o	GPL	✘	✔	✔	✔	⊘	Keywords	⊘	⊘	✔	✘	Mature	£0.00	5.5
DokuWiki	/ww.dokuwiki.or	GPL	✘	✔	✔	✔	⊘	File Name	⊘	⊘	✔	✔	Mature	£0.00	6.5
PmWiki	www.pmwiki.org	GPL	✘	✔	✔	⊘	⊘	✘	⊘	⊘	✔	✔	Mature	£0.00	6
WikkaWiki	ww.wikkawiki.o	GPL	✘	✔	✔	✔	✘	✘	⊘	✘	✔	✘	Mature	£0.00	4.5
TWiki	www.twiki.org	GPL	✘	✔	✔	✔	⊘	Content	✔	✔	✔	✔	Mature	£0.00	7.5
XWiki	www.xwiki.org	GPL	✘	⊘	✔	✔	✔	Content	✔	✔	✔	✔	Mature	£0.00	7.5
Mind Touch	vw.mindtouch.cc	GPL	✘	✔	✔	✔	✔	content	✔	✔	✔	⊘	Mature	£0.00	7.5
Boltwire	ww.boltwire.coı	GPL	✘	✔	✔	✔	✔	✘	✘	✔	✔	✘	Mature	£0.00	6
Zoho Wiki	www.zoho.com	Licenses	✔	✔	✔	✔	✔	/	✔	✔	✔	✘	/	$600 /year	7
Wikia	www.wikia.com	Licenses	✔	✔	✔	✔	✔	Keywords	✔	⊘	✔	⊘	/	£0.00	7

Figure 60. Wiki software bench marking

Video Sharing Script	WWW	Certified Hosting	Video Comments	Blog / Forum	Upload Video	Embedded Video	Usage Stats	Email Notif	Online Help	Branding	Branding removal cost	Cost	Rating	Rating with cost
PHPmotion	www.phpmotion.com/	2	✔	✔	✔	✔	✔	✔	✔	✔	$75	Free	8	8
ClipShare	www.clip-share.com/	-	✔	⊘	✔	✔	✔	✔	✔	⊘	-	$299	7	4
Clip Bucket	clip-bucket.com/	2	✔	⊘	✔	✔	⊘	✔	✔	✔	$90	Free	7	7
DZOIC Cliphouse	www.dzoic.com	1	✔	✘	✔	✔	⊘	⊘	✔	✔	$49	$200	6	4
MediaShare3	www.mediasharesuite.com/	1	✔	✘	✔	✔	✔	✔	✔	⊘	-	$239	6.5	4
Video Plus	www.theme-junkie.com/	-	✔	✘	✔	✔	⊘	⊘	✔	⊘	-	$100	5.5	4.5
VideoWatch	www.videowatchpro.com/	1	✔	✘	✔	✔	⊘	⊘	✔	⊘	-	$300	5.5	2.5
RayzzLabs	www.rayzz.net/	9	✔	✔	✔	✔	✔	✔	✔	⊘	-	$297	7.5	4.5
PHP Melody	www.phpsugar.com/	24	✔	✔	✔	✔	✔	✔	✔	✔	-	$59	8	7
Alstrasoft	www.alstrasoft.com/	1	✔	✘	✔	✔	✔	✔	✔	✔	-	$100	7	6
VidiScript	vidiscript.co.uk/	2	✔	✔	✔	✔	✘	⊘	✔	⊘	-	Free	6	6
HD VideoShare	www.apptha.com/	-	✔	✘	✔	✔	✘	⊘	✔	⊘	-	$150	5	3.5

Figure 61. Video sharing bench marking

From this benchmarking exercise and a trial period of the short listed applications, PHP Melody by PHPsugar.com was chosen as the application for development. Several modifications were required to the application's original source code. Mainly, the creation of the login page, shown in Figure 62, in order to create controlled access to named users only, while at the same time, removing any preview of the system to outside internet users. The creation of the various web page templates to create the front ends of the knowledge sharing platform. The page templates needed to offer users ease of navigation and simplicity to search and view stored knowledge and also how the knowledge is presented and structured. A further modification was the creation of the knowledge request system which is explained in the following section.

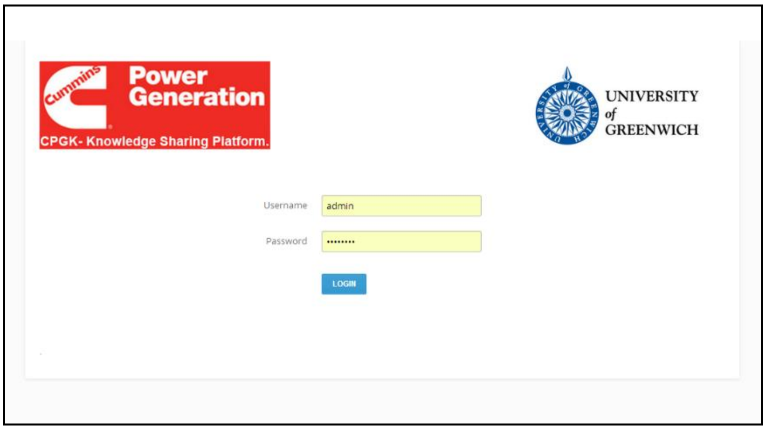


Figure 62. Knowledge sharing platform - Login page

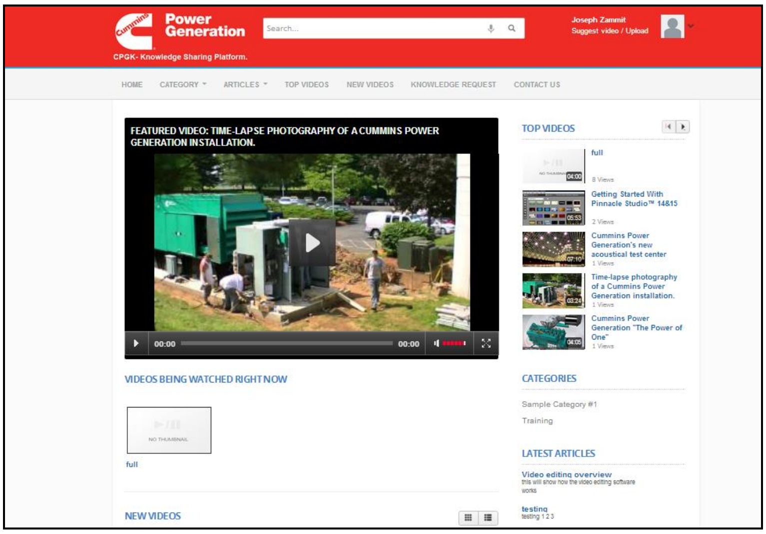


Figure 63. Knowledge sharing platform - primary landing page

Once the test system had been created, it was uploaded on to a live server in order to provide access to other users. The domain chosen for the knowledge sharing system was www.cpgk-knowledgesharing.com which is made up of the collaborating company site name and the name of the tools; CPGK stands for Cummins Power Generation Kent. The security encryption for the database was setup by the Internet Service Provider (ISP) hosting the database. Figure 62 and Figure 63 show the primary login page of the knowledge sharing platform and the primary landing page.

5.5 Development of the Knowledge Request Tool

The requirements of the knowledge request tool were that it provides a fully integrated system which manages the knowledge request, its approval and any revisions or iterations of modifications to the knowledge request, the selection of the knowledge contributor and finally management of the approval and any revisions or iterations of modifications to the knowledge contribution plan. It should also manage the revisions and iterations of the knowledge request /contributions to provide a historical picture of the evolution of the knowledge request / contribution. The tool should be able to automatically send notifications to people involved in the knowledge request / contribution of any changes or approvals in order to facilitate collaboration and team communication synchronization. The tool process flow is illustrated in Figure 64. The pink items represent inputs from the knowledge request originator, while the green items represent inputs from the system administrator and the blue items represent inputs from the knowledge contributor.

As the process flow shows, the system should provide complete visibility and a clear understanding between the three main characters, that of the knowledge requester, administrator and knowledge contributor.

This fully integrated system, while being the ideal tool, was not viable for development for this project due to lack of time and programming resources. Therefore, a limited system was implemented for the purpose of the tool's proof of concept. The implemented process still follows the process flow shown, with the exception of the required automation. Several automation features have been implemented using a manual process.

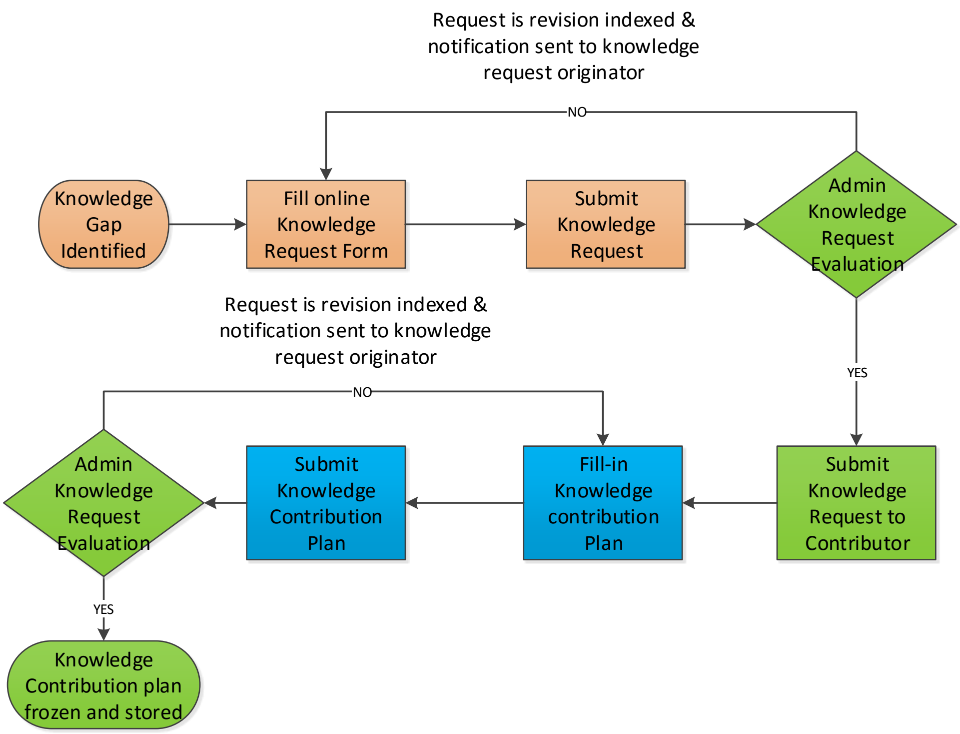


Figure 64. Required knowledge request process flow

The initial knowledge request has been implemented into the knowledge sharing platform on the main page of the system, where the user has the option on the top bar menu to select a knowledge request. During early trials, feedback from a senior manager was received, who asked for an extra dialog pop-up to be created which asks users if they have already checked the database for the knowledge they have requested.

This is followed by the knowledge request form, in which the knowledge requester fills in the information required. In order to provide structure and commonality, a specific structure was created with all of the mandatory fields, in order to avoid users submitting partially completed requests. The fields used in the knowledge request form are: Title, Category, Aim, Description and Learning outcomes. It was determined that, as a user submitting a request, they must understand the reason and the outcomes from capturing the knowledge they are requesting. If they are unable to determine or justify a reason, the request would not be of substance. Once submitted, the system administrator receives an email with all information requested. An example of this is shown in Figure 65 and Figure 66.

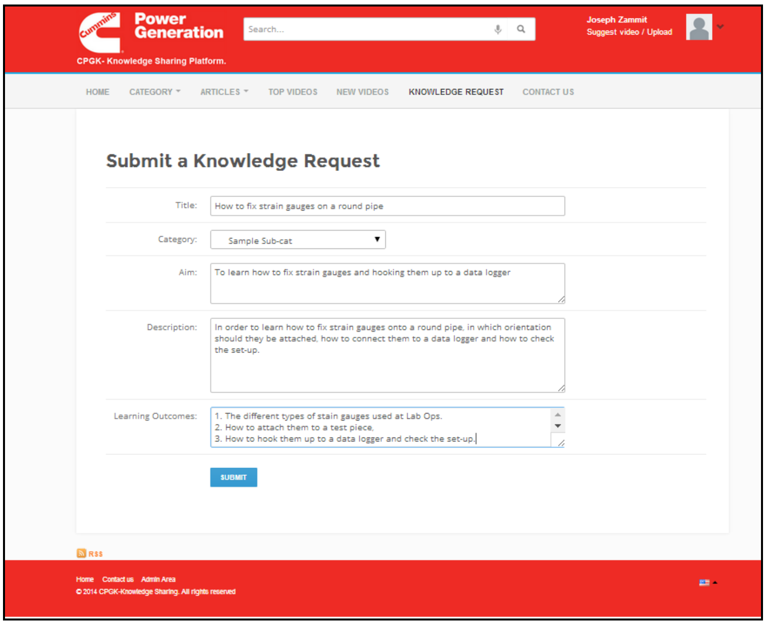


Figure 65. Knowledge sharing platform -Knowledge request form

Hello,

You have a new request from CPGK-Knowledge Sharing.

Here are the details of the submission:

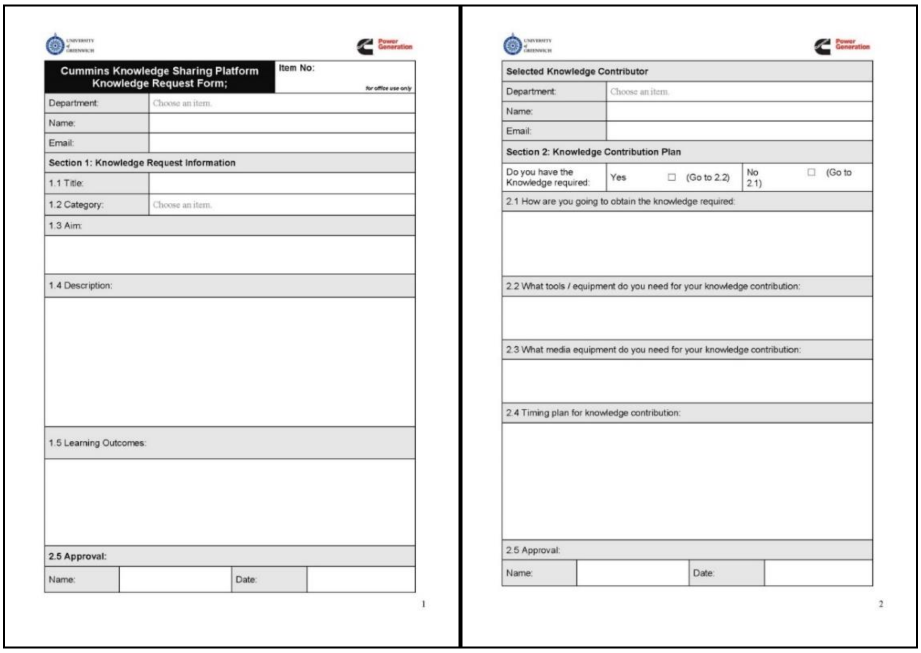
Title: How to fix strain gauges on a round pipe
Category: Sample Sub-cat
Aim:
To learn how to fix strain gauges and hooking them up to a data logger
Description:
In order to learn how to fix strain gauges onto a round pipe, in which orientation should they be attached, how to connect them to a data logger and how to check the set-up.
Learning Outcomes:

1. The different types of stain gauges used at Lab Ops.
2. How to attach them to a test piece,
3. How to hook them up to a data logger and check the set-up.

This request has been submitted form IP: 92.251.5.39

Figure 66. Knowledge request Admin email

At this point, the administrator must evaluate the content of the request and determine if it should be processed or not. Once it has been approved, the information is inserted into a Knowledge Request Form (KRF), shown in Figure 67, and submitted by email to the knowledge contributor. The KRF is a template word document divided into two sections. Section one contains the information from the knowledge request, while section two contains the information that the knowledge contributor needs to complete as part of the effort to document the plan of how they will create and capture the knowledge contribution.



Cummins Knowledge Sharing Platform
Knowledge Request Form;

Item No:

for office use only

Department:	Choose an item.
Name:	
Email:	
Section 1: Knowledge Request Information	
1.1 Title:	
1.2 Category:	Choose an item.
1.3 Aim:	
1.4 Description:	
1.5 Learning Outcomes:	
2.5 Approval:	
Name:	Date:

1

Selected Knowledge Contributor		
Department:	Choose an item.	
Name:		
Email:		
Section 2: Knowledge Contribution Plan		
Do you have the Knowledge required:	Yes ☐ (Go to 2.2)	No ☐ (Go to 2.1)
2.1 How are you going to obtain the knowledge required:		
2.2 What tools / equipment do you need for your knowledge contribution:		
2.3 What media equipment do you need for your knowledge contribution:		
2.4 Timing plan for knowledge contribution:		
2.5 Approval:		
Name:	Date:	

2

Figure 67. Knowledge request form example (KRF)

The KRF document is a simplification of the ideal knowledge request tool and forms part of the manual process created to full fill this software short coming. Once the knowledge contribution plan has been created, it is sent back to the administrator for evaluation and once approved, the knowledge contributor will be informed either in person or email.

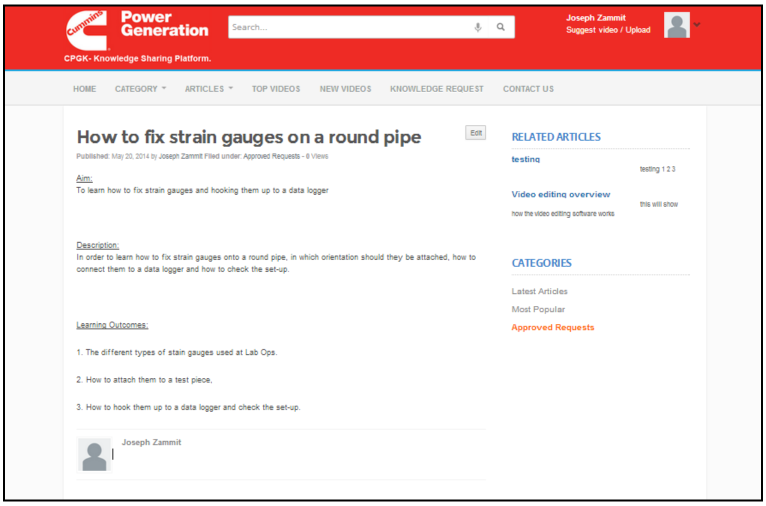


Figure 68. Knowledge sharing platform – request discussion board

The collaboration aspect for the knowledge request and knowledge contribution was completed manually, but through the developed knowledge sharing platform in the form of an article with comment fields for discussion between the administrator and the knowledge requester and contributor, which is shown in Figure 68.

This described method has been used as part of the validation process for the system proof of concept. It still remains the researcher’s opinion that the fully integrated knowledge request process should be implemented if the system is adopted by the collaborating company. The benefits of having a fully integrated system are immense, including providing the ability to document and share past knowledge requests both approved and rejected. It could provide insight to the user regarding what requests have been submitted in the past and provide the possibility for the user to check if a similar request in the past has already been rejected and, therefore, avoid repetitions. Another major benefit could be the ability to have direct links between the requester and the contributor while capturing the communication and collaboration between the two parties would only enrich the content.

5.6 Development of the Knowledge Capture Tool

The key principle of any kind of knowledge capture for this framework requires the use of video capture of knowledge situations such as processes or demonstrations. Therefore, a key element is the hardware that will be used. In selecting the most appropriate video recording equipment, an investigation was conducted. A number of criteria was drawn up to aid in this selection process, which consisted of items such as picture quality, the ability to take still pictures, optical zoom, working conditions (dust & moisture) and, most importantly, price.

The results from the benchmarking exercise can be seen in the table below. The chosen camera for the project was the Panasonic HX-WA30EB-K. The main reasons for choosing this camera, apart from the good picture quality, was the ease of use and the positive online reviews the camera received. It was also chosen for the dust and water protection due to the engineering environment these cameras will be used in. During the investigation, it was determined that the class and type of camera was also important, having a compact easy to use and hand held version would provide the versatility required to capture images in situations which can be considered unfriendly or challenging to access. Noise cancelling headphones, with incorporated microphones, were also required for when knowledge contributors compiled their knowledge contribution to create the voice over track.

Camera Name	Manufacturer	Full HD	Res	Photo stills	Zoom	Optical Zoom	Weight	Screen size	Work Temp	Dust proof	Water proof	Cost
HDR-GW66VE	Sony	✔	15 Mpix	✔	17x	10x	188g	3"	-	✔	✔	£399.00
HX-WA30EB-K	Panasonic	✔	11.9 Mpix	✔	18x	5x	268g	2.6"	-10 - 45 deg	✔	✔	£250.00
HX-DC3EB-K	Panasonic	✔	11.9 Mpix	✔	16x	5x	162g	3"	0 - 40 deg	✘	✘	£149.00
Camileo P20	Toshiba	✔	3 Mpix	✔	16x	-	127g	3"	-	✘	✘	£120.00
LEGRIA HF R26	Cannon	✔	3.2 Mpix	✔	28x	20x	272g	3"	-	✘	✘	£392.00
Xacti VPC-CG21	Sanyo	✔	5 Mpix	✔	10x	5x	154g	3"	-	✘	✘	£120.00
Xacti CA100	Sanyo	✔	10 Mpix	✔	10x	5x	227g	3"	-	✔	✔	£199.00

Figure 69. Equipment selection – Benchmarking of video capturing tools

Figure 70. Knowledge capture tools

An assumption of the project was that video cameras today have become very common due to the widely available communication equipment available, such as smartphones, tables and digital cameras. Therefore, it was assumed that the majority of people have a basic working knowledge of video cameras and photography equipment. Still, a basic 'how to use a camera training video' was created to demonstrate this skill. In general, however, it is assumed that the majority of people would know how to use one from past experience. The quality of the capture footage will be analysed in the next Chapter. Once the raw video images had been captured by the knowledge contributor, the next step in the knowledge capturing system is to compile the raw media together into a single coherent video, delivering a knowledge message.

This is achieved by compiling a knowledge video using a video editing software. For this project Adobe Premier Pro has been selected, for the simple reason because it's the only video editing software available in the collaborating company software store. Fortunately, this software package is one of the leading commercially available video editing software. Video editing software allows for the process of editing segments of video footage, special effects and sound recordings as voice over for video footage. Extensive training material how to use the video editing software has been developed using the knowledge capturing methodology and is mentioned in the next section.

In order to produce a coherent knowledge video, it was determined that the knowledge contribution needed some form of structure in order to aid the knowledge contributor to build the media but help the knowledge receiver to absorb the knowledge by creating knowledge contributions that have common features, such as ease of knowledge understanding and knowledge structure.

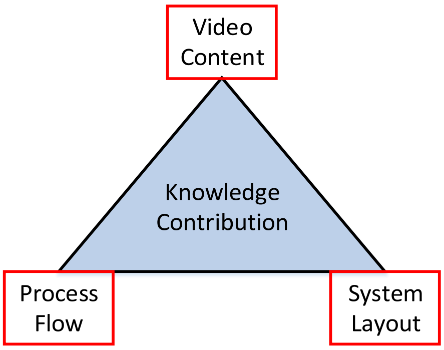


Figure 71. Knowledge contribution main components

The key elements identified to improve a user's understanding of a knowledge contribution are shown in Figure 71. This is made up by (1) the video content with voiceover explaining what is being demonstrated, (2) the process flow chart of what is being demonstrated, and (3) the physical layout of the system to aid the knowledge receiver to comprehend the location dynamics. This layout provided the best knowledge format, reviewed by the system users which allowed them to make links and connections to what they are seeing in the video in relation to the physical location and the order in the process tree. This structure was then created into a template which was used by the knowledge contributors for the case study.

The template created consisted of a title page, physical layout page and the process tree page. These pages provide the opportunity for the knowledge contributor to explain these various items in detail, prior to the knowledge video portion. Examples of these are shown in Figure 72, Figure 73 and Figure 74.

Figure 72. Knowledge contribution template – title screen example

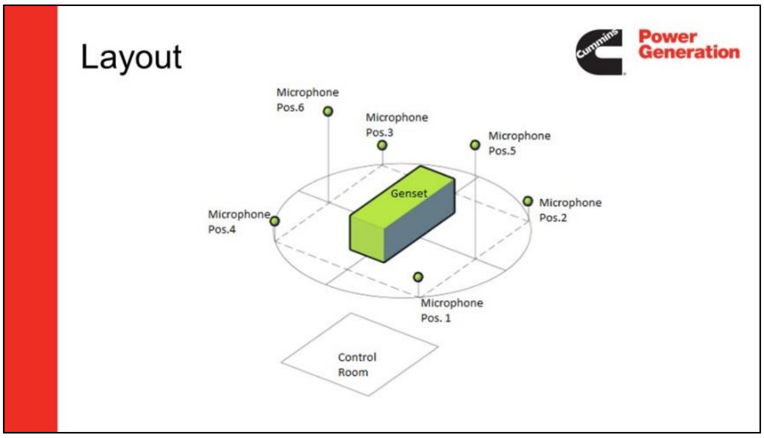


Figure 73. Knowledge contribution template – system layout example

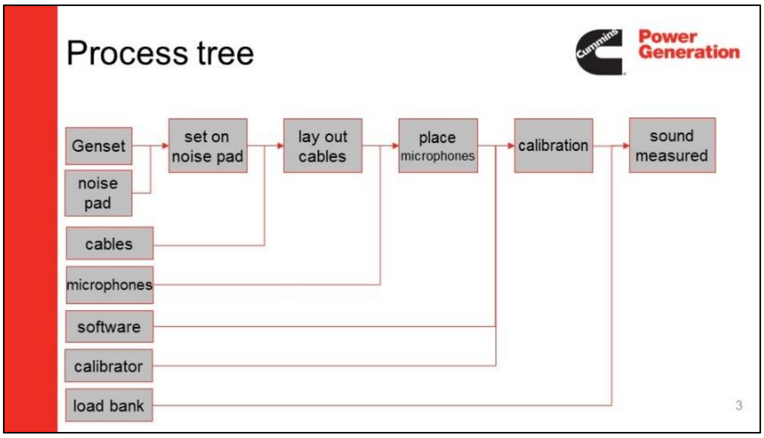


Figure 74. Knowledge contribution template – process tree example

These introduction screens are followed by the knowledge video. Instead of showing the video in full screen, it is combined with the process flow and layout which are shown on the side. The intention of this is to highlight the location, both in the layout and process flow, depending on what stage of the video presentation it is at. This combination allows users to make links and connections to what they are seeing in the video in relation to the physical location and the order in the process tree. Figure 75 shows an example of a noise measurement process setup.

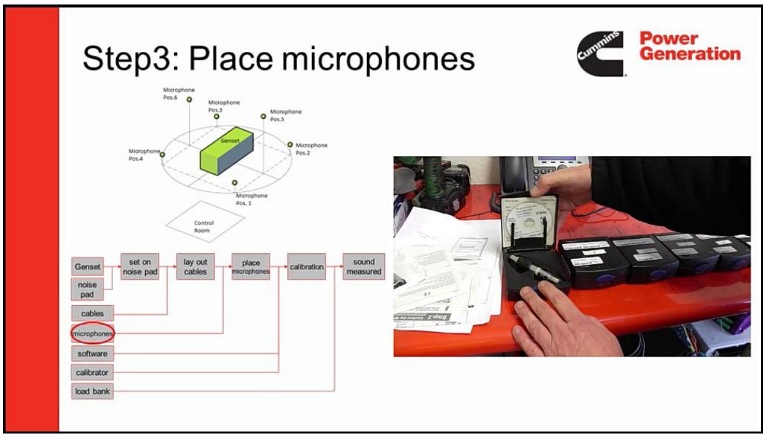


Figure 75. Knowledge contribution template – complete example

Another important concept to be evaluated during the case study was the duration of the knowledge contribution. During the end-user knowledge preferences questionnaire, the users indicated that they preferred to view short knowledge contributions, lasting between 5 – 10 minutes each, rather than longer presentations. This benefits the attention span of the users; the longer the knowledge contribution is, the greater the possibility of users losing interest or even stopping the video halfway through. Therefore, a time duration recommendation was put into place and knowledge contribution should be between the 5 – 10 minutes in length. This concept has been tested and compared with longer presentations during the case study with feedback being presented in the Chapter 7.

5.7 Development of the End User Training Material

Any software development, commercially or otherwise available, requires some form of manual or training material in order to explain to users how the system works, even though the developed system is based on commonly used technology. This sections describes the training material created for the end user.

The training material method of delivery was the same medium developed for the knowledge sharing framework being that the training material is also another form of knowledge that needs to be transferred to the user. It also provided the opportunity to test first-hand the theory of the framework.

The main aim and learning outcome of the training material was to provide users with a basic understanding and primary building blocks that a user would need to use the developed knowledge sharing framework and also be competent enough to create knowledge captures. One of the measures used to quantify the usability and the quality of both the presentation techniques and content of the training material, was from the amount of queries received from knowledge contributors during the knowledge capture case study system trail and from user feedback received after the knowledge contributions were completed. In both cases, the feedback was positive with most of the queries received during the user knowledge capturing exercise regarding additional video editing functionality in order to enhance the knowledge contribution content. While verbal feedback during the final interviews with the knowledge contributors was also very positive and found to be a ‘fun’ experience and different from their normal working day.

The presentation of the training material followed the same principles as described in the previous sections, that of connecting the knowledge being shown on video in conjunction with the process flow and, in some case, where applicable, the location. The training material identified is listed below:

- Using the Cummins knowledge sharing platform,
- Making a knowledge sharing platform media contribution,
- Using a video camera,
- Video editing - Premiere Pro Overview,
- Premiere Pro Video Editing Lesson 1,
- Premiere Pro Video Editing Lesson 2,
- Premiere Pro Video Editing Lesson 3,
- Snap it – computer desktop video grab.

The selection of training material provides basic training for the use of the knowledge sharing platform. Training on how to structure and build a knowledge contribution, using the supplied video camera purchased for the project and basic training for the video editing software and computer desktop screen software is provided.

5.8 Summary of the Developed Knowledge Sharing Tool

In summary, this Chapter has described the four solutions developed during this research project. These are as follows:

- A novel knowledge sharing framework, which enables the capture and sharing of employee knowledge, with complexity of knowledge varying from simple explicit knowledge to more complex tacit knowledge content within the PD department of the organisation with primary focus to PD testing, and identifying the different critical components required for knowledge transfer. Fulfilling the first three set research objectives that of to investigate industrial requirements of knowledge management, to investigate previous and current academic and industrial methods to represent knowledge, and to propose a new methodology for capturing and sharing PD and testing employee's knowledge;

- Development of a prototype knowledge sharing tool using social media, Web 2.0, storytelling and video sharing technologies, to support and enable knowledge transfer, and collaboration for global PD within an organisation for complex engineering knowledge, providing a contribution to both industrial and academic knowledge and learning. Fulfilling the fourth set research objective that of to design and prototype a framework and methodology to improve communication and sharing of knowledge within the testing team;

- A novel concept of empowering actual knowledge experts at all levels to contribute and share their experience and knowledge in a complex engineering environment by using main stream social media tools like video sharing and storytelling as a medium to capture and share their knowledge contribution. Fulfilling the fourth and fifth set research objectives that of to design and prototype a framework for testing knowledge capture and sharing, and to carry out an industrial case study to validate the designed framework; and

- A series of guidelines to enable organisations to make best use of this knowledge sharing tool, aiding collaboration and knowledge sharing practices, using video sharing and storytelling technologies to represent the tacit knowledge which is a major challenge in the PD testing application for knowledge capture and transfer. Fulfilling also the fifth set research objective.

In the next Chapter, an example of the use of the developed knowledge framework is provided in a user case format, providing a story line of typical use.

Chapter 6: Knowledge Sharing Framework User Case

In this Chapter, an example of the use of the developed knowledge framework is presented in a user case format, providing a complete story line of typical use of the framework, from the identification of a knowledge requirement, creating the knowledge contribution and consuming the knowledge captured.

6.1 Introduction to the Use Case

This Chapter provides a typical example in the form of a use case of the developed knowledge sharing framework. The user case will provide a typical storyline, explaining why and how the framework will be used to capture and share engineering knowledge in a PD testing environment.

This framework is aimed to capture different types of knowledge situations and of different complexity. Some examples are;

- Product design improvement identified through the use of the product during testing,
- Testing procedures providing detailed explanations of why a process is executed in such away,
- Specialised training material which is testing oriented,
- Lessons learned from past testing projects, and
- Introduction or evaluation of new testing equipment,

There are many other situations that this knowledge framework methodology can be applied to, but as an example to further explain the framework usage, a user case that of the introduction and evaluation of a new testing equipment will be explored. To setup the scene for this examples the actors need to defined and describe the initial requirement that will initiate this knowledge cycle. There actors that will be used in this example are, the originator requesting the knowledge, the administrator and the knowledge contributor. The initial knowledge requirements of the originator came about due to frequent inaccurate and costly calibration of thermal expansion measurements equipment during PD testing. Currently the testing facility uses lasers to measure thermal expansion / displacement in the Genset during testing. The originator wanted to find an alternative method to perform such measurement.

After a quick search on the internet of alternative measurement devices he came across an eddy current sensor that could be used instead of the current lasers, offering a cheaper alternative but with limited information and no management approval to purchase these sensors he could not proceed without providing a case study and convincing management of their use. The scene has been set and the identified steps that will be described in this user case are:

- The originators: identifying a knowledge requirement and logging into the Knowledge Sharing Platform to search existing knowledge;
- The originator: identify there is a gap in the available knowledge and creating a knowledge request;
- The administrator: evaluates the knowledge request and selects a knowledge contributor;
- The knowledge contributor: creates the knowledge contribution and submits for approval;
- The administrator: evaluates and approves knowledge content for upload and informs originator;
- The originator: evaluates newly captured knowledge content and it’s uses;

6.2 Step 1: Identify a Knowledge Requirement and Search the Knowledge Sharing Platform

The originator identifies a knowledge requirement, lack of information about eddy current sensor, and he requires an overview of the eddy current sensor and explore the possibility to adopt this sensor as a replacement of current laser measurement equipment.

Therefore, he opened up his internet browser and accesses the CPGK – Knowledge Sharing Tool: www.cpgk-knowledgesharing.com. A log in page, shown in Figure 76, will be displayed in which the user must fill in their user name and password.

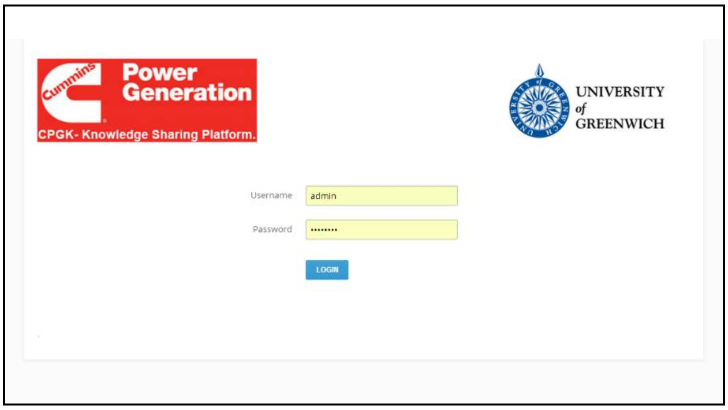


Figure 76. CPGK - Knowledge Sharing Platform Log in page

Once logged in, the user will be redirected to the main page shown in Figure 77, where the main functions of the knowledge repository can be found. These include a search bar, user settings, menu bar, providing the main storage categories and functions of the site. He can search for the required knowledge by using keywords like Eddy Current Sensor in the main search bar, producing a list of knowledge contributions relative to his search parameters. If the required knowledge is not available, the originator has identified a gap.

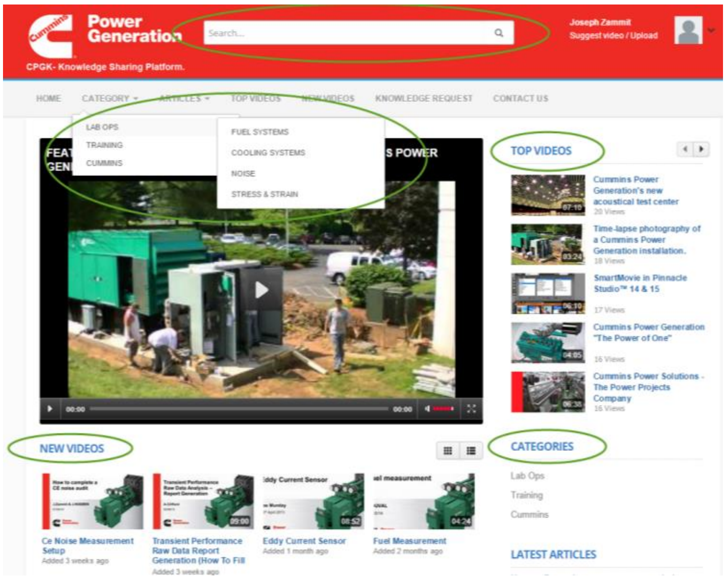


Figure 77. CPGK - Knowledge Sharing Platform Main Search Tools

6.3 Step 2: Identify Knowledge Gap, Create a Knowledge Request

Once a knowledge gap has been identified by the originator he needs to request a knowledge request inside the knowledge sharing platform. On the main page of the system the user has the option, on the top bar menu, to select a knowledge request. A dialog pop-up window shown in Figure 78 will asking the originator if he has checked the knowledge repository to avoid submitting requests for knowledge which are already in the system.

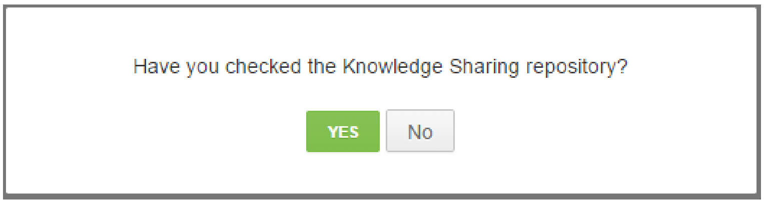


Figure 78. CPGK - Knowledge Sharing Platform Knowledge Request

Once the user selects 'No' confirming that they have checked the knowledge sharing repository, they are taken to the knowledge request form shown in Figure 79, in which the knowledge request originator needs to fill in the information of the required knowledge.

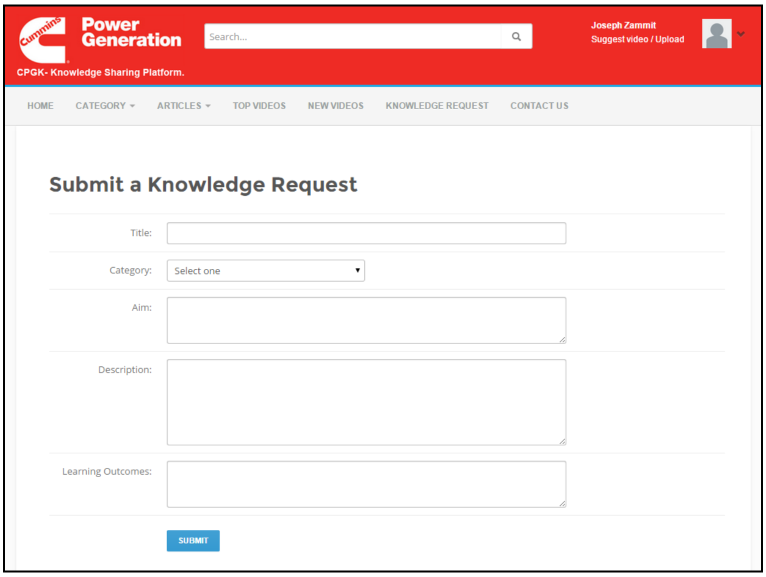
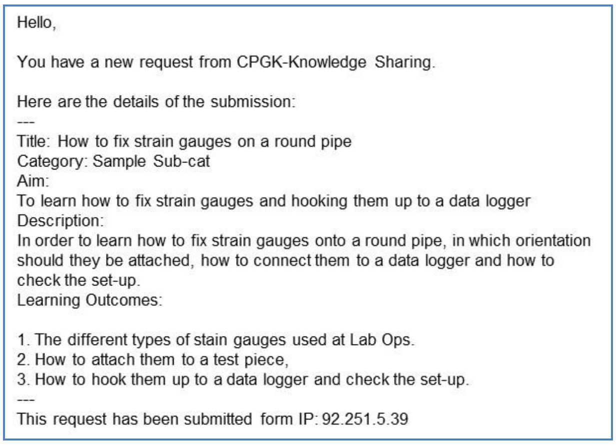


Figure 79. CPGK - Knowledge Sharing Platform knowledge request form

The fields used in the knowledge request form are: Title, Category, Aim, Description and Learning outcomes. It was determined that, as a user submitting a request, they must understand the reason and the outcomes from capturing the knowledge they are requesting. If they cannot determine or justify a reason for the request it would not be of substance. These requirements being the description and reason of the knowledge request relating to the eddy current sensor providing an overview and explore the possible adoption to replace laser measuring equipment. Once submitted, the system administrator receives a notification of the knowledge request.

6.4 Step 3: Evaluation of Knowledge Request and Approval

After the originator has submitted a knowledge request, the administrator receives a notification in his email box of the request shown in Figure 80. At this point, the administrator will evaluate the content of the request and will determine if it should be processed or not.



Hello,

You have a new request from CPGK-Knowledge Sharing.

Here are the details of the submission:

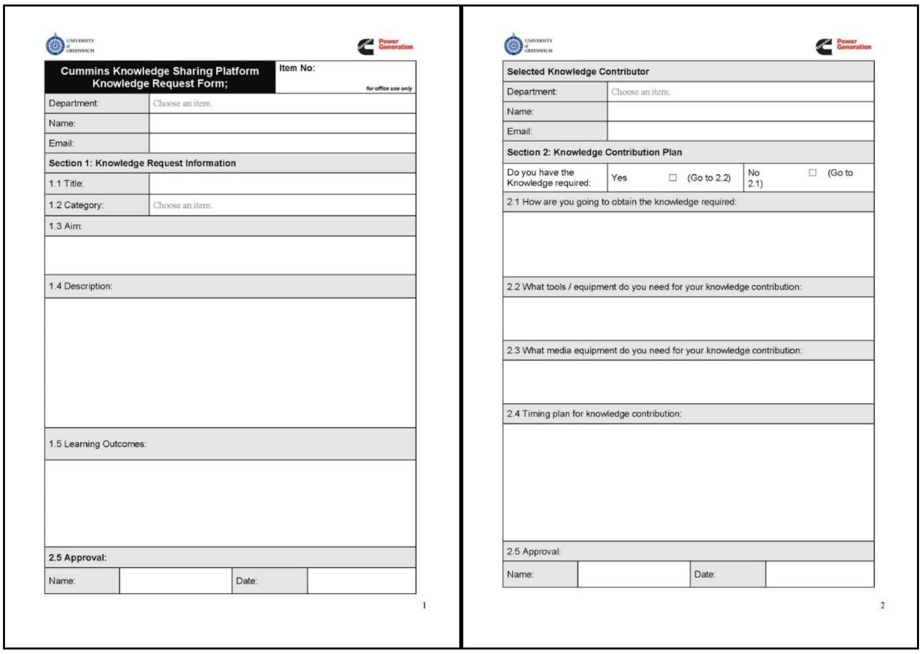
Title: How to fix strain gauges on a round pipe
Category: Sample Sub-cat
Aim:
To learn how to fix strain gauges and hooking them up to a data logger
Description:
In order to learn how to fix strain gauges onto a round pipe, in which orientation should they be attached, how to connect them to a data logger and how to check the set-up.
Learning Outcomes:

1. The different types of stain gauges used at Lab Ops.
2. How to attach them to a test piece,
3. How to hook them up to a data logger and check the set-up.

This request has been submitted form IP: 92.251.5.39

Figure 80. Knowledge Request Admin email

Once a knowledge request has been approved by the administrator, the submitted information is inserted into a Knowledge Request Form (KRF), shown in Figure 81. At this stage the administrator also needs to identify a knowledge contributor that will create and capture the knowledge requested. The KRF is submitted by email to the knowledge contributor. The KRF is a template, provided in word processing format, divided into two sections. Section one contains the information from the knowledge request, while section two contains the information that the knowledge contributor needs to complete as part of the effort to document the plan of how they will create and capture the knowledge contribution.



Cummins Knowledge Sharing Platform Knowledge Request Form;

Item No:	For office use only
Department:	Choose an item.
Name:	
Email:	
Section 1: Knowledge Request Information	
1.1 Title:	
1.2 Category:	Choose an item.
1.3 Aim:	
1.4 Description:	
1.5 Learning Outcomes:	
2.5 Approval:	
Name:	Date:

1

Selected Knowledge Contributor			
Department:	Choose an item.		
Name:			
Email:			
Section 2: Knowledge Contribution Plan			
Do you have the Knowledge required:	Yes ☐ (Go to 2.2)	No ☐ (Go to 2.1)	
2.1 How are you going to obtain the knowledge required:			
2.2 What tools / equipment do you need for your knowledge contribution:			
2.3 What media equipment do you need for your knowledge contribution:			
2.4 Timing plan for knowledge contribution:			
2.5 Approval:			
Name:		Date:	

2

Figure 81. Knowledge request form example (KRF)

6.5 Step 4: Creating a Knowledge Contribution and Approval

Once the knowledge contributor receives the KRF the key element need to be determined by the knowledge contributor inserted in the KRF document and sent to the administrator for approval. The key elements are; what knowledge is required, what tools / equipment is required, what media equipment is required; and timing plan to create knowledge contribution. Once these have been determined and input into the form, these are then sent to the administrator for approval. Once approved the knowledge contributor will proceed with the knowledge contribution.

The creation of a knowledge contribution consists of 3 basic steps: planning the knowledge contribution, capturing the required knowledge, and finally, compiling the captured knowledge into a single organised knowledge contribution.

The planning of the knowledge contribution consists of creating a flow diagram of how a user is going to capture and explain their knowledge topic. The diagram, shown in Figure 82, displays two examples of knowledge capture process plan. The first example is hand written while the second example is created using MS. Visio shown in Figure 83.

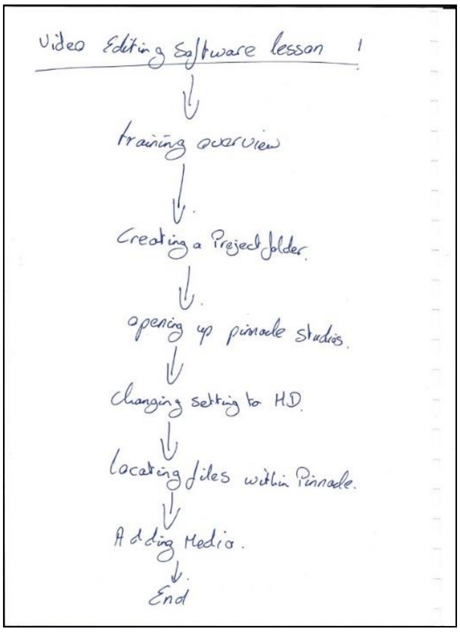


Figure 82. Knowledge Contribution Process Plan Example 1

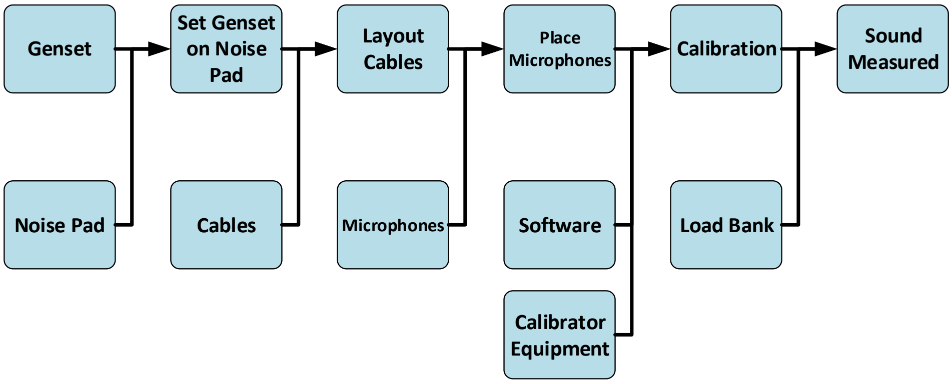


Figure 83. Knowledge Contribution Process Plan Example 2

The aim of this process plan is to provide a logical order of how the knowledge is going to be explained to the knowledge receiver, while also providing a logical map of the knowledge steps required to be captured in order to construct the final knowledge contribution. It is also advised that a voice over script is prepared at this stage, in order to determine the length of time required to explain a specific portion of the knowledge being captured. Once the voice over time required is determined, this can be used to plan the video footage duration in order to simplify knowledge contribution editing later on in the process.

Once the knowledge video footage segments have been captured using the provided video camera equipment, it is time to compile the knowledge contribution. In order to obtain a common knowledge contribution format, the user needs to download the knowledge contribution template from the knowledge repository. The template consists of a number of slides which are the basic building blocks required for the knowledge contribution. The template created consists of a title page, physical layout page and the process tree page; these pages provide the opportunity for the knowledge contributor to explain these various items in detail prior to the knowledge video portion. Examples of these pages are shown in Figure 84 to Figure 86.

Figure 84. Knowledge contribution template – title screen example

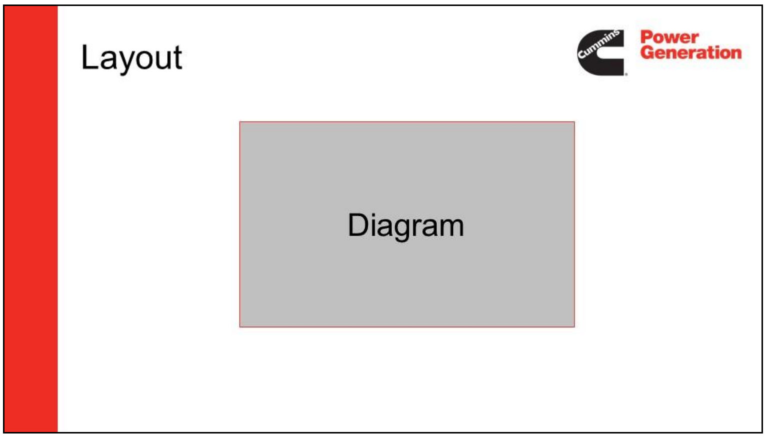


Figure 85. Knowledge contribution template – system layout example

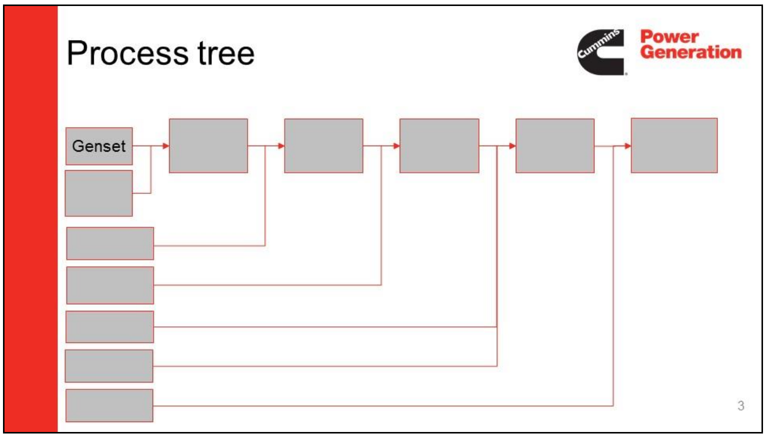


Figure 86. Knowledge contribution template – process tree example

These introduction screens are followed by the knowledge video. Instead of showing the video in full screen, this is combined with the process flow and layout which are shown on the side. The intention is to highlight the location, both in the layout and process flow, depending on what stage of the video presentation the user is at. This combination allows the user to make links and connections to what they are observing in the video in relation to the physical location and the order in the process tree.

Figure 87 to Figure 90 show the captured knowledge contribution providing an overview of the eddy current sensor, the setup and the comparative measurement test between the laser and eddy current measuring and finally presenting the measurement results of the two measuring methods.

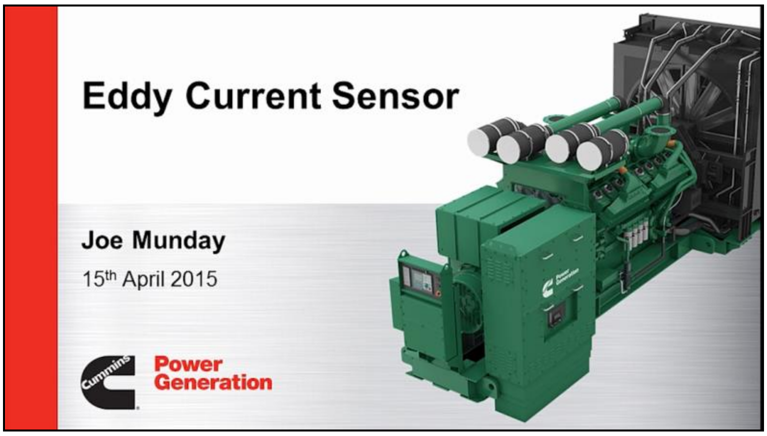


Figure 87. Knowledge Contribution - Eddy Current Example 1

Figure 88. Knowledge Contribution - Eddy Current Example 2

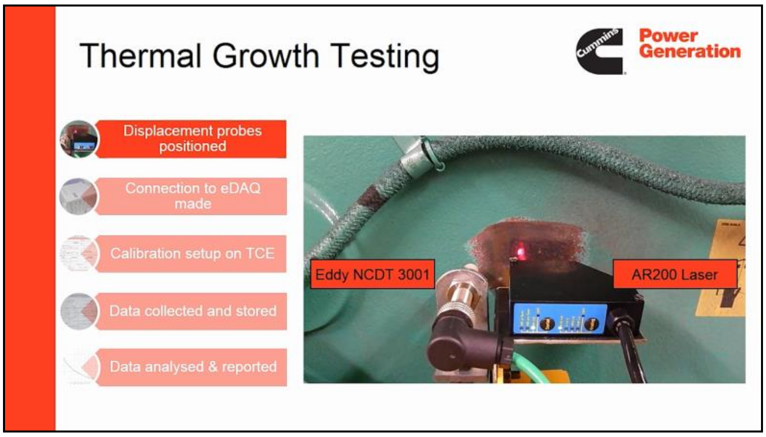


Figure 89. Knowledge Contribution - Eddy Current Example 3

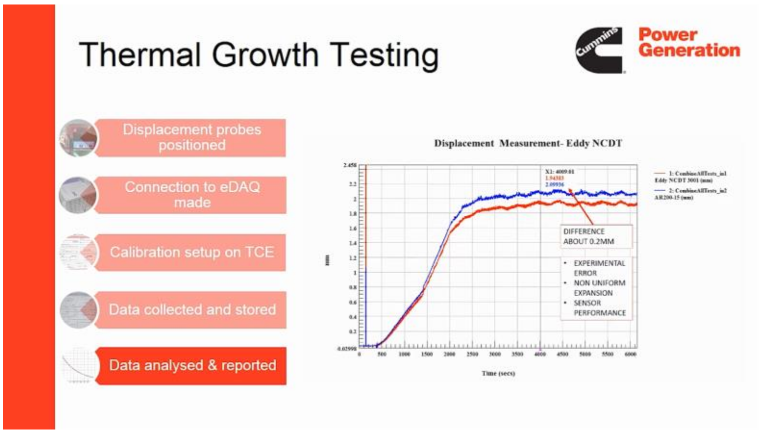


Figure 90. Knowledge Contribution - Eddy Current Example 4

Once the knowledge contribution has been created, it needs to be submitted to the administrator for a content check and quality approval, by uploading the video file on to the knowledge sharing platform shown in Figure 91.

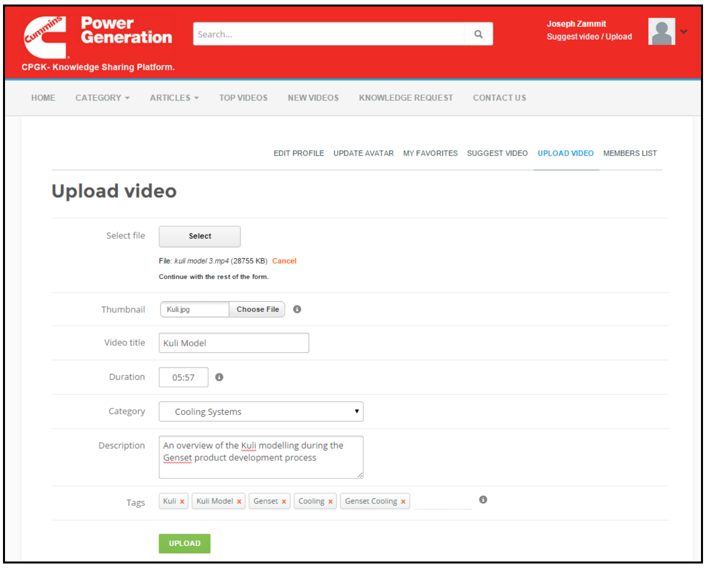


Figure 91. CPGK - Knowledge Sharing Platform Content Upload

6.6 Step 5: Knowledge Contribution Approval and Uploading

Once a knowledge contribution has been created, the administrator will receive a notification and a link of the submitted knowledge contribution which he will need to check and approve. At this point, the administrator is required to log into the knowledge repository and access the administration backend of the knowledge repository, as shown in Figure 92.

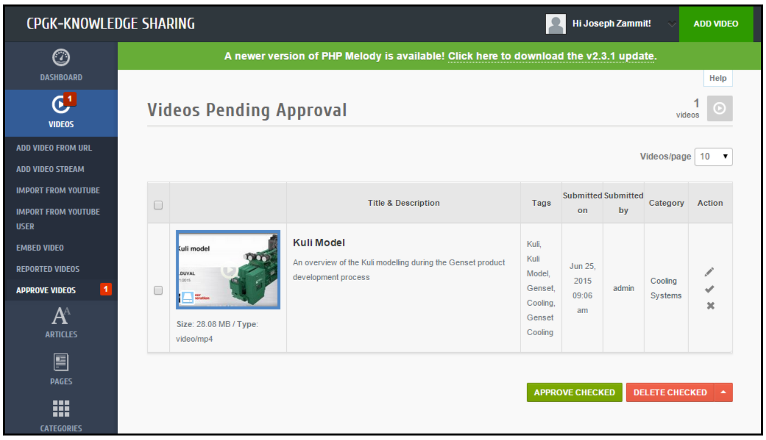


Figure 92. CPGK - Knowledge Sharing Platform Admin View

At this point, the administrator needs to check the quality and content of the contribution and edit any information pertaining to the knowledge contribution, such as title, description or tagging, as shown in Figure 93. If the administrator is not competent on the subject matter, they might ask for assistance from either the knowledge contributor or other experts in the company to check that all technicalities are correct and meet engineering standards.

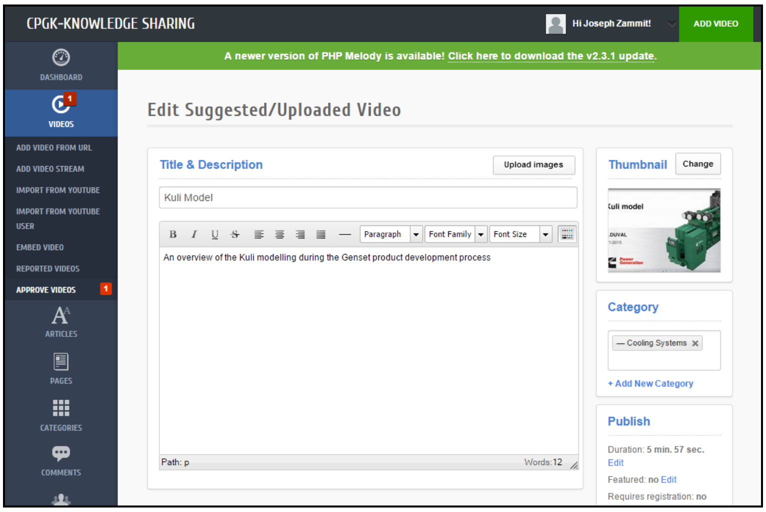


Figure 93. CPGK - Knowledge Sharing Admin Content Editing Window

Once all the quality and content checks are completed the administrator either approves or rejects the knowledge contribution. If it is approved the knowledge contribution will be instantly activated in the knowledge repository and accessible by other users. The administrator will also inform the originator that the knowledge contribution he requested is available on the Knowledge sharing Platform.

6.7 Step 6: Evaluate Newly Captured Knowledge Content and Use it

Once the knowledge contribution is approved the originator is informed that his knowledge request has been captured. If the knowledge did not fulfil the originators requirements or he requires clarifications on specific point he has the opportunity to discuss this with the knowledge contributor and or administrator using the social media tools provided. The primary purpose of this creation of this knowledge request was to provide an overview of the eddy current sensor, show the setup required to setup an eddy current sensor, conduct a comparative study between the eddy current sensor and the measuring laser and finally provide a comparison report of the two measuring equipment. With all of this information and knowledge about the eddy current sensor in a compacted 5 mint video presentation the originator can provide a link to the chief Engineer or managers both local or abroad to see for them self's the tests carried out and the comparative study with the financial benefits this change will bring with it.

Once such a change is approved and adopted by this testing facility this knowledge can also be used to train other testing technicians the theory behind the eddy current sensor and also how it is setup and used on the products being tested. This can also be used to demonstrate other sites within the company the benefits and the setup of such equipment. The additional benefit being that situations like these where new process and improved methods are being developed that can be show cased for others to also consider and adopt in there testing environment.

6.8 Summary

In this Chapter a typical example in the form of a user case of the developed knowledge sharing framework has been presented, explaining the actions of the various actors in parallel with an explanation of the functionality of the developed tools. The example chosen for this user case, was the knowledge capture of an Eddy Current sensor that was actually conducted during the proof of concept.

This user case provides a real scenario which used the developed framework to capture newly acquired knowledge in the company and uses that knowledge to educate and convince people of the benefits of introducing these new eddy current sensors. The tool aided the originator to address a real engineering issue that the PD testing was trying to improve upon. The successful capture and subsequent knowledge sharing activities demonstrate the usefulness of the developed framework.

In the next Chapter, the validation of the developed framework is presented. Providing first a description of the methodology used, followed with the feedback of the users.

Chapter 7: Validation of the Developed Framework

In this Chapter, the methodology and developed framework will be evaluated with the knowledge users at the collaborating company.

Firstly, the developed knowledge capturing methodology will be evaluated and validated with a number of knowledge contributors by capturing and creating knowledge contributions. These are then evaluated by knowledge receivers for content and transfer of knowledge. This is followed by a live workshop to evaluate actual knowledge transfer effectiveness, by users performing tasks from the captured knowledge contributions. Finally, the benefits and achievements of the developed methodology will be acknowledged.

7.1 Introduction to Validation Process

The validation process of the knowledge sharing tool was necessary to confirm: 1) the developed framework was relevant to the collaborating company requirements, identified at the outset of this project, and 2) to assess the capabilities of the developed knowledge sharing tool by going through the process either as a contributor or receiver of knowledge. This was achieved by conducting a validation exercise undertaken by carefully selected employees from the collaborating company. The participant selection criteria varied from different age groups ranging from 20+ to 40+, and different levels of education ranging from Technicians to Engineers and Managers, in order to obtain a balanced user experience, representing the complete workforce from the collaborating company.

The validation process consisted of two groups of participants, that of knowledge contributors and knowledge receivers, while the researcher acted as the knowledge sharing tool administrator/moderator. The knowledge contributors group consisted of 6 employees while the knowledge receivers group consisted of 10 employees, all selected according to the set criteria. The knowledge contributors consisted of 3 engineers and 3 testing technicians, while knowledge receivers consisted of 3 managers, 6 engineers and 6 testing technicians. User feedback on the validated prototype was gathered using a one on one workshop followed by a survey. The sample size for the validation process was relatively small (16) and, therefore, the results may only be considered indicative, but the feedback obtain suggested a promising and affective knowledge sharing tool with strong user acceptance and usability, with also the intention from the collaborating company to carry on developing the existing research.

A summary of the feedback and relevant comments from the participants are contained within this Chapter. It is noted that an additional trial period is required in order to increase the amount of knowledge contributions captured within the system and include a larger group of people capturing and receiving knowledge; this was identified as a future action for the collaborating company.

7.2 Design and Execution of the Validation Exercise

The aim of the validation exercise was to establish if the developed knowledge sharing framework, methodology and prototype knowledge sharing tool, fulfils the collaborating company's need to capture, disseminate and transfer knowledge efficiently and effectively throughout the organisation using rich media and social media tools. This validation study should provide an indication of the framework's adaptability to a wider audience and, therefore, show that it is not limited to the collaborating company's usage.

In order to validate the developed system, the validation process has been designed into four steps:

- Creating a number of knowledge contributions;
- Workshop organised with knowledge contributors to capture end-user feedback;
- Workshop organised with knowledge receivers to capture end-user feedback; and
- Live workshop with knowledge receivers to assess knowledge transfer.

The steps shown above are logically organised in the way they have been executed. In order to attempt a knowledge transfer exercise, there must initially be a knowledge capturing exercise in order to populate the knowledge sharing repository. In the following sections, the design of the validation process will be explained in more detail.

7.2.1 Validation Design – Knowledge Contribution

The primary function of a knowledge contribution is to capture and document employee knowledge into an electronic format in order for it to be shared amongst other employees within the company. In order to validate the developed methodology, a knowledge contribution exercise was designed. This knowledge contribution exercise assessed the developed training material, the knowledge request form process, the knowledge contribution plan and content approval, the capture and compiling of a knowledge contribution, and finally the content and quality approval of the knowledge contribution content.

The first step in the validation process was to select a number of knowledge contribution example topics and the corresponding knowledge experts that were qualified in the subject area to capture and create the knowledge contribution. Once the six participants were identified, a formal meeting was scheduled to inform the participants and provide them with instructions and documentation to start the knowledge capture exercise. Once the knowledge contributors followed the training material provided, they were asked to complete the knowledge request form, which is covered in Chapter 5 and 6. In the knowledge request form, the knowledge contributors were asked to explain how they were going to capture the knowledge contribution, as in content and timeline, and submit this document for approval. Once approved, they carried out their plan by capturing and compiling the knowledge contribution. Once completed, the knowledge contribution was submitted for approval. The primary deliverables of this exercise were:

- Six knowledge contribution videos uploaded into the knowledge sharing tool;
- Six knowledge contributions of substance that provided correct knowledge content and quality;
- Six knowledge contribution videos created by the user unaided and with minimal supervision; and
- Successful knowledge transfer through the use of the developed training material.

In sections 7.3.1 and 7.3.4, the results set out from this validation exercise are discussed.

7.2.2 Validation Design – W/Shop Knowledge Contribution User

Once knowledge contributions had been created, an in depth workshop with the knowledge contributors was carried out in order to gather user feedback of the knowledge capture process. This was conducted as one-on-one sessions with each knowledge contributor. In order to obtain a comparable response between the users, a questionnaire was devised. The questionnaire provided the ideal tool to obtain feedback from the multiple users in the same context and setting. The questions used for the questionnaire asked for feedback against a rating, based on the different steps the user took in order to create a knowledge contribution. Two examples of the questions used in this questionnaire are:

Was the quantity of training material enough, to complete your knowledge contribution?

Needs	**1**	**2**	**3**	**4**	**5**	**There is**
More	❑	❑	❑	❑	❑	**Enough**

and…

With your current experience of digital cameras (limited or extensive) how difficult did you find capturing video images for your knowledge contribution?

Very	**1**	**2**	**3**	**4**	**5**	**Very**
Difficult	❑	❑	❑	❑	❑	**Easy**

The complete questionnaire used during the workshop can be found in the Appendix H. In section 7.3.2, the feedback received from this workshop is presented and analysed.

7.2.3 Validation Design – W/Shop Knowledge Receiver User

A similar workshop, as discussed above, was organised for knowledge receivers, in order to gather user feedback of the knowledge receiving process. Similar to the previous workshop, this was conducted as one-on-one sessions with ten participants. In order to obtain comparable responses between the users, a similar questionnaire was devised providing similar conditions as explained in the knowledge contributors' user workshop; the only difference being that participants of this workshop, before being given the questionnaire, were provided with access to the knowledge sharing tool to use the system and view the training material and two knowledge contributions created by their colleagues in order to evaluate the knowledge repository and evaluate the content and quality of the knowledge material created. Two examples of the questions used in this questionnaire are:

Did you find the information from the knowledge contribution informative and did you learn something out of it?

Very	**1**	**2**	**3**	**4**	**5**	**Very**
Difficult	❑	❑	❑	❑	❑	**Easy**

and…

Would you consider contributing to the system?

Un-	**1**	**2**	**3**	**4**	**5**	**Very**
Likely	❑	❑	❑	❑	❑	**Likely**

The complete questionnaire used during the workshop can be found in Appendix J. In section 7.3.3 the feedback received from this workshop is presented and analysed.

7.2.4 Validation Design – Live W/Shop Assess Knowledge Transfer

The assessment of knowledge transfer has been achieved by asking participants to view the captured knowledge material and asking them to perform a task that they were shown in the knowledge contribution unaided by experts in the subject area. This evaluation process was carried out at two different stages of the project, 1) during the knowledge capture portion of the project, and 2) during the final proof of concept workshop evaluation.

The first knowledge transfer evaluation was conducted during the knowledge capture exercise. Knowledge contributors were asked to view the training material provided to instruct them in how to use the knowledge sharing tool and how to create a knowledge contribution, and how to use the video editing software to compile a knowledge contribution. The success of the knowledge transfer during the process was in the form of the participants creating knowledge contributions unaided with minimal supervision. This situation would mean that the content quality and knowledge format enable adequate knowledge transfer for them to create knowledge contributions.

The second knowledge transfer evaluation was conducted by selecting volunteers to view a knowledge contribution created by one of their colleagues and perform the task shown in the knowledge contribution successfully unaided. Successful task replication would indicate effectiveness of the tool. The volunteers in both evaluation processes were interviewed for their feedback of the process. In section 7.3.4, the feedback received from the knowledge transfer evaluation is presented and analysed.

7.3 Survey Results and Analysis

In this section, the results from the four stages of the validation process are presented and analysed in detail from the feedback received from the end-users.

7.3.1 Knowledge Contribution

The first step in creating a knowledge contribution was to identify appropriate knowledge subjects that would provide value to the collaborating company, and also to identify participants who were considered to be experts in their subject areas and could contribute whilst also taking into consideration the participants selection criteria, that of different age groups ranging from 20+ to 40+, and different levels of education ranging from Technicians to Engineers and Managers, in order to obtain a balanced user experience, representing the complete workforce from the collaborating company. The research conducted, in collaboration with the testing facility manager and coach, came up with the following list:

- Overview of the Precision Power Analyser (PPA) data logger,

- Genset testing cooling system – rigging and derigging,
- Genset testing fuel measurement system,
- Application of stain gauges to testing Genset,
- Setting up a European Conformity (CE) noise measurement test,
- Transient performance raw data report generation
- Overview of Kuli (Thermal cooling simulation software) modelling tool, and
- Overview of the eddy current sensor and how it is applied to a Genset.

The selected participants to capture the above knowledge contributions varied from technician, to fresh engineering graduates to experienced engineers, providing a good representation of the workforce, both in terms of the level of education and age groups. From the eight original knowledge contributions set out to be captured, six were completed with one being scraped due to the knowledge being captured being obsolete and the last one being that the participant failed to complete a knowledge contribution. Therefore, out of seven viable knowledge contributions, six were completed, giving an 86% completion rate.

While the originally optimistic planned duration to complete the knowledge capturing exercise by all the participants was to take three months, this process ended up taking longer than this, in fact almost 6 months in time. This delay was attributed to several issues that were beyond the control of the researcher and, therefore, had to be absorbed in the timing plan. The main reasons for the delay was the lack of availability of staff, equipment, facilities and company commitment towards supporting the business.

However, while the process took longer than originally expected, all knowledge contributors found the process refreshing and interesting, providing a different perspective to their job function, that of planning, capturing and compiling the information into a complete knowledge contribution. It was noted that while all participants in the study had used to a varying degree social media and digital equipment, those who were more familiar and confident found the task easier and were more enthusiastic about using the technology to capture knowledge. Others, both young and older, who were less familiar and confident in the use of digital equipment, software and social media found the task slightly more difficult not because the training material was not clear enough or because they lacked the skills to complete the task, but because of lack of confidence and uncertainty as they questioned their ability to complete the task.

From the progress meeting carried out with participants during the knowledge capture phase, it was noted that young engineers were more open to sharing their knowledge and not worried about getting it wrong or being criticized on the content that they have created. This could result from their recent university experience where, in general practice, engineering students are encouraged to work and solve problems together on group projects where consequences of mistakes are more forgiving than they are in industry. On the other hand, the older generation and the young technicians that did not have university experience, were more apprehensive about the knowledge content they created.

An additional observation noted during this stage was the issue of language or for people that English is there second language. In engineering, the English language is generally used worldwide as the common communication language, even for non-English speaking countries. The effect of having knowledge contributions created by non-native English speakers was also explored during the knowledge capture phase. This was carried out by selecting one of the knowledge contributors that was not a native English speaking person. Fortunately, the participant selected, had a strong accent that required a user's full attention when talking to them in order to understand them, but because the knowledge content created did not rely solely on the person explaining the knowledge, they tried to convey the knowledge, but also show it; the effects of non-native English speaking personnel and strong foreign accents did not show any indication that this represented an issue towards the knowledge capturing methodology.

The critical issue that persisted throughout the knowledge capturing process and which resulted in extending this phase longer than originally anticipated, was the lack of availability of staff, equipment, facilities and company commitment towards supporting the business. This is an understandable issue if literature is consulted relating to knowledge management failures. Over and over again, lack of time and effort are highlighted as critical failure points for any knowledge management system.

7.3.2 Workshop Knowledge Contribution User Response

During this workshop, the six knowledge contributors were asked to rate, against a 5-point Likert scale, several items within the knowledge capture process, in order to evaluate the developed knowledge capturing process. The first question queried if the quantity of the training material was enough to complete a knowledge contribution. The majority of participants felt that there was enough training material to complete the knowledge contribution with 17 % giving a rating of 4, while 83% gave a rating of 5 that there was enough material as shown in Appendix I: Figure 121.

When asked the difficulty to complete the knowledge contribution form, again the majority of the knowledge contribution participants stated that the process was simple and straight forward.

When asked about the difficulty to collect information and plan for the knowledge contribution, in order to complete the knowledge request form, 50 % of participants replied with a difficulty rating of 2, with the remaining 50% providing a rating ranging from 4 to 5, describing the process as easy as shown in Appendix I: Figure 123.

When participants were asked to elaborate on why they rated the process so low, the reason behind this was that they felt that they did not have enough time dedicated to work on the knowledge capturing task during their normal working week. This made the task difficult to complete in the specified timeframe. This also resulted in the extension of two months, mentioned in the previous section. The same situation was experienced by the participants when preparing for the knowledge contribution, involving the collection of information, writing up and planning for the knowledge capture. 67% of participants gave a 3 rating, while 33% of participant gave a 5 rating of very easy, as shown in Appendix I: Figure 124. This again resulted in not having the right equipment or facilities available when required and each time the participant had to postpone and reschedule the task at hand, which created delays in the process and prolonged the task.

One hypothesis of this project was that the extensive use of social media and smartphones in participant's daily lives would mean that that they have enough skills to use social media tools. When participants were asked how difficult they found capturing video content for their knowledge contribution, all rated the process as very easy, with 33% giving a rating of 4 and 67% giving a rating of 5 shown in Appendix I: Figure 127. These results and the quality of video captured from the knowledge contributors provide a good indication that this assumption has some weight, and provides some confidence to the statement.

With regard to the compilation and editing of the knowledge contribution using the provided video editing software, the participants found that the training material and the usability of the software greatly simplified this process and did not find any problems. The majority of participants gave a rating of 4 and 5, stating that the process was easy, as can be seen in Appendix I: Figure 128.

When asked about the difficulty of the knowledge contribution process, the majority of participants (83%) gave a rating of 4, which is considered easy, as shown in Appendix I: Figure 129.

When asked for additional comments / feedback towards their knowledge contribution experience, the main issue that was highlighted again was the dedicated time allocation to work on the knowledge contribution, emphasizing the need to have access to the right Genset equipment required for the knowledge contribution and that time should be set aside for capturing material content and editing the knowledge contribution. In general, the feedback from participants was positive and that knowledge contributions would be a useful tool for knowledge dissemination. Further Questions which are common to Knowledge contributors and knowledge receivers will be covered in the next section.

7.3.3 W/Shop Knowledge Receiver User Response

A further workshop was organised amongst the six knowledge contributors and ten knowledge receivers whom were asked to rate, using a 5-point Likert scale, several items within the knowledge sharing process in order to evaluate the developed knowledge sharing process. The first question queried the user's difficulty in navigating the knowledge sharing repository. The users rated this functionality as easy and found it user-friendly, with 31% giving a rating of 4, while 69% giving a rating of 5, as shown in Appendix K: Figure 133. The initial idea of using every day social media tools in order to create an environment which the users can associate with and be confident enough to navigate through the information, was very important in order to guarantee user acceptance.

When asked about the knowledge transfer process, which was covered in the training material, and whether this material was easy to follow and aided them to complete the task being shown, the majority stated that the material was easy to follow, with 63% giving a rating of 4 and 38 % providing a rating of 5.

When asked about the quality of the training material provided, all participants rated the material of good quality with 38% providing a rating of 4 and 63% providing a rating of 5, as shown in Appendix K: Figure 136. This approval rating by the users provides a good indication of training material content and quality.

After being shown two knowledge contributions created by their colleagues, the knowledge receivers were asked if they found the information informative and if they had learned something from it. The majority found the knowledge contributions very informative, as shown Appendix K: Figure 138, with 38% rating the experience as 4 and 63% rating it as 5. This question brought up a lot of comments on the benefits of having this type of knowledge readily available video format for viewing and quick knowledge absorption.

One new employee who had recently joined the company commented that, if when he joined the company during the induction process he had the opportunity to quickly view the different job functions and processes, the shadowing period with experienced employees would have been more fruitful because he would have already been provided with an introduction to the subject area before the actual shadowing sessions and, therefore, he could have prepared questions that the experienced employees could have answered, resulting in a more effective shadowing session.

The length of the knowledge contribution video was also discussed during this workshop. Users expressed differing points of view, as was originally stated during the KM framework end user questionnaire which was discussed in section 4.6.2. During the investigation, users had split opinion, between short video presentations of 5 – 10 minutes and medium length videos lasting between 15 – 25 minutes. Now that the users had been shown a knowledge contribution, the majority preferred to view shorter video presentation lasting between 5-10 minutes. The reasons given were that shorter presentation would increase the likelihood of people using the knowledge system and that users would possibly lose interest if longer videos were used.

With regard to the quality of knowledge contributions created by colleagues, they also rated this as of good quality, with 50% giving a 4 rating and 50% providing a 5 rating. This provides a good indication that the quality of the knowledge captured was good. Some did comment on the consistency of the sound quality which in some knowledge contributions created a drop in volume during some sections and sometimes back ground noise was audible. This has been attributed to selecting the wrong work space by the knowledge contributors when creating the knowledge contributions.

As part of the recommendations, a quiet meeting room should be used for when the voice over process is being prepared for the knowledge contribution, in order to improve this shortfall. This highlights the need to have dedicated time set aside for these assignments, because when asked why they didn't use a quiet meeting room in the first place, as it was a recommendation given by the researcher, the knowledge contributors stated that they preferred staying close to their desk in case they needed to attend to their daily job function.

When participants were asked what improvements the knowledge contributions created and shared with them, most stated that the knowledge captured was of good quality and that there wasn't much to improve, but wanted to give the system time in order to grow in the number of knowledge contributions captured and stored on the system. An important issue related to the consistency being kept throughout. Some highlighted the benefit of the user rating system which is available in the system. The fact that they can judge and rate the quality and content of any knowledge contribution on the system made them feel included in the decision and quality control process. Another point mentioned by one of the participants was the lack of labelling of equipment within the company. This point was highlighted during a knowledge contribution demonstration where one of the users pointed out from the video he was watching as an improvement measure not for the system but for the company as a whole. This highlighted issue unintentionally achieved one of the deliverables of the project. One of the reasons for using rich media was, apart from capturing knowledge so that it could be shared with others, was that it also created a wider audience to questions and challenged existing procedures and, at the same time, provided another perspective to existing processes.

When asked whether they saw value in such a system, all agreed that the created KM system would be of benefit to them and the company. When participants were asked if they would contribute towards knowledge discussions using the blog / comments section attached to each knowledge contribution, they all stated that they would and that they saw great benefit in being able to receive comments from the originator of the knowledge contribution, as can be seen in Appendix K: Figure 141, where 19% gave a rating of 4 while 81 % gave a rating of 5, meaning that they are very likely that they will contribute.

A positive response was received when asked if participants would use such a system to search for knowledge, with 38% giving a rating of 4 and 63% giving a rating of 5 which are both ratings as ‘highly likely’ that they will use such a system, as shown in Appendix K: Figure 142. When asked whether they would be consider contributing a knowledge contribution, the majority stated that they would, with only one person providing a rating of 3 which is the halfway mark in the Likert scale. Their related to the fact that they did not believe that time would be dedicated for such a task and, therefore, would need to do this task in their own time instead of during normal working hours.

The likelihood in users contributing was also explored during the KM framework end user questionnaire in section 4.6.3. Users were asked if they would be willing to share their knowledge with others, after they were shown the developed framework and tools the response from the users improved. While, in the same questionnaire, the users were asked if they would need some form of incentive in order to contribute towards such a system; over 75% stated that they would not require any form of incentive, but it is still the authors opinion that some form of incentive should be put in place to reward knowledge contributors in one form or another. This should be in such a way that both the employee and the company could mutually benefit. Incentives could be implemented that take into consideration user contributions and reward them with recognition or career advancement.

One critical concept of the system was to create an environment where the knowledge user determines the knowledge direction the system should take in order to reduce the administration burden and also target the required knowledge to be captured because the knowledge user is asking for it. Therefore, participants were asked to propose a topic that they were interested in learning about and would like to see captured. The following list was provided; vibration data post processing, overview and explanation of all R&T tests, how to access WI's and report forms on the system, how to use Ariba, overview of CAD drawing techniques, how to use PLM, R&T test request procedure, VPI & VPC processes, overview of product design process all the way to product validation, all LabOps / Applied Tech testing, and LabOps and business unit's knowledge transfer.

7.3.4 Live Workshop to Assess Knowledge Transfer User Response

As explained in the case study design live workshop section, the assessment was divided into two different stages: 1) during the knowledge capture portion of the project, and 2) during the final proof of concept workshop evaluation process.

The first group that got assessed were the knowledge contributors that needed to follow the training material in order for them to understand what a knowledge contribution entailed and how to actually create it. The primary success indicator for successful knowledge transfer would be the successful completion of a knowledge contribution unaided, which can be considered achieved. The only help participants required was minor hints and tips and encouragement to complete their task. The second indicator related to the quality and the medium that the knowledge was obtained from; the feedback received from the users in the previously discussed workshops, from which positive feedback resulted.

The second group assessment was during the final proof of concept stage, where a live workshop experiment was organised with volunteers, who viewed a knowledge contribution created by one of their colleagues and, from which, they needed to replicate the task shown without any help or guidance from others. This exercise was carried out in a normal working environment in order to simulate a typical working day with phones ringing and people coming in and out of the work space, interrupting the volunteers. In all cases, the task was replicated correctly even though at different durations. The difference in duration to replicate the task is directly contributed to the interruptions and also to the different level of knowledge retention of the volunteers. It was noted that some volunteers had to repeat portions of the replication, either because they were not paying enough attention or the subject was harder for them to understand. However, by having the functionality to stop, think and continue, or stop, rewind and start over again, gave them the independence and autonomy to absorb the knowledge at their own pace and complete the task.

A further improvement that was suggested during the workshop, was that users could use headphones when viewing a knowledge contribution. The noisy work space and people coming and going, did create a challenging environment for volunteers to really pay attention during the viewing of the knowledge contribution.

7.4 Evaluation of the Developed Knowledge Sharing Framework

In general, the majority of users responded positively to the use of the developed knowledge repository and the knowledge contributions created using the developed methodology. The same positive feedback came from the participants that captured and created the knowledge contributions. All participants saw benefit to them and the company in contributing to and receiving knowledge from such a KM system.

Looking back at the deliverables of this research project, it can be considered a success from the positive feedback and the intention of the collaborating company to further invest and pursue this research project by implementing it to a larger audience. The first deliverable was a novel knowledge sharing framework, which enables the capture and sharing of employee knowledge, with complexity of knowledge varying from simple explicit knowledge to more complex tacit knowledge content within the PD department of the organisation with primary focus to PD testing, identifying the different critical components required for knowledge transfer;

The evaluation process has shown that the methodology was effective in producing the knowledge contribution set out to be captured and analysis has showed that knowledge transfer has occurred and the end user has accepted both the knowledge capture and sharing process. The second deliverable was to development of a prototype knowledge sharing tool using social media, Web 2.0, storytelling and video sharing technologies, to support and enable knowledge transfer, and collaboration for global PD within an organisation for complex engineering knowledge, providing a contribution to both industrial and academic knowledge and learning;

This can also be considered successful, with the system running live from which the user's' successfully followed the developed training material in order for them to create their knowledge contributions and the carried out workshops with knowledge receivers being able to demonstrate its usability. The third deliverable was a novel concept of empowering actual knowledge experts at all levels to contribute and share their experience and knowledge in a complex engineering environment by using main stream social media tools like video sharing and storytelling as a medium to capture and share their knowledge contribution;

User feedback relating to willingness to search for knowledge in such a system and to contribute towards the system with either knowledge contributions, knowledge direction or through knowledge discussion, has shown the future potential of such an innovative tool to capture employee knowledge that provides users with a level to control the direction and quality of knowledge being stored. The last deliverable was a series of guidelines to enable organisations to make best use of this knowledge sharing tool, aiding collaboration and knowledge sharing practices, using video sharing and storytelling technologies to represent the tacit knowledge which is a major challenge in the PD testing application for knowledge capture and transfer.

This deliverable has been extensively explained in the description of the methodology applied, the user case example, the end-user guide attached in Appendix Q and in the developed training material stored on the knowledge sharing tool, therefore this deliverable can be considered as completed.

The majority of the feedback received during the evaluation process was positive, but also highlighted some improvement points which have already been implemented and described in this thesis. The commitment from participants also helped the project being completed successfully without any major issues or significant difficulties. The culture of the collaborating company helped teamwork and also contributed to the success of this project.

7.5 Summary

In this Chapter, the design and analysis of the validation exercise for the developed framework and knowledge sharing tool have been described and discussed in detail. The novelty of the developed knowledge sharing tool in the application area of PD testing to capture and share complex engineering knowledge has been validated by the users and the collaborating company with their intention to continue working on the developed framework. This achievement is a contribution towards knowledge.

The analysis of the knowledge captured content by the users has shown that that storytelling and video sharing technologies can be used to provide a rich and informative knowledge content medium that enables knowledge sharing and transfer. The validation of actual knowledge transfer from the conducted live workshops 1) during the knowledge capture portion of the project, and 2) during the final proof of concept workshop evaluation process has confirm this. The developed methodology provides a tool to capture and manage tacit knowledge this can also be considered as a contribution towards knowledge.

The use of social media and Web 2.0 tools to collaborate and discuss complex engineering knowledge meets the requirements of the social aspects of communication and knowledge management to offer further explanation to the already captured knowledge or to build and create new knowledge from existing within the knowledge sharing tool.

The feedback given demonstrates that the functionality and usability of the developed system can be further developed and expanded for a larger audience to further confirm the system capabilities and functionality, of the developed methodology. All the benefits and advantages of the proposed methodology have been described and discussed in this Chapter.

Chapter 8: Conclusions and Future Work

8.1 Conclusions

The intention of this research project was to answer the research question of whether social media and video sharing tools were capable of facilitating the capturing and sharing of employee knowledge during the PD testing cycle. Based on this was the development of a knowledge capture and sharing framework that is directly driven by the knowledge user providing both knowledge direction and content. An OEM company was used as a case study to develop and test this methodology, which can also be applied to other design or manufacturing companies and general business.

The novelty of this research lies in the developed methodologies for capture and sharing and testing of related knowledge to address the special nature and application context of the integrated PD and testing operations. Also in the use of social media, video sharing and storytelling technologies to capture complex engineering knowledge by the knowledge experts themselves, rather than by media professionals whom are paid to develop content. This should guarantee more informed knowledge content and a reduction in costs to develop the knowledge content in a rich media format. Another topic explored in this research was the possibility of giving administrative control of knowledge direction and content to the knowledge user as the main driver of the knowledge management system.

From the literature review, there is a lack of research in the area of capturing and managing testing related knowledge and tools and methods to support the improvement of testing operations. There is significant previous research in knowledge management for product design, manufacturing and management, whilst very little reported work in improving the testing efficiency as an integrated process of global product development. It was also highlighted that knowledge content, through the use of video sharing, has widely been used in University classrooms to supplement or replace traditional knowledge transfer from lectures, however it was identified that there are no formal methodologies for the knowledge experts to capture and prepare this knowledge content in a rich media format. It was also highlighted that both the process of capturing and sharing knowledge, through the medium of social media tools, like video sharing, has not been abundantly investigated in an industrial setting even though there is extensive literature showing the benefit of knowledge transfer through video sharing techniques.

The industrial investigation identified five possible project directions that could offer improvement to overall operational, collaboration and knowledge sharing practices within the PD testing facility at the collaborating company. The selected direction of the project was to improve knowledge management practices in product testing, with a strong necessity for a new innovative methodology to capture and share organisational and employee knowledge in a user friendly, quick, concise and globally accessible manner. Knowledge users should be able to use the developed methodology and tool easily, revisiting it on a regular basis to explore newly uploaded content and contribute to the knowledge database. This research direction was presented to the collaborating company management which they approved. The identification of the industrial requirements from the PD testing facility is one of the set deliverable of this project. Since the literature review has not reported any in-depth investigation to bring out real industrial requirements in the PD testing context this can also be considered as a contribution towards knowledge.

The developed framework provides a theoretical method for users to capture, document and share knowledge that they have acquired during their years of service at the collaborating company. The developed methodology is founded on the principles of social media, video sharing and storytelling techniques as a way to enhance and extend the capabilities of knowledge management tools. By using commonly used social media tools that employees use in their everyday lives, the developed tool’s acceptance by the case study participants has been of success. The main advantage of the developed methodology is that it improves accessibility of knowledge, whilst existing text-based knowledge management systems are considered heavy, laborious, dull and sometimes ignored.

The proposed methodology consists of a knowledge capture and sharing framework, providing the theoretical underpinning of the system, process, procedures and templates to aid knowledge capture. A knowledge repository has been developed so that users can search, remix and transfer knowledge and training materials, providing a guide in how to capture knowledge. The conducted case study and validation exercise at the OEM company verified that the developed methodology, tools and guidelines have shown that such a system can be used and is of benefit to employees and the company, an example of the use of the framework has also been explained in detail in Chapter 6 which provides a typical example of a use case conducted during the proof of concept. The developed knowledge management tool can be used to capture employee knowledge, and to reduce the loss of knowledge when people move ahead in their career either within the company or elsewhere. It reduces the need for expert people to waste time explaining specific tasks over and over again to different people in the company. Also reducing the use of valuable human resources for new employee training, improves the awareness of employees of other job functions around them and creates employee independence to obtain knowledge transfer.

The results of the case study and validation exercise have confirmed that the proposed methodology has the capacity to develop a comprehensive KM system to manage both knowledge and procedures, based on business and user requirements. Making both the developed framework and methodology, in fulfilment of the industrial requirements, and therefore a contribution to knowledge.

In Summary, the main achievements and contributions to knowledge of this research project are:

- An in-depth comprehensive industrial investigation highlighting the challenging problems and required improvements to the business operations in product development testing at an OEM PD testing facility;

- Design and testing of a novel knowledge sharing framework, which enables the capture and sharing of employee knowledge, with complexity of knowledge varying from simple explicit knowledge to more complex tacit knowledge content within the PD department of the organisation. The primary focus for this framework is on PD testing, identifying the different critical components required for knowledge using ICT technologies such as social media, video sharing and storytelling;

- A series of guidelines to enable organisations to make best use of this knowledge sharing tool, aiding collaboration and knowledge sharing practices, using video sharing and storytelling technologies to represent the tacit knowledge which is a major challenge in the PD testing application for knowledge capture and transfer; and

- Training material for end-users, both in text format and rich media format, using the develop methodology to guide users in the use of the developed system.

8.2 Further Work

During this research project, there were several areas of interest that were identified during the execution of project and the industrial investigation, especially due to the wide scope of the initial investigation that was carried out. Some of these areas of interest were not pursued due to not contributing to the company-recognised aim and objectives set out by the researcher and the supervision team. Most of the issues highlighted during the industrial investigation have been explored by the company and translated into 6-sigma projects executed by the company; these issues were highlighted and discussed in Chapter 4. During this research project, it has been recognised that future work needs to be carried out in a number of areas, which will now be discussed.

This project has been conducted in collaboration with an OEM organisation operating in the power generation industry, with the main sponsor championing the project, being the product development testing facility, and the main focus being on engineering. While an extensive case study has been conducted with different participants at different levels of the company hierarchy, a wider study should be conducted in other areas of the business, such as sales, customer services and operations; this would provide the possibility to continue to verify the flexibility and simplicity of the developed tool and also provide greater awareness across the whole company and provide an easy and accessible portal to cross train the different functions.

In Chapter 4, a utilization metrics system was developed during the industrial investigation to measure time wastage during the product development testing process. At the time, this tool aided in identifying and ranking the main time wastage factors in the testing process, and since it has been in place, has also managed to measure utilization improvements in the testing process from implemented enhancements. This tool could be used to measure whether the developed knowledge management system could improve the testing facility utilization by improving knowledge transfer and employee awareness of other job functions and knowledge.

Although the collaborating company is based in the UK it forms part of a global enterprise with many sites. While staff at a number of sites within the company have been consulted, interviewed and visited during the investigation, they did not participate in the verification and evaluation of the developed methodology. This was omitted for a number of reasons, including time constraints, resources and cost implications. However, the evaluation process still applies for these sites due to the same nature and environment of the business. In order to overcome this, a shortened case study should be setup at a different site in order to further confirm the same results and benefits achieved in this case study, which seems to be the intention of the collaborating company.

Even though the research was in collaboration with a specific industrial partner, the developed methodology has been developed with general use in mind, so that it can be applied across different business units within the enterprise and can be applied to industry in general. This can be considered as a short coming, by not generalizing the validation of the framework across different industries but, due to confidentiality agreements, this was not possible. Further research could be conducted to explore other industrial setups to validate the envisaged usage of the methodology.

The developed tool to manage knowledge requests, The Knowledge Repository, searches for knowledge discussions and was created for the sole purpose of the proof of concept using open source software that was modified and adapted for the required use. While the developed software served its purpose to a great extent, a more purpose built software package is required to move this project forward, and address all the system shortcomings listed in Chapter 5, which were overcome by having manual tasks put in place.

In Chapter 7 the effect of having knowledge contributions created by non-native English speakers was also briefly explored during the knowledge capture phase. As an objective of the tool is that it be used by multiple people spread out in a global enterprise the effectiveness of knowledge contributions created by non-native English speakers should also be further validated to confirm the initial findings.

All of the points listed above are possibilities for future integration in to the knowledge capture and sharing tool. Unfortunately, for the purpose of this PhD project, further development lies outside of the current scope.

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Appendix A: Critical Analysis of Relevant Literature

The aim of this critical review is to identify latest work related to the project area. This review is divide into two sections, first exploring where and who is carrying out this research in the subject area, then a number of papers that have been highly cited are examined and a brief explanation of their achievements and shortcomings is given. Which provides us with the opportunity to identify the gaps that exist within the literature.

Literature Search Method

Elsevier's academic database, Scopus, was used to identify research papers related to the subject area of Knowledge Management, by using several keywords listed below. The papers identified by the Scopus, where also cross-referenced with other databases provided by the university to confirm their validity. The selected keywords were searched using different combinations of Boolean search queries in order to identify and eliminate papers that use the principle keyword of Knowledge Management but in different fields of study. These search queries provided a list of 516 papers that have been written in the last ten years between 2005 till 2015 period.

- Product Development
- Knowledge Management,
- Knowledge Sharing,
- Knowledge Transfer,
- Tacit Knowledge,
- Social Media,
- -Learning,
- Storytelling,

- Video Sharing.

Publications by year

The below chart Figure 94 shows the quantity of academic paper that have been published each year from 2005 till 2015. The trend of the chart has a bell shape form starting off with 23 published papers in 2005, peaking with 84 published papers in 2011 and then going down again with 22 published papers in 2014. The amount of published papers in 2015 is expected to rise significantly more than 2 published papers due to the fact that this data was extracted in January 2015 therefore it is only natural that more papers will be published in this coming year.

The majority of publications in any one year was reached in 2011 with 84 publications (60 conference proceedings, 18 journal articles, 5 book series and 1 book). Prior to 2005, only 19 published papers have been identified (16 Journal articles, and 3 conference proceedings) with the first research work being published by Niwa (1990). These publications have been examined but have not been included in this analysis in order to reduce the scope of the search and reduce the amount of data presented in the chart below.

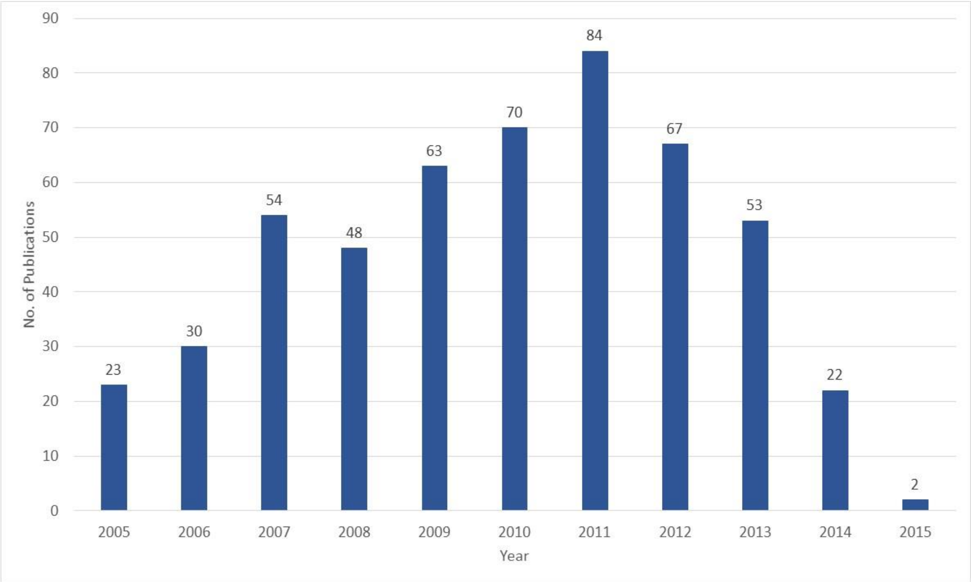

Figure 94. Publications by year

Publications by Country

The majority of publications resulting from the selected keywords originated from China (See Figure 95), where 108 papers in total have been published, with Wuhan University and Tongji University being the most contributing universities with 6 publications each. The second highest amount of publications originated from the United States with 79 publications, with Pennsylvania State University and Arizona State University being the most contributing universities with 3 publications each. Apart from China and United States as can be seen in Figure 95 other countries have also contributed to this field of study, such as the United Kingdom, Germany and Australia to name a few.

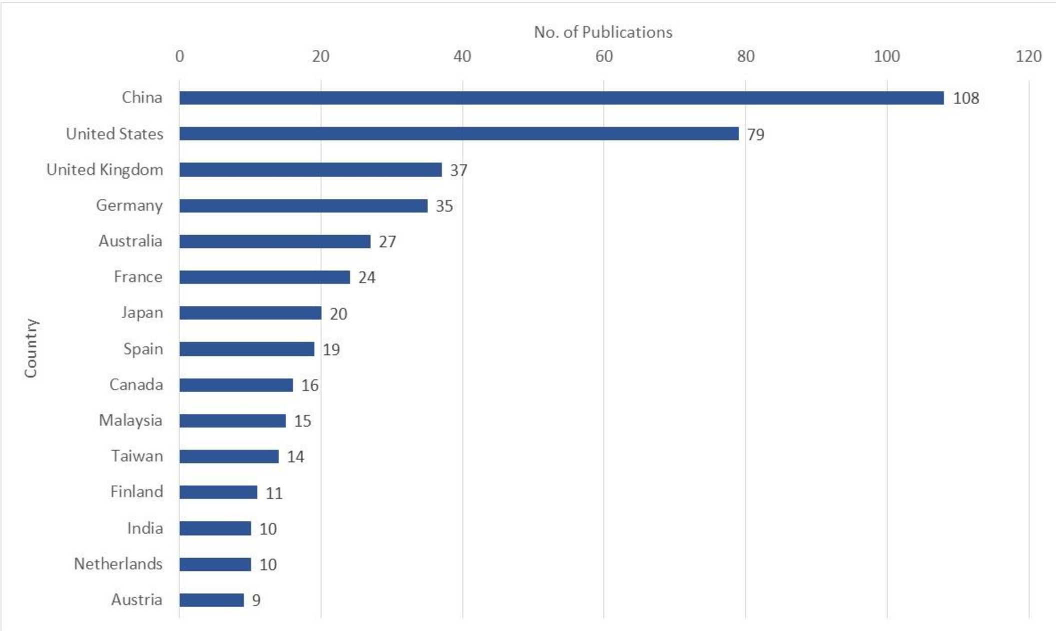

Figure 95. Publications by Country

Publications by Author and Affiliations

The most published author from the literature search of the selected keywords was, Nousala. S from Aalto University in Finland, who published 5 papers in total on the subject area between 2008 and 2010. Which publications were cited 16 times according to Scopus. Holleis. P from the DoCoMo Communications Laboratories Europe GmBH in Germany, Hardy, R from Lancaster University in United Kingdom, Rukzio, E from the Universitat Ulm in Germany all of which published 4 papers in the subject area. More author that have published in the subject are can be seen in Figure 96 below.

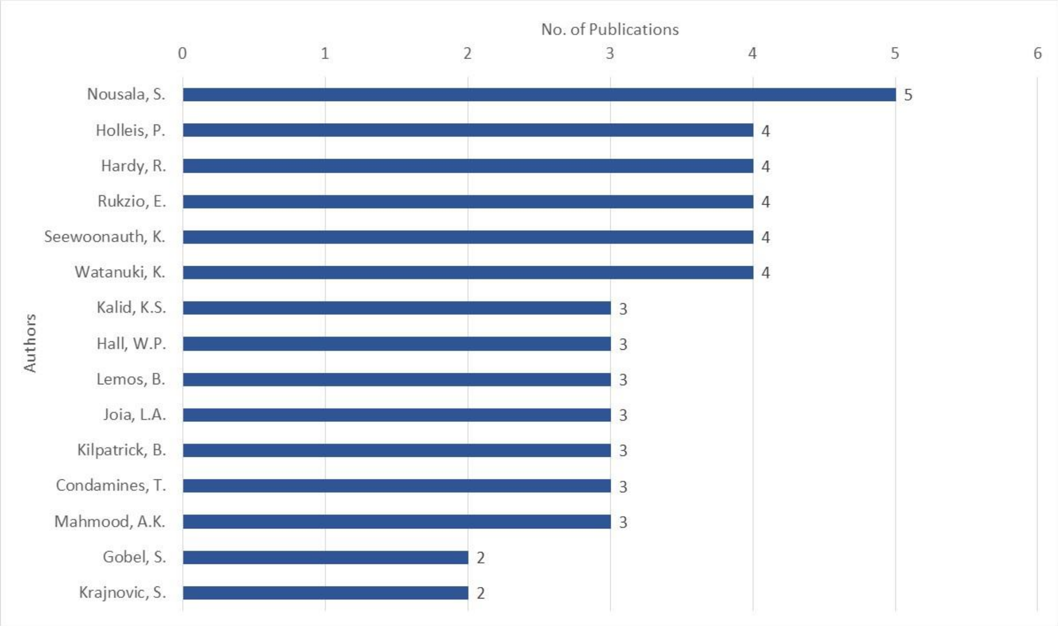

Figure 96. Publications by author

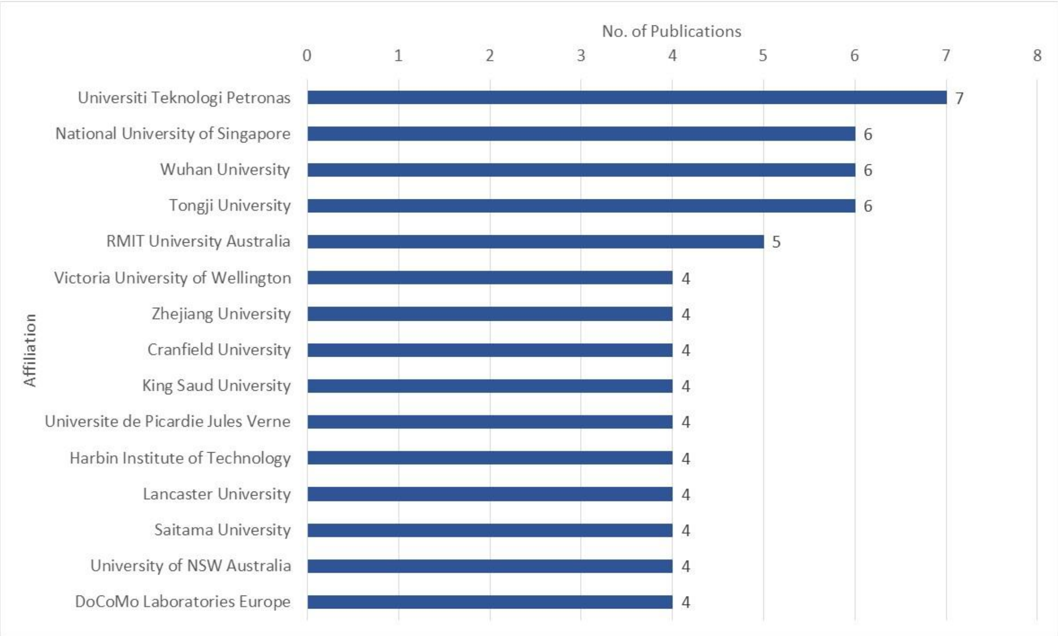

Figure 97. Publications by affiliation

When examining the affiliations that are producing the most published work, the Universiti Teknologi Petronas in Malaysia is classified first with 7 publications. The National University of Singapore in Singapore, the Wuhan University in China and Tongji University also in China all managed to publish 6 papers each. If you further examine Figure 97 above you will see that the first 7 universities are all from the Asian pacific region, which also indicates that countries in this region apart from the United States are the most interested contributors in this subject area.

Publications Subject Area and Document Type

From the identified 516 papers, as shown in Figure 98 have been classified as 340 were published as conference papers, 160 as journal articles, 13 as review papers, 2 as book Chapters and 1 as a short survey. Regarding where the papers were published, the most popular were: Proceedings of the European Conference on Knowledge Management Eckm (56), Journals Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics (20), ACM International Conference Proceeding Series (13) and the Journal of Knowledge Management (12).

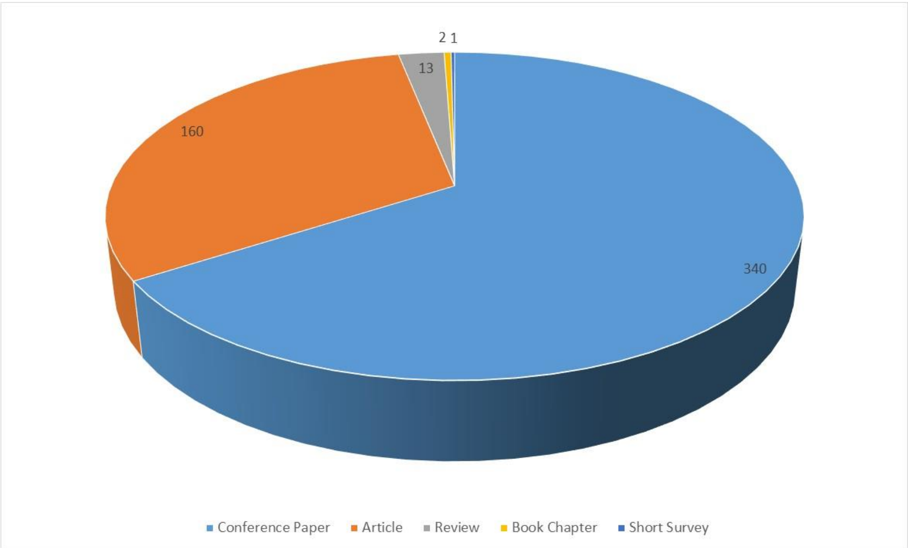

Figure 98. Publication type

When reviewing the discipline shown in Figure 99 from where these publications come from the majority are from computer science field with 278 papers. Engineering was the classified second with 133 publications while business, management and accounting and decision science where a joint third with 114 publications each.

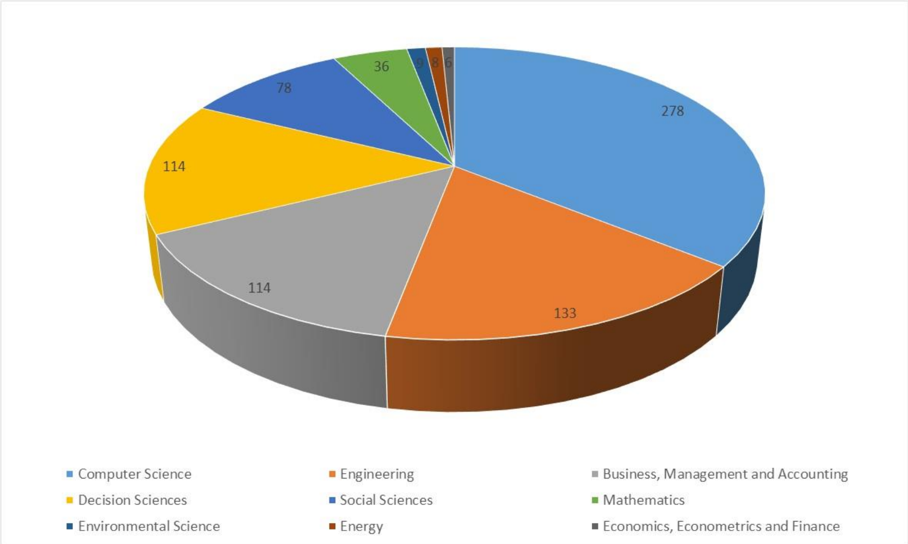

Figure 99. Publication topic area

Publications by Citations

The most cited paper found in the literature search was written by Haas and Hansen (Haas and Hansen 2005) of Cornell University in the United States and INSEAD, in France. The research paper was published in the Strategic Management Journal in 2005 under the title “When using knowledge can hurt performance: The value of organisational capabilities in a management consulting company”; and received 159 citations according to Scopus. Other papers worth mentioning are;

- Roux, Rogers et al. (2006) – (133 citations),
- van den Hooff and Huysman (2009) – (76 Citations),
- Chen and Hung (2010) – (52 Citations),
- Blumenberg, Wagner et al. (2009) – (51 Citations).

Appendix B: Modelling Tools for Process Modelling

In industry, processes are generally described and illustrated by means of flow chart diagrams. These diagrams enable complicated processes to be explained in a simple manner by means of one or a small number of easy to follow diagrams / charts. These tools are generally used to explain processes or project tasks, sequences, resource plans and schedules *inter alia*. This method empowers team members to communicate and share this information (Georgakopoulos, Hornick et al. 1995).

Before starting to model a process, one needs to ask 'The 6 W's'. These questions include: 1) why are you modelling? 2) Who are the models for? 3) What are you modelling? 4) When will the models be relevant? 5) Where will the models be relevant?, and 6) How will you go about modelling? These help the modeller to determine how the modelling process should be undertaken and enable the process to be set before starting in the wrong path (Becker 2013).

This section introduces the standard modelling tools that are typically used in industry, while a brief explanation of the selected tools is given.

BPMN – Business Process Model and Notation

Business Process Management (BPM) has been referred to as a "holistic management" approach (Brocke and Rosemann 2010) to align an organisation's business processes with the wants and needs of its clients. It promotes business effectiveness and efficiency while striving for greater innovation, flexibility, and integration with technology. BPM attempts to improve processes continuously. It can, therefore, be described as a 'process optimisation process'.

Business Process Model and Notation (BPMN) is a standard for business process modelling that provides a graphical notation for specifying business processes in a Business Process Diagram (BPD) (Simpson 2004), based on a flowcharting technique very similar to activity diagrams from Unified Modelling Language (UML) (White 2006).

There are three main types of business processes:

1) **Management processes**, which govern the operation of a system. Typical management processes include corporate governance and strategic management;

2) **Operational processes**, that constitute the core business value stream. Typical operational processes are purchasing, manufacturing, marketing, and sales; and

3) **Supporting processes**, which support the core processes.

The analysis of business processes typically includes the mapping of processes and sub-processes down to activity level. The level of detail and the flexibility of the tool make it one of the tools selected to be used for this project.

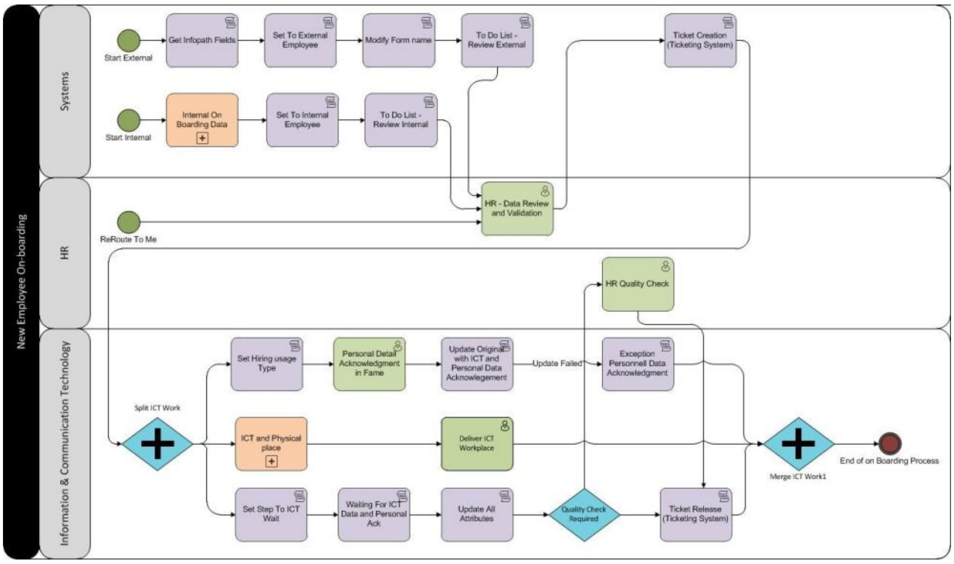

Figure 100. BPMN process modelling example

Design Road Map

(Park and Cutkosky (1999)) developed the Design Roadmap in order to overcome the limitations they found in other modelling tools. Their method provided a comprehensive alternative method for project management. The system is based upon two entries: Tasks and Features.

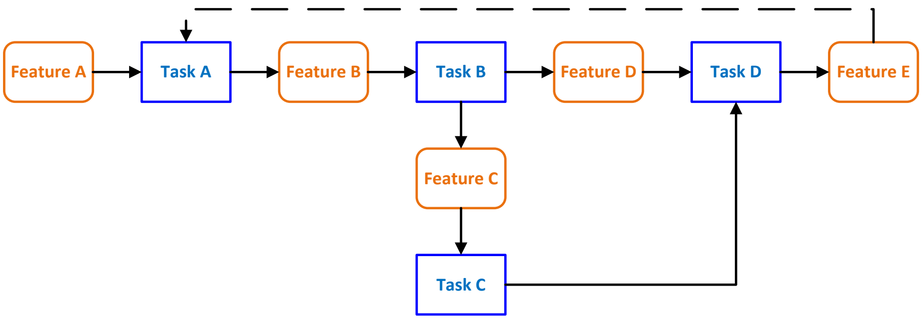

Figure 101. Design Roadmap example

Tasks are the primary element of the process model while the *Features* are the input and output actions produced from the tasks, meaning that any task will have at least two or more features, one of which being the input and another being the output. In the case that two or more features exist, the combinations can be mixed but always one will be present at the input and output of the task. Tasks and features are connected by arrow lines; which direction give the flow of the system being described. This tool also offers the possibility of a feedback loop which can be seen in Figure 101. This modelling tool is able to deal with both simple and complex processes making it ideal to show process flow where both the task and action doing that task is required.

Appendix C: Industrial Investigation Questionnaire

This appendix contains the first industrial investigation questionnaire used for the pilot study.

UNIVERSITY of GREENWICH

Power Generation

PhD project: Improving Testing Facilities Performance to Reduce Time-to-Market for New Product Development @ Cummins Power Generation, Kent, UK

Research Questionnaire – Pilot Study

My name is Joseph Zammit and I am conducting research into Improving Lab Ops performance in order to reduce time to market for new product development for Cummins Power Generation which aims to improve Product Development (PD) and the sharing of Knowledge and information within the company.

Consequently, I would appreciate your input to this project by providing some answers to the questions contained in this questionnaire. Any additional comments and advice are highly appreciated.

1. Name: (optional)

2. Job title?

3. Site?

4. Kindly describe your responsibilities in the Company.

Part 1: (Communication)

5. Please describe how you collaborate with other staff within
   (i) Your site;

   (ii) Global organisation;

1

Figure 102. Industrial Investigation Questionnaire Page 1

UNIVERSITY of GREENWICH

Power Generation

6. Describe situations/tasks when you are expected to collaborate with colleagues in product development activities?

7. How can the Company improve communication between colleagues during the product development process?

8. If a communication framework were to be developed to improve the collaboration between different departments/divisions within Cummins Power Generation, what kind of medium would you think would be the most effective?

9. What training would you require, if any, in order to be able to use communication software (such as a social media portal) to improve communication?

Part 2; (Process)

10. What are the good aspects of existing product development process at Cummins Power Generation, and the problems?

11. What improvements do you think are required in the product development processes / procedures at Cummins Power Generation?

2

Figure 103. Industrial Investigation Questionnaire Page 2

UNIVERSITY of GREENWICH

Power Generation

12. What do you think of the existing planning process of human and equipment resources?

13. How could Cummins Power Generation improve it's planning for product development testing?

14. When a problem is encountered during Product development do you find adequate support from other departments?
Yes ❑ No ❑

15. How can Cummins Power Generation improve inter department support for product development when problems are encountered?

16. How do you think your skills can be developed further by the Company to improve your performance?

Part 3 (Data & Knowledge)

17. Do you feel that you spend significant amount of time searching for information, data and/or knowledge, any quantitative indication?

3

Figure 104. Industrial Investigation Questionnaire Page 3

UNIVERSITY of GREENWICH

Power Generation

18. How could Cummins Power Generation improve the management of knowledge within the company?

19. Is there a need to change the way knowledge is captured and handled at Cummins?
   (i) At Your Site;

   (ii) At other Sites;

20. What training would you require to store and retrieve information on a knowledge base system?

21. In what shape or form do you expect a knowledge management system to be in?

22. How could Lab Ops improve keeping people informed of current products being tested (such as publishing live data in real time, daily/weekly progress meeting, etc)?

Thank you very much for your input and assistance in my research.

Joseph Zammit

4

Figure 105. Industrial Investigation Questionnaire Page 4

Appendix D: Industrial Investigation Questionnaire, Sample Response

This appendix contains a sample of the response received from the industrial investigation questionnaire.

Part 1: (Communication)

Questions 1 – 4 are identification questions.

5. Please describe how you collaborate with other staff within
   (i) Your site;
   Email, telephone, face to face meetings, IM (sametime) and chasing people to check

   (ii) Global organisation;
   Email, telephone, IM (sametime), conference calls, WebEx and delegating people at other sites to support work.

6. Describe situations/tasks when you are expected to collaborate with colleagues in product development activities?
   - *I have to collaborate in order to complete work function I find it vital to talk to people involved ideally face to face on a daily basis in order to make sure that people understand what I need from them and to get the job done.*
   - *Some people's mentality is the problem, with a "Them & Us" attitude instead of sometimes trying to work as a team; it's easier to just blame others. A day working with each other now and then might break down barriers.*
   - *When testing, suggesting improvements & feedback.*
   - Chase Lab Ops for testing, test schedule, meetings, contact suppliers. All depending on project requirements.

7. How can the Company improve communication between colleagues during the product development process?

- *Daily morning quick 15-minute meeting would help to tackle problems early in the day, it would also serve as a refresher for all the people involved to know what are the day targets and priorities. The meetings should only be attended by the stakeholders that have products being tested at Lab Ops so that to avoid having extra noise interfering with the testing in hand.*
- *Break down the silos that still exist between functions, this includes within Engineering. Need more transparency, still a lot of them and us mentality at all levels of the organisation. There are many tools available such as the eWiki site, but people are reluctant to use them effectively, partly because there are so many tools: QSi, PLM, eWiki, MyCummins, Notes dBases etc. Which do you trust?*
- *Engineers more actively involved when testing in the area witnessing & supporting.*
- *Email is heavily used as a defence mechanism. Realistic deadlines and getting the whole team on board with the project. And prioritizing the delivery of product, to the end customer.*

8. If a communication framework were to be developed to improve the collaboration between different departments/divisions within Cummins Power Generation, what kind of medium would you think would be the most effective?
    - *Written communication is authenticated with time stamps, face to face bridge short comings. Important for engineers is to educate themselves about what is involved to conduct specific tests and that they should from time to time participate at Lab Ops with the testing in order to better understand what is involved.*
    - *In an ideal world, it would all be face to face. However, this is not practicable, but we do have video conference facilities that should be utilised as much as possible. Also, the framework should, to a certain extent, ensure that all functions/depts. etc. corroborate and*

not get forgotten, only to inadvertently put a spanner in the works at the eleventh hour!

- *Depends on how the information is distributed. If you set the right criteria at the beginning, you can structure the project more efficiently.*
- *Anything that promotes more face to face discussions and more regular reporting.*

9. What training would you require, if any, in order to be able to use communication software (such as a social media portal) to improve communication?
    - *There is probably little software training required.*
    - *No training pretty confident in social media software.*
    - *No Training.*
    - *Not a lot just an induction tutorial to get to know the basic functions.*

Part 2; (Process)

10. What are the good aspects of existing product development process at Cummins Power Generation, and the problems?
    - *Testing practices and testing processes in some areas are very extreme. Standard check sheet should be developed for every test to trace back what happened. All development sets should have a development log book that gives out a clear history of the product.*
    - *Good – we try to ensure all functions support the project with a core team of people at the minimum.*
      Bad – Constant push for unreasonable deadlines
    - *VPI process would be good if all followed it to the full. The process should be more disciplined with formal system sign-offs required*
    - *At the moment the not all of the info is readily available when the project is transferred to Lab Ops. Several times project milestones are changed which can have a significant impact on the facility.*

Still Lab Ops try to be as flexible as possible to these changes if this changes are minimized Lab Ops performance would be greatly improved.

11. What improvements do you think are required in the product development processes/ procedures at Cummins Power Generation?
    - *More testing bays to improve utilization, apart from having more test cells the need for preparations areas would greatly help the Lab Ops team to improve their facility utilization. Each test cell should have a prep area where the Genset can be pull on to for Genset servicing or maintenance.*
    - *More development time allocated to work on Genset performance.*
    - *All development sets should have a development log book that gives out a clear history of the product.*
    - *System driven process – Automated escalation process*

12. What do you think of the existing planning process of human and equipment resources?
    - *Gaps in abilities, only one person is specialised in a specific area giving the facility lack of capacity.*
    - *Planning – is not full proof due to unforeseen failures, H&S incidents, equipment constrained by investment at times, continued improvement and upgrades are needed, test cells upgrades and more attention required in the designs.*
    - *I think the intentions are good and training and guidance is also good. However, there is often little buffer time allowed and things often go awry once a vague requirement cannot be met*
    - *Planning is very reactive which puts us in a catch up position.*

13. How could Cummins Power Generation improve its planning for product development testing?
    - *An assistant could be implemented to help coordinate things that waste time from the testing technicians.*

- *TPL's & Supply need to be more efficient, seems like we are always delayed by parts missing.*
- *Improvements in the testing times and rigging times used for planning.*
- *The business needs to focus on the aim of the project and that we should all be working as one to achieve the same targets.*

14. When a problem is encountered during Product development do you find adequate support from other departments?

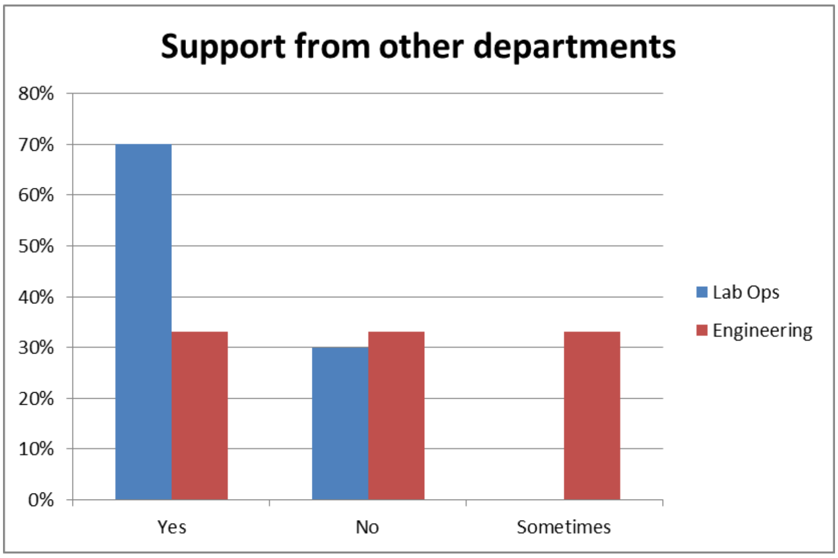

Figure 106. Support from Other Departments

15. How can Cummins Power Generation improve inter department support for product development when problems are encountered?
    - *Clear and timely communication is required, more robust planning to be made for every project with a project leader will be able to build trust and show evidence that the project is holding to the plan. Implementation of preventive measures rather than being reactive to problems encountered during testing. One of the items could be having more parts to save guard against breakdowns.*
    - *Team building, transparency, resource, empathy. Improve the soft skills. Effective issue management.*
    - *People have to understand that everyone should have the same goal that of getting the product delivered to the customer at the*

given date. A lot of attention is given to team budgets and who's being charge for a specific job. People's energy should be focused on the product rather than the department's expenses.

- *The business needs to focus on the aim of the project and that we should all be working as one to achieve the same targets.*

16. How do you think your skills can be developed further by the Company to improve your performance?
    - *Leader ship skills also Lab Ops should have a plan to develop the test technicians so that they will feel more motivated through their job function.*
    - *Training on Microsoft Products*
    - *Refresher training on things like project management, issue management, remote global team working.*
    - *More training and exposure to different work practices*

Part 3 (Data & Knowledge)

17. Do you feel that you spend significant amount of time searching for information, data and/or knowledge, any quantitative indication?
    - *Gaps exist everywhere. Testing requirements are not filled in properly and Lab Ops should be given the right data from the beginning. Documents need to be signed off so that it's a deterrent so that documents are filled in correctly.*
    - *Yes. There is no enforced structure/method/process for managing data. Only 10+ years in Cummins enables me to be able to find the data I need. Despite frameworks being defined by various projects, there is no single drive to use them in the future as every team think they have the best solution to the issue and that the framework available is not what they want.*
    - *Pretty good at finding information only because I previously worked on information systems so I have a good idea where to look for information.*

- *Too much time trying to find information in the vast amount of systems / databases. Non-Value added activities when information should be readily available*

18. How could Cummins Power Generation improve the management of knowledge within the company?

- *Data & Knowledge are not properly stored and it's not managed properly. Also test reports are not properly filled in and not securely stored.*
- *Databases that are easily accessible and user friendly.*
- *Standardise on a framework/process/method and make people accountable to use it. WindChill could help with this but I suspect that it will be left fairly broad as it is a CMI solution, the BUs may be able to further refine but won't happen for a few years yet.*
- *People should spend time in other departments to get a broader view of different job functions.*

19. Is there a need to change the way knowledge is captured and handled at Cummins?

(i) At Your Site;

- *Yes*
- *Yes, we need to share our experiences*
- *A set form of communications and linking it to project requirements. Improving communication making it more efficient and affective. Roles and responsibilities of people's job function within the company should be developed.*
- *The ability to share data with other sites and allow 'viewing' to take place in 'real time'*

(ii) At other Sites;

- *Yes*
- *Yes – People should have the opportunity to visit other sites to understand how they work*

- *The ability to share data with other sites and allow 'viewing' to take place in 'real time'*
- *Yes – we need better storage & sharing of knowledge to avoid repetition / future errors A transparent approach for all to share / communicate best practice etc*

20. What training would you require to store and retrieve information on a knowledge base system?
    - *How to use the system, really Not sure what a knowledge system is to be honest – make need a culture improvement at Cummins Inc.*
    - *Full training should be provided to all users Train the trainer training to key specialists for on-going maintenance.*
    - *No training pretty confident with computers.*
    - *Familiarization of how to* operate the software.

21. In what shape or form do you expect a knowledge management system to be in?
    - *Testing procedures from Fridley are not 100% correct therefore engineers should spend some time at Lab Ops so that they get a better understanding of testing process.*
    - Web based system which is easily accessible and searchable.
    - Not to fussed - but in a way that is easy to interact with by the user Simple is better
    - *More storage structure and security of files.*

22. How could Lab Ops improve keeping people informed of current products being tested (such as publishing live data in real time, daily/weekly progress meeting, etc)?
    - 9 o'clock meeting between project stakeholders both engineers and test technicians. And publishing live data to quickly check what's going on.

- TPLs should be aware of any data if they manage well enough, ie. Speak to technician regularly. It could be published as and when DATA is gathered and is convenient for technician to do so for everyone else.
- *I would like to see a daily/weekly dashboard as a minimum. Perhaps it already exists... Daily dashboard would make sense, but also with a week/month view as well for people in planning roles etc.*
- Electronic tick sheet, of tests being conducted that identifies its progress. A system that allows you to find the testing status without moving from your desk. Data can be collected with swipe cards coming in and out of the test cell. Actual costs of tests and priority scoring.

Appendix E: Industrial Investigation Site Visit Questionnaire

This appendix contains the questionnaire used for the Cumins site visits.

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PhD project: Getting an understanding of Lab Ops processes at Fridley and Columbus.

My name is Joseph Zammit and I am conducting research into Improving Lab Ops performance in order to reduce time to market for new product development for Cummins Power Generation which aims to improve Product Development (PD) and the sharing of Knowledge and information within the company.

1. Name:

2. Job title?

3. Site?

Part 1: (Testing site)

4. What types of tests are carried out at this site?

5. What sizes of Gensets are tested at this site? (Power & physical size);

6. The Genset structure, from where are the parts coming from? Engine, Alternator, controller, etc?

7. How and where are the Genset test samples manufactured?

1

Figure 107. Industrial Investigation Site Visit Questionnaire Page 1

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8. What resources are available at this site? (how product development test cells are available)

9. What is the average utilization of product development test cells?

10. What is the current testing capacity? Supply demand of test requests

11. How many human resources are available at this Lab Ops site?

12. What are the skill structures of the staff available?

13. What are the normal working hours at Lab Ops? & shift patterns?

14. Could you please walk me through the DVP&R & TR processes?

2

Figure 108. Industrial Investigation Site Visit Questionnaire Page 2

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Part 2; (Documentation & software tools)

15. How is documentation controlled and stored? Do you use any kind of CMS tools to store and control documents? Could you please show me & send me a screen shot.

16. Documentation sign off; are DVP&R, and test reports signed off by relevant people?

17. Are there any documentation control process upgrades in the near future?

18. Data acquisition – what software is used? Could you please show me and send me a screen shot.

19. Test planning – How are tests planned? And what software is used for test scheduling?

20. Are the test schedules static or dynamic to changes? If the plan schedule is software based is it reactive to changes?

3

Figure 109. Industrial Investigation Site Visit Questionnaire Page 3

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Part 3 (Test cell Detractors)

21. What are the major waste detractors at Lab Ops?
    - Setup, ☐
    - Waiting detractors, ☐
    - Genset detractors, ☐
    - Infrastructure detractors, ☐
    - Admin detractors, ☐
    - Genset tear down, ☐
    - Operator detractors, ☐

22. How are Genset moved in and out of test cells?

23. Genset rig time – do you use any techniques to reduce time. Pre – rigging prep work, CAD simulations, or any form of planning?

24. Equipment issues – when issues/problems arise do you find support from other parts of the business, such as engine or alternator part of the company?

Thank you very much for your input and assistance in my research.

Joseph Zammit

4

Figure 110. Industrial Investigation Site Visit Questionnaire Page 4

Appendix F: Industrial Investigation Site Visit Questionnaire, Sample Response

This appendix contains a sample of the response received from the Cummins site visits.

Part 1: (Testing Site)

Questions 1 – 3 are identification questions.

4. What types of tests are carried out at this site?

   Columbus: Calibration development and gas blending levels & relation to methane number (waste gasses from landfills)

   Fridley: Genset testing, sound, performance testing, emissions, max power, transients, LATS, Cold testing, Endurance testing, UL, Rain, Short circuits, elevated temperatures.

   Kent: Equipment trial, Controls function, Tuning, Transients, NFDA, Gensize, Block Load, Long term steady state, Max power, Vibration (both linear and torsional), Duration & drawdown, LAT, Alt temp rise, Circuit breaker temp rise, Water ingress, Noise, EMC (external), Surface temp, Fuel Consumption, LVRT, Short circuit, Strain, IMop.

5. What sizes of Gensets are tested at this site?

   Columbus: 3.3l – 78l depending on test cell size and capabilities. While power wise the range is 1.2 MW – 2 MW for 78l engines. For the whole facility the power range varies from 750KW al the way up to 2.5MW max.

   Fridley: from 2KW to 4.5MW. 2KW = suitcase size while 4.5MW = Semi trailer.

   Kent: from 3.1L to 91L – 20KVA to 2500KVA

6. The Genset structure, from where are the parts coming from? Engine, Alternator, controller, etc?

   Columbus: Minor mods on engine parts, rather than testing Alpha builds

   Fridley: Varies – can be manufactured @ Fridley, India, china, etc, At Fridley we manufacture the skid, enclosures, controls, and small alternators under 7KW.

Kent: Generally gensets come from the VPI build area or from the shop floor. All parts are brought on site from other plants.

7. How and where are the Genset test samples manufactured?

   Columbus: in-house we generally use old Genset and modify them depending on the required testing.

   Fridley: Lab Ops build their own.

   Kent: VPI build area, on the shop floor or other sites.

8. What resources are available at this site?

   Columbus: 5 test cells, 4 of which are performance. Emissions testing can be performed at the site but no certification work can be performed. Product development resources consist of gas blending and an engine build area.

   Fridley: 25 performance test cells, and 40 endurance test cells

   Kent: 25 performance test cells, and 1 noise pad: 2 High Voltage test cells both Gas and Diesel, 1 Low Voltage test cell up to 1.5MW & High Voltage 11KV Diesel (2.5 KVA), 1 High Voltage test cell 6.6, 11, 13.8KV Diesel (2.5 KVA), 1 Bund area diesel 3.3KVA and 1 noise pad diesel 2.5KVA.

9. What is the average utilization of product development test cells?

   Columbus: 2013 – 29% average while 2014 so far the facility is running on an average utilization of 30% (up to March)

   Fridley: The lowest utilization is 5 – 10%. Other exception 3 shift cell 139 or cell 140 runs on a utilization of average 30%

   Kent: 12% - 15%.

10. What is the current testing capacity? Supply demand of test requests

    Columbus: 2013 demand exceeded supply, while in 2014 the product development list got reduced from top management in order to consolidate and concentrate on projects that will give financial benefit to the business. So at the moment supply is equal to demand.

Fridley: Testing demand is cyclic, at times peak of work load, backlog does exist, but can be managed.

Kent: Unable to truly cater for demand, but not massively.

11. How many human resources are available at this Lab Ops site?

    Columbus: 17 Lab Ops testing personnel.

    Fridley: 50 test technicians, 10 fabrication technicians, and 6 testing equipment support.

    Kent: 12 people including applied technicians & test systems technicians, In Lab Ops 1 coach, and 5 test techs.

12. What are the skill structures of the staff available?

    Columbus: Project Engineer, Site leader, HSE leader, Admin support, material handler, Engineering support, instrumentation support and 10 test cell operators TSS (not technicians).

    Fridley: Less experienced techs must have a 2-year degree (associates) minimum. Most have a 4-year degree (Bachelor's degree).

    Kent: All technician based staff.

13. What are the normal working hours at Lab Ops? & shift patterns?

    Columbus: Office 6am – 6pm, while the test cell operational hours 1st shift 07:00 – 15:30, 2nd shift 15:00 – 23:30, 3rd shift 23:00 – 7:30. The test cells are run on a 3 shift – 5 days a week.

    Fridley: Test cell operational hours 1st shift 07:00 – 15:30, 2nd shift 15:00 – 23:30, 3rd shift 23:00 – 7:30. The test cells running on a 3 shift – 5 days a week.

    Kent: Test cell operational 5 days a week 1 shift. But we are flexible depending on project requirements.

14. Could you please walk me through the DVP&R & TR processes?

    Columbus: All the planning and test schedules are created and controlled by Engineering, and Lab Ops just follow the test plan. Once a unit is planned the required parts are put together and inserted into a test cell and the planned tests are performed. Test data is collected and in its raw form is sent out to the engineers for analysis.

Fridley: Varies by program, TR are improving, Arrow program have questioned test requests. Lab Ops in general is improving.

Kent: Has been modelled and presented in Chapter 4

Part 2: (Document & Software)

15. How is documentation controlled and stored? Do you use any kind of CMS tools to store and control documents?

    Columbus: At the moment we use 2 databases, CPG performance & development team room on Lotus notes.

    Fridley: Lotus notes database (DVP&R) or on network drive.

    Kent: Lotus notes database (DVP&R) or on a network drive.

16. Documentation sign off; are DVP&R, and test reports signed off by relevant people?

    Columbus: No sign off process, it doesn't work.

    Fridley: Program specific, should be engineers & program managers.

    Kent: Currently the DVP&R process sign off is not working, but 6-sigma projects are in place to tackle this issue.

17. Are there any documentation control process upgrades in the near future?

    Columbus: Not sure.

    Fridley: GLIMS is still a few years' out

    Kent: GLIMS

18. Data acquisition – what software is used?

    Columbus: Cyflex – stripchart for emission data.

    Fridley: TDACS - Cyflex

    Kent: TDACS – Cyflex should be introduced in the near future.

19. Test planning – How are tests planned? And what software is used for test scheduling?

    Columbus: Test plans are produced by Don & Carey with engineering in MS project. But once it arrives to Lab Ops the plan is transformed into excel format. But the planning schedule is tied to the project rather than the capacity of the test cell.

    Fridley: Excel, MS project.

    Kent: Excel

20. Are the test schedules static or dynamic to changes? If the plan schedule is software based is it reactive to changes?

    Columbus: Test schedules are on Excel and the document is manually updated depending on testing requirements.

    Fridley: Dynamic, constantly changing to requirements.

    Kent: Static, changes create lots of issues.

<u>Part 3: (Test Cell Detractors)</u>

21. What are the major waste detractors at Lab Ops?

    Columbus: Setup and Infrastructure detractors.

    Fridley: Waiting detractors, Genset tear down, and Genset build waiting for parts to arrive.

    Kent: Waiting detractors, Genset tear down.

22. How are Genset moved in and out of test cells?

    Columbus: Engines are moved around and in and out of test cells mainly by fork lift. A 3rd party fork lift is used.

    Fridley: Tugger

    Kent: Fork lifts' in conjunction with new crane system.

23. Genset rig time – do you use any techniques to reduce time. Pre – rigging prep work, CAD simulations, or any form of planning?

Columbus: Patch panels on engines are setup during rigging in order to reduce engine installation time in the test cell. With the patch panel all the sensors are quickly hooked up to the data acquisition equipment reducing the engine rigging inside the test cell.

Fridley: Pre-installation and common exhaust hook-ups.

Kent: Currently no but on project list as one of the improvements to be implemented.

24. Equipment issues – when issues/problems arise do you find support from other parts of the business, such as engine or alternator part of the company?

    Columbus: The major problem that is encountered is finding needed parts for testing, put support is prompt. If facility problems arise these issues are sorted out by our self's

    Fridley: Some limited. Have to figure out on our own, but we do get support if needed.

    Kent: Distance, lose at least a day's utilisation waiting for arrival of parts or support personnel.

Appendix G: Industrial Investigation End-user Questionnaire

This appendix contains the investigation questionnaire used to identify end-user requirements.

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Power Generation

PhD project: A knowledge sharing framework for improving the testing processes in global product development @ Cummins Power Generation, Kent, UK

Research Questionnaire

My name is Joseph Zammit and I am conducting research in improving knowledge capture and sharing within a product development testing facility to reduce time to market for new product development for Cummins Power Generation. Consequently, I would appreciate your input to this project by providing some answers to the questions contained in this questionnaire. Any additional comments and advice are highly appreciated.

1. Job title?

Part 1: (Social media)

2. Do you use social media in your everyday life to communications or share your experiences and ideas or to keep up with what your friends are doing, on such mediums as twitter, Facebook, LinkedIn, YouTube, online forums, blogs, etc.

    - Yes, ❑
    - No, ❑

3. How much of a social media user do you consider you're self to be?

    - I hardly use it, ❑
    - I use it from time to time, ❑
    - I use it daily, ❑
    - I'm a heavy user, ❑
    - I cannot live without it, ❑

4. Do you consider yourself as a passive user (only read / follow what others are writing / posting) or an active user (you write/post things yourself) of social media tools? (twitter, Facebook, LinkedIn, YouTube, online forums, blogs, etc.)

    - Passive user, ❑
    - Active user, ❑

Part 2: (Learning)

5. Learning Methods –there are 7 learning categories; lectures, reading, audio-visual, demonstrations, discussions, practice of doing and teaching others. Which learning category do you consider most effective for you?

    - Lectures, ❑
    - Reading, ❑
    - Audio-visual, ❑
    - Demonstrations, ❑
    - Discussions, ❑
    - Practice of doing, ❑
    - Teaching others, ❑

1

Figure 111. Industrial Investigation End-user Questionnaire Page 1

Industrial Investigation End-user Questionnaire

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6. Do you consider yourself as a passive learner (knowledge has to be feed to you) or an active learner (you learn/seek knowledge on your own initiative)?

- Passive learner, ☐
- Active learner, ☐

7. If audio-visual & demonstrative media is used as a knowledge sharing mechanism, what length of time do you feel would be most effective?

- Short, straight to the point content, (5 -10 mints) ☐
- More detailed content, (15-25 mints) ☐
- Longer more detailed content of the subject, (30-60 mints) ☐

Part 3: (Knowledge Sharing)

8. DO you encounter situations where you need to share knowledge with your colleagues?

- Never, ☐
- Rarely, ☐
- Sometimes, ☐
- Often, ☐
- Daily, ☐

9. How do you feel about sharing with others the knowledge that you have acquired during your time at Cummins?

- I don't like sharing, ☐
- I only share when it's to my benefit, ☐
- I share when I am asked to, ☐
- I share with others, ☐
- I openly share with other because it makes my life easier, ☐

10. What kind of incentive would trigger or improve your participation to share your knowledge?

- No incentive needed I share knowledge willingly, ☐
- Recognition - status, ☐
- Career advancement, ☐
- Gift compensation, (tickets to see the latest movie, dinner, etc.) ☐
- Monetary compensation, ☐

Thank you very much for your input and assistance in my research.

Joseph Zammit

2

Figure 112. Industrial Investigation End-user Questionnaire Page 2

Appendix H: Case Study: W/Shop Knowledge Contribution Questionnaire

This appendix contains the validation questionnaire used for the knowledge contributor participants.

UNIVERSITY of GREENWICH

Power Generation

PhD project: A knowledge sharing framework for improving the testing processes in global product development @ Cummins Power Generation, Kent, UK

Research Questionnaire – Knowledge Contributors

My name is Joseph Zammit and I am conducting research in improving knowledge capture and sharing within a product development testing facility to reduce time to market for new product development for Cummins Power Generation. Consequently, I would appreciate your input to this project by providing some answers to the questions contained in this questionnaire. Any additional comments and advice are highly appreciated.

1. Job title?

Part 1: (Knowledge sharing platform)

2. Did you access the knowledge sharing platform http://www.cpgk-knowledgesharing.com?

   Yes, ❑
   No, ❑

3. How did you find the navigation of the knowledge sharing platform website page?

	1	2	3	4	5	
Very Difficult	❑	❑	❑	❑	❑	Very Easy

4. Did you access the training material provided on the knowledge sharing platform http://www.cpgk-knowledgesharing.com?

   Yes, ❑
   No, ❑

5. Was the training material easy to follow and did it aid you in understanding the task at hand?

	1	2	3	4	5	
Very Difficult	❑	❑	❑	❑	❑	Very Easy

6. How do you rate the quality of the training material provided?

	1	2	3	4	5	
Needs Improving	❑	❑	❑	❑	❑	Good Quality

7. Was the quantity of training material enough, to complete your knowledge contribution?

	1	2	3	4	5	
Needs More	❑	❑	❑	❑	❑	There is Enough

1

Figure 113. Case Study: W/Shop Knowledge Contribution Questionnaire Page 1

Case Study: W/Shop Knowledge Contribution Questionnaire

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Part 2: (Knowledge Contribution)

8. How difficult did you find filling in the knowledge contribution form?

Very	1	2	3	4	5	Very
Difficult	☐	☐	☐	☐	☐	Easy

9. How difficult did you find collecting information and planning your knowledge contribution in order to fill in your knowledge request form?

Very	1	2	3	4	5	Very
Difficult	☐	☐	☐	☐	☐	Easy

10. Do you think there is something missing from the knowledge request form that would have been helpful to you in preparing and planning your knowledge contribution?

11. During the execution of the knowledge contribution capture, how difficult did you find it to prepare the material / script & planning of resources & work in order to create your knowledge contribution?

Very	1	2	3	4	5	Very
Difficult	☐	☐	☐	☐	☐	Easy

12. Have you ever used social media?

Yes, ☐
No, ☐

13. Have you ever used a digital camera or a camera or a smart phone to capture still or moving pictures (photos / videos)?

Yes, ☐
No, ☐

14. If 12 or 13 you answered yes proceed with this question, if you answered no go to question 15.
With your current experience of digital cameras (limited or extensive) how difficult did you find capturing video images for your knowledge contribution?

Very	1	2	3	4	5	Very
Difficult	☐	☐	☐	☐	☐	Easy

15. If you answered question 14 skip to question 16.
With no experience of digital cameras, how difficult did you find it to capture video images for your knowledge contribution?

Very	1	2	3	4	5	Very
Difficult	☐	☐	☐	☐	☐	Easy

2

Figure 114. . Case Study: W/Shop Knowledge Contribution Questionnaire Page 2

Case Study: W/Shop Knowledge Contribution Questionnaire

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16. Once you have captured your video images how difficult did you find compiling your knowledge contribution into a finished video using Adobe Premier Pro?

Very	1	2	3	4	5	Very
Difficult	❑	❑	❑	❑	❑	Easy

17. As a complete process how difficult did you find the creation of your knowledge contribution?

Very	1	2	3	4	5	Very
Difficult	❑	❑	❑	❑	❑	Easy

18. As a process do you have any additional comments / feedback towards your knowledge contribution experience?

Thank you very much for your input and assistance in my research. It is highly appreciated.

Joseph Zammit

3

Figure 115. . Case Study: W/Shop Knowledge Contribution Questionnaire Page 3

Appendix I: Case Study: W/Shop Knowledge Contribution Questionnaire, Sample Response

This appendix contains a sample of the response received from the validation exercise of the knowledge contributors.

Part 1: (Knowledge sharing platform

2. Did you access the knowledge sharing platform http://www.cpgk-knowledgesharing.com?

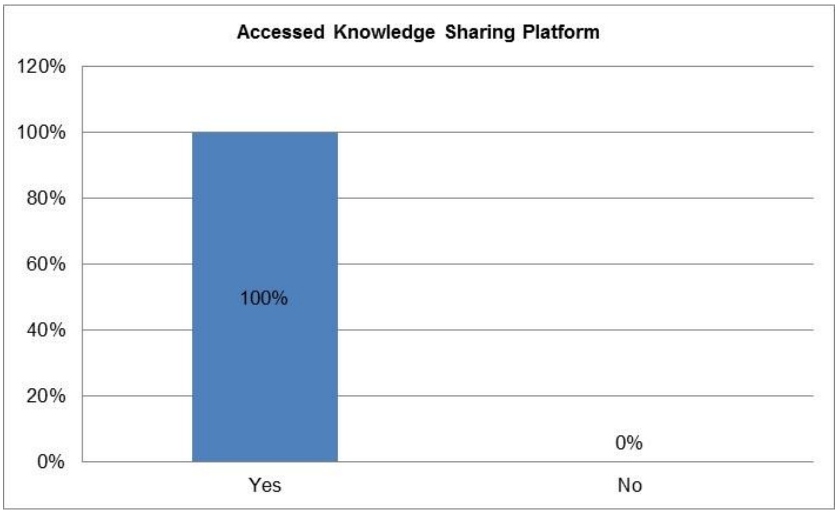


Figure 116. Accessed the Knowledge Sharing Platform

3. How did you find the navigation of the knowledge sharing platform website page?

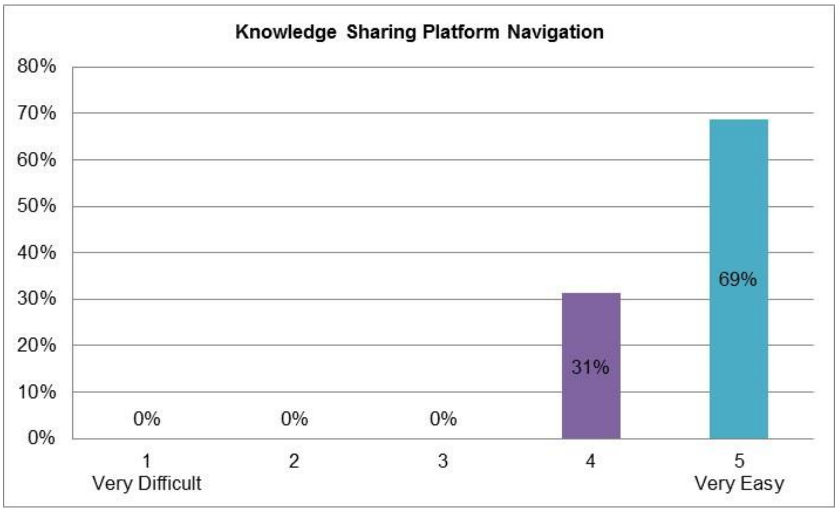


Figure 117. Difficulty to Navigate Through the Knowledge Sharing Platform

4. Did you access the training material provided on the knowledge sharing platform http://www.cpgk-knowledgesharing.com?

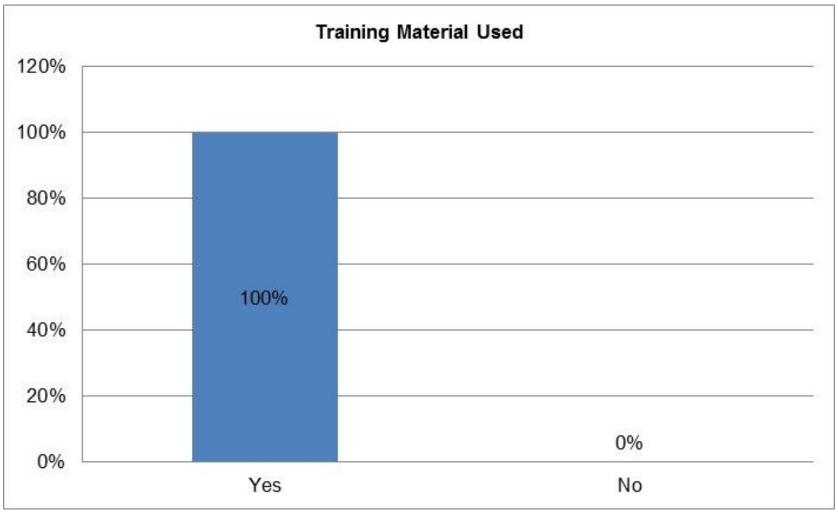


Figure 118. Use of Training Material

5. Was the training material easy to follow and did it aid you in understanding the task at hand?

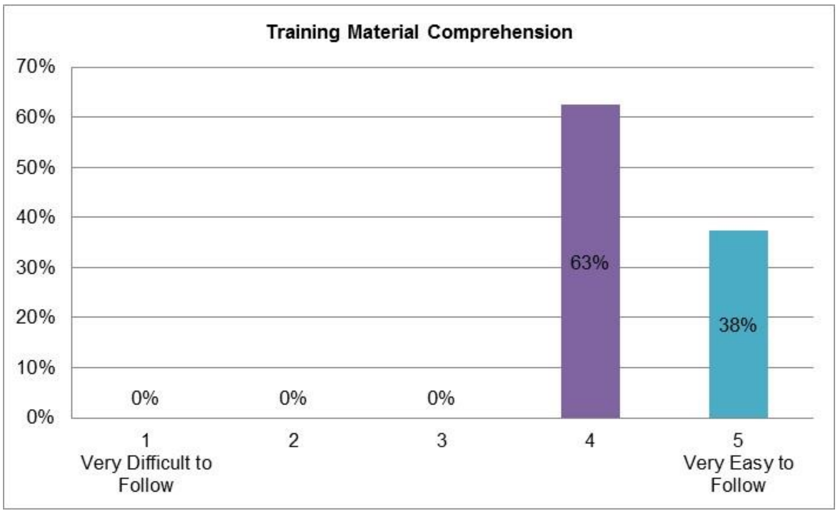


Figure 119. Difficulty to Follow Training Material

6. How do you rate the quality of the training material provided?

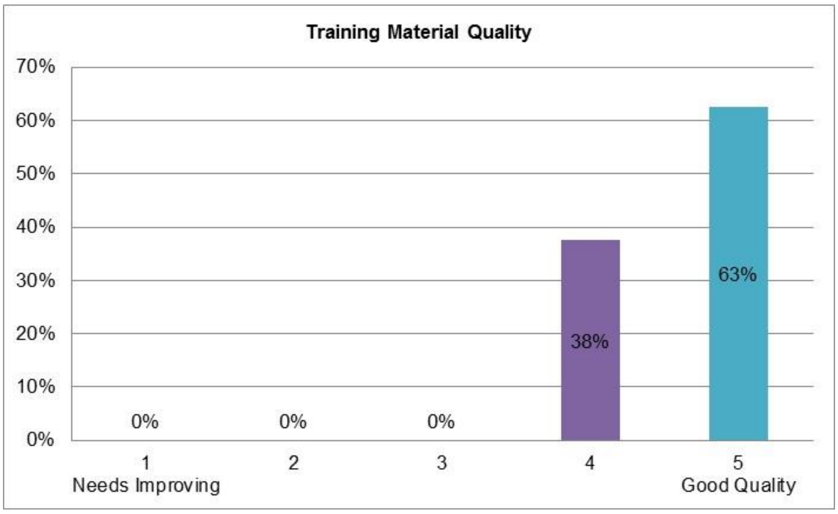


Figure 120. Quality of Developed Training Material

7. Was the quantity of training material enough, to complete your knowledge contribution?

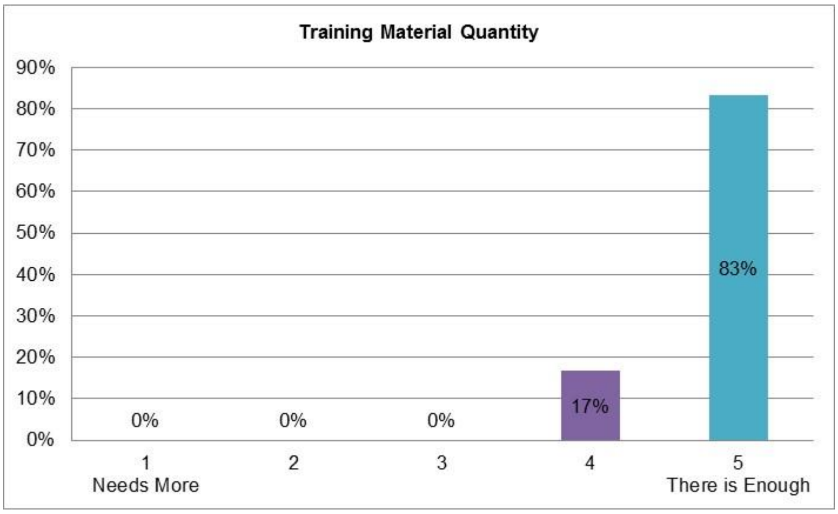


Figure 121. Quality of Training Material to Complete a Knowledge Contribution

Part 2: (Knowledge Contribution)

8. How difficult did you find filling in the knowledge contribution form?

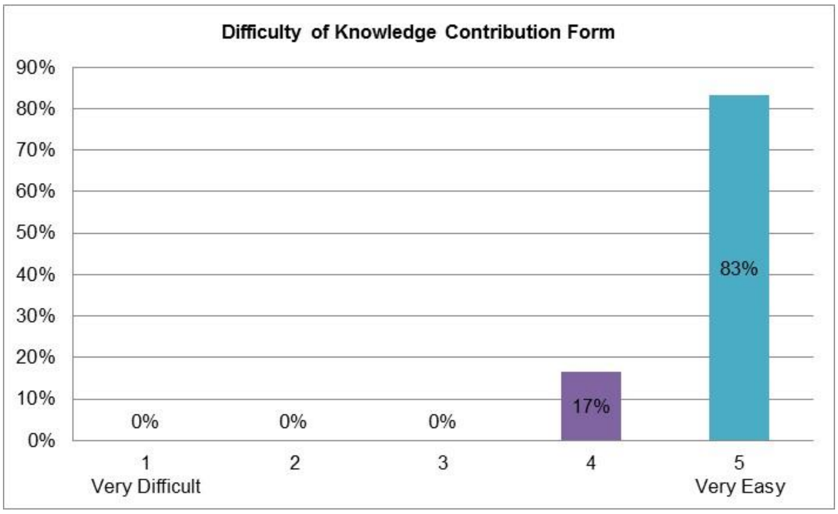


Figure 122. Difficulty to Complete the Knowledge Contribution

9. How difficult did you find collecting information and planning your knowledge contribution in order to fill in your knowledge request form?

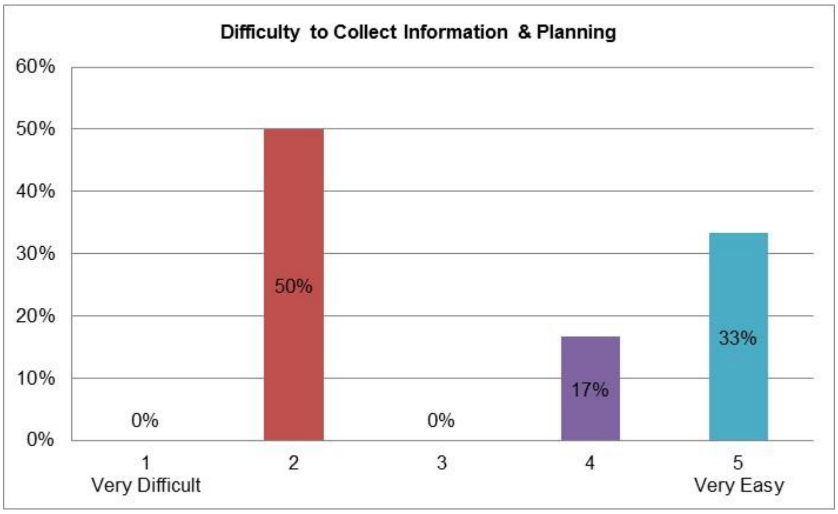


Figure 123. Difficulty to Collect Information & Planning of Knowledge Contribution Form

Comments from 50% 2 rating: dedicated time to work on the knowledge contribution and a quiet place to work in.

10. Do you think there is something missing from the knowledge request form that would have been helpful to you in preparing and planning your knowledge contribution?

    NO

11. During the execution of the knowledge contribution capture, how difficult did you find it to prepare the material / script & planning of resources & work in order to create your knowledge contribution?

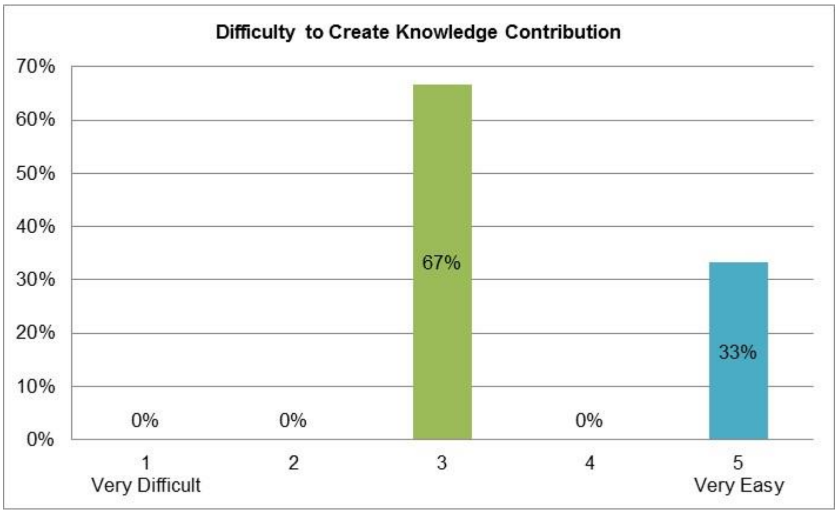


Figure 124. Difficulty to Create Knowledge Contribution

12. Have you ever used social media?

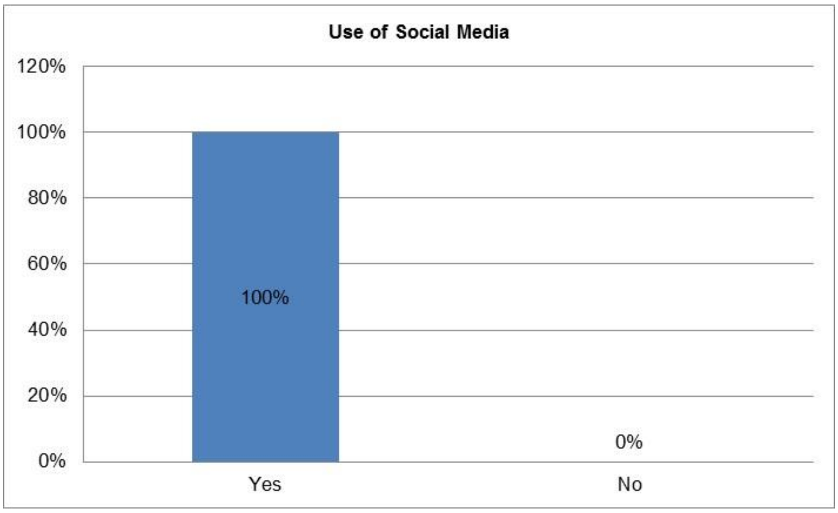


Figure 125. Use of Social Media

13. Have you ever used a digital camera or a camera or a smart phone to capture still or moving pictures (photos / videos)?

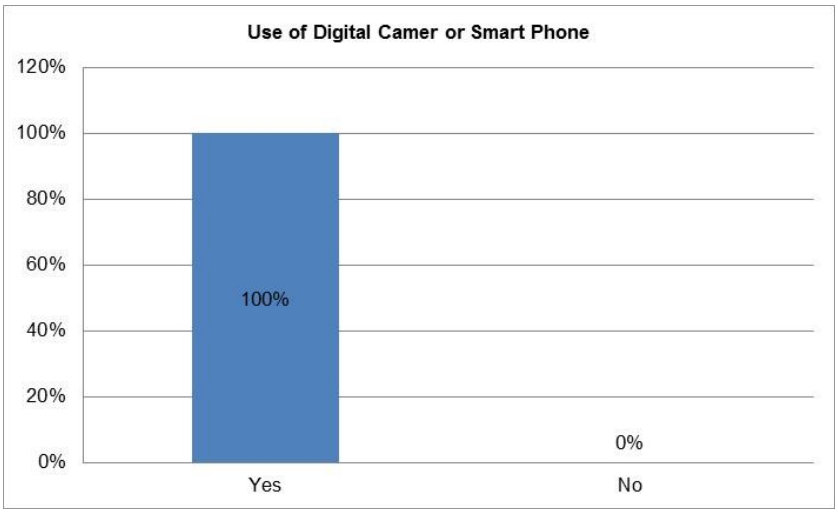


Figure 126. Use of Digital Camera or Smart Phone

14. With your current experience of digital cameras (limited or extensive) how difficult did you find capturing video images for your knowledge contribution?

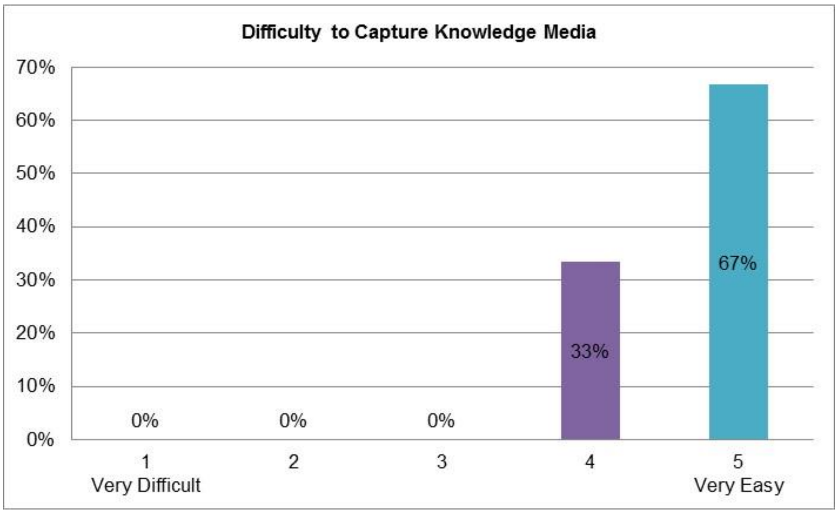


Figure 127. Difficulty to Capture Knowledge Media

15. If you answered question 14 skip to question 16. With no experience of digital cameras, how difficult did you find it to capture video images for your knowledge contribution?

N/A

16. Once you have captured your video images how difficult did you find compiling your knowledge contribution into a finished video using Adobe Premier Pro?

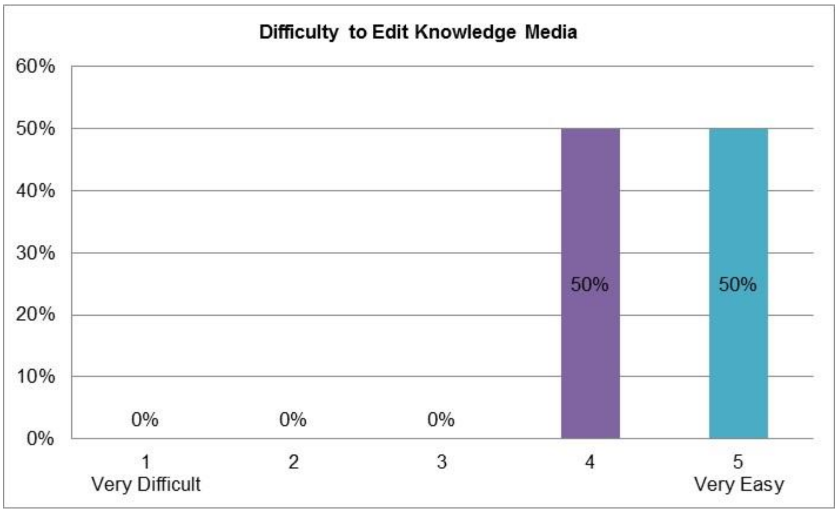


Figure 128. Difficulty to Edit Knowledge Media

17. As a complete process how difficult did you find the creation of your knowledge contribution?

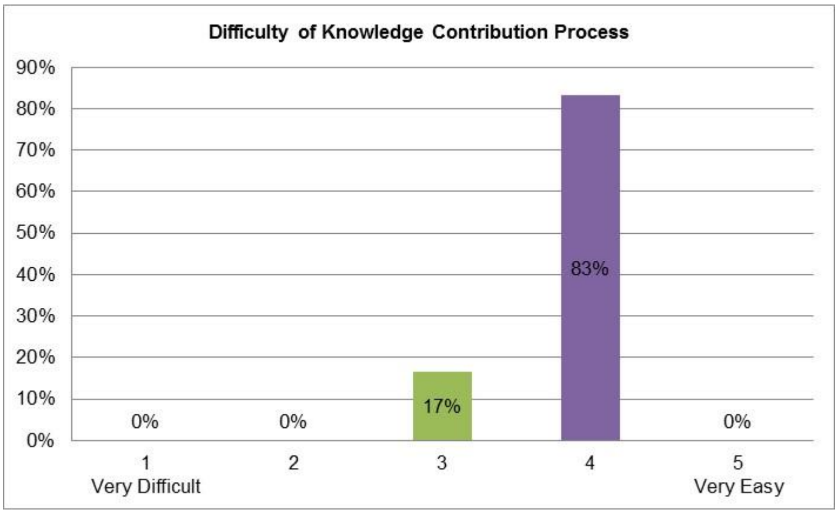


Figure 129. Difficulty of Knowledge Contribution Process

18. As a process do you have any additional comments / feedback towards your knowledge contribution experience?

The main problem has been 1. Access to the right Genset equipment on which knowledge contribution is on 2. Time to be set aside for capturing material content and editing.

Throughout it was good, with good administration ensuring suitability & quality, the knowledge contributions seem to show capabilities and would be useful for knowledge dissemination

Appendix J: Case Study: W/Shop Knowledge Receiver Questionnaire

This appendix contains the validation questionnaire used for the knowledge receiver's participants.

UNIVERSITY of GREENWICH

Power Generation

PhD project: A knowledge sharing framework for improving the testing processes in global product development @ Cummins Power Generation, Kent, UK

Research Questionnaire – Knowledge Receivers

My name is Joseph Zammit and I am conducting research in improving knowledge capture and sharing within a product development testing facility to reduce time to market for new product development for Cummins Power Generation. Consequently, I would appreciate your input to this project by providing some answers to the questions contained in this questionnaire. Any additional comments and advice are highly appreciated.

1. Job title?

Part 1: (Knowledge sharing platform)

2. Did you access the knowledge sharing platform http://www.cpgk-knowledgesharing.com?

   Yes, ☐
   No, ☐

3. How did you find the navigation of the knowledge sharing platform website page?

Very Difficult	1	2	3	4	5	Very Easy
	☐	☐	☐	☐	☐	

4. Did you access the training material provided on the knowledge sharing platform http://www.cpgk-knowledgesharing.com?

   Yes, ☐
   No, ☐

5. Was the training material easy to follow and did it aid you in understanding the task at hand?

Very Difficult	1	2	3	4	5	Very Easy
	☐	☐	☐	☐	☐	

6. How do you rate the quality of the training material provided?

Needs Improving	1	2	3	4	5	Good Quality
	☐	☐	☐	☐	☐	

7. Did you access knowledge contributions uploaded onto the knowledge sharing platform?

   Yes, ☐
   No, ☐

1

Figure 130. Case Study: W/Shop Knowledge Receiver Questionnaire Page 1

UNIVERSITY of GREENWICH

Power Generation

8. Did you find the information from the knowledge contribution informative and did you learn something out of it?

	1	2	3	4	5	
Very Difficult	❑	❑	❑	❑	❑	**Very Easy**

9. How would you rate the quality of the knowledge contributions available on the knowledge sharing platform?

	1	2	3	4	5	
Bad Quality	❑	❑	❑	❑	❑	**Good Quality**

10. What do you think should be improved in the knowledge contributions you have seen if anything?

11. Do you see value in having a knowledge sharing platform where you can view skills and processes captured by your colleagues?

Yes, ❑
No, ❑

12. What other topics / subjects would you like to see as a knowledge contribution that would be of interest to you?

13. In the comments section that has been shown how useful do you feel this tool would be to ask for clarifications or to challenge a knowledge contribution?

	1	2	3	4	5	
Un-Likely	❑	❑	❑	❑	❑	**Very Likely**

14. Would you use a system like this to search for certain knowledge?

	1	2	3	4	5	
Un-Likely	❑	❑	❑	❑	❑	**Very Likely**

15. Would you consider contributing to the system?

	1	2	3	4	5	
Un-Likely	❑	❑	❑	❑	❑	**Very Likely**

Thank you very much for your input and assistance in my research.

Joseph Zammit

2

Figure 131. Case Study: W/Shop Knowledge Receiver Questionnaire Page 2

Appendix K: Case Study: W/Shop Knowledge Receiver Questionnaire, Sample Response

This appendix contains a sample of the response received from the validation exercise of the knowledge receivers.

Part 1: (Knowledge sharing platform)

- Did you access the knowledge sharing platform http://www.cpgk-knowledgesharing.com?

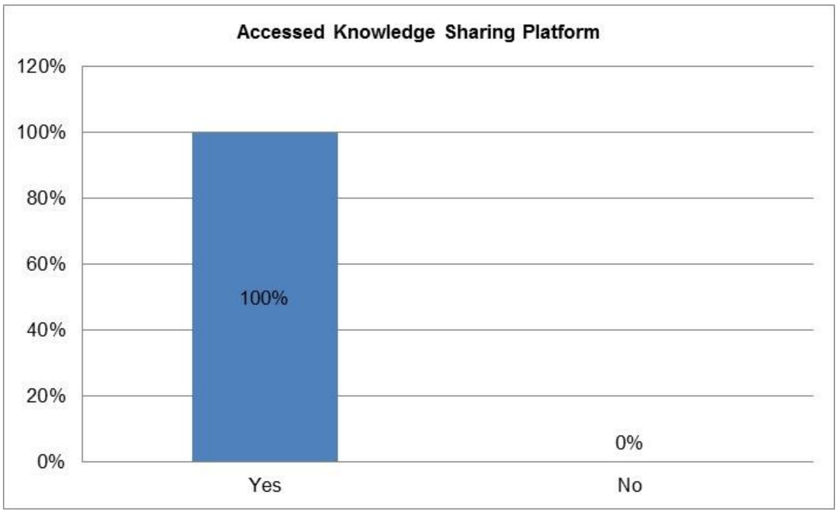


Figure 132. Accessed the Knowledge Sharing Platform

- How did you find the navigation of the knowledge sharing platform website page?

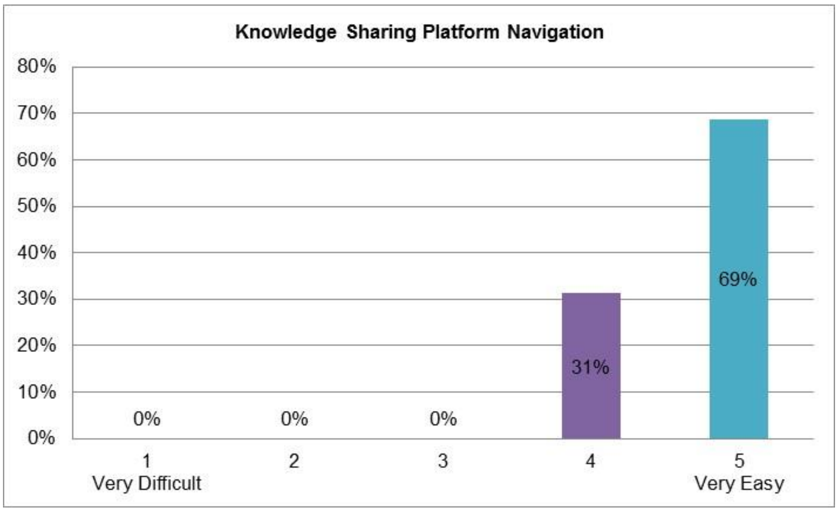


Figure 133. Difficulty to Navigate Through the Knowledge Sharing Platform

- Did you access the training material provided on the knowledge sharing platform http://www.cpgk-knowledgesharing.com?

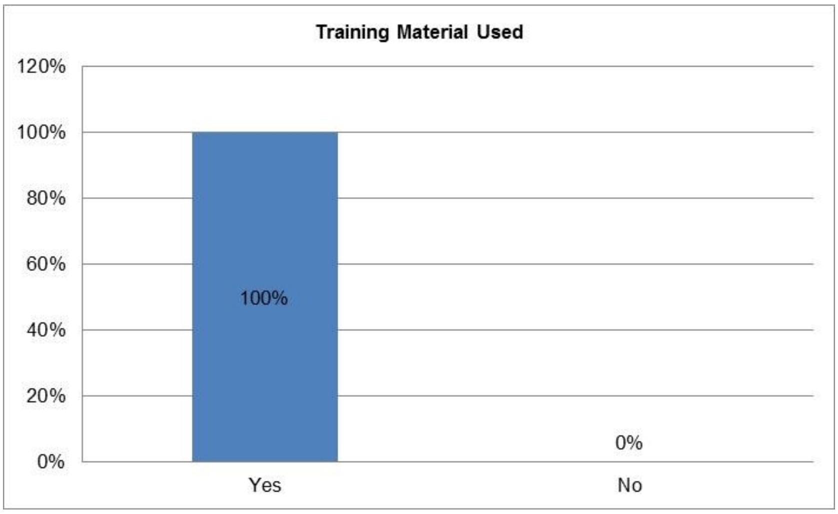


Figure 134. Use of Training Material

- Was the training material easy to follow and did it aid you in understanding the task at hand?

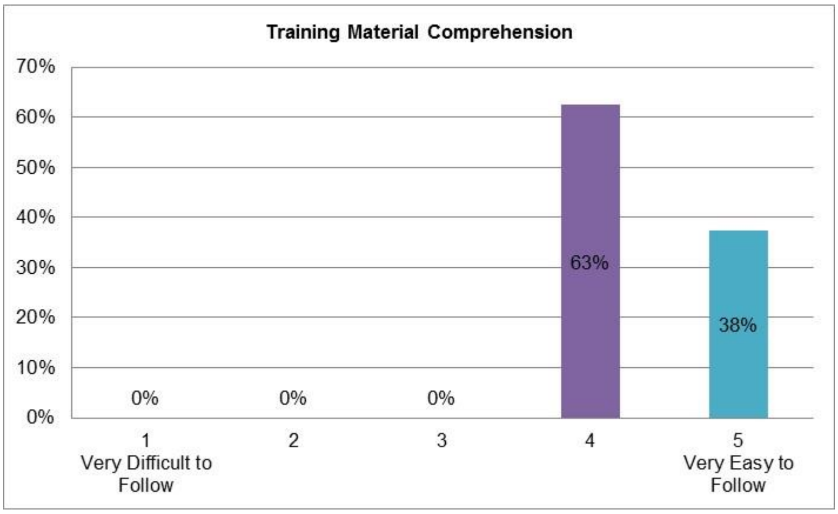


Figure 135. Difficulty to Follow Training Material

- How do you rate the quality of the training material provided?

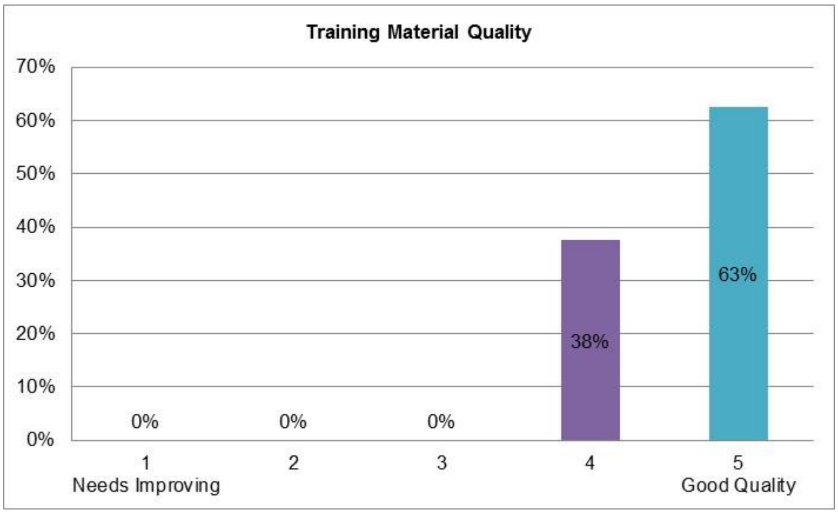


Figure 136. Quality of Developed Training Material

- Did you access knowledge contributions uploaded onto the knowledge sharing platform?

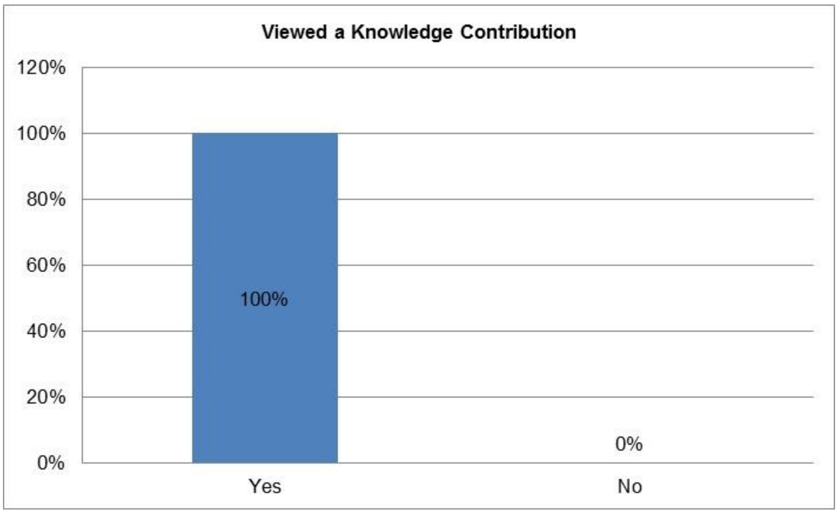


Figure 137. User Viewed Knowledge Contribution

- Did you find the information from the knowledge contribution informative and did you learn something out of it?

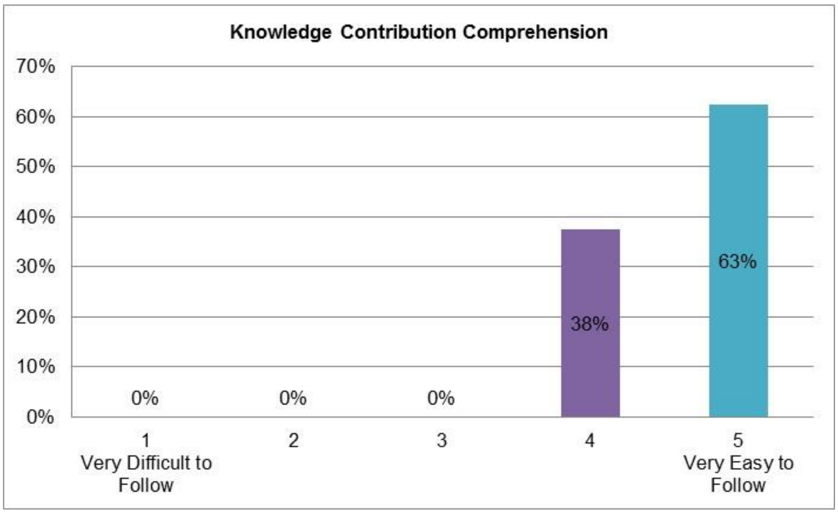


Figure 138. Knowledge Contribution Comprehension

- How would you rate the quality of the knowledge contributions available on the knowledge sharing platform?

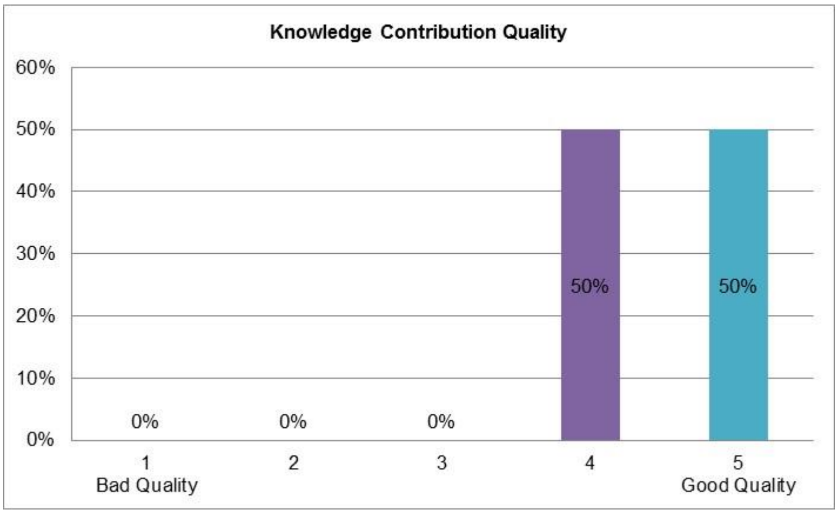


Figure 139. Knowledge Contribution Quality

- What do you think should be improved in the knowledge contributions you have seen if anything?
- People should be able to rate quality & usefulness of video,
- Sound quality dropped during the video so needs someone to edit / approve videos before being uploaded,
- No changes - to let the website grow and then reassess,
- Nothing really - clear and direct instruction were given, But infrastructure on the work place could be improved equipment labelling,
- As the number of contributions grows, it would be good to keep the style consistent.

- Do you see value in having a knowledge sharing platform where you can view skills and processes captured by your colleagues?

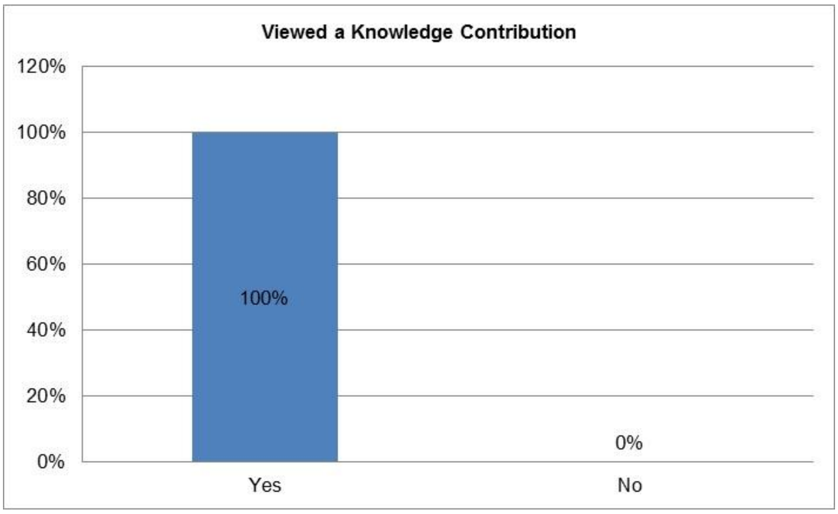


Figure 140. Value in Knowledge Sharing Platform

- What other topics / subjects would you like to see as a knowledge contribution that would be of interest to you?
- Vibration data post processing,
- R&T tests explained,
- How to access WI's and report forms on the system,
- How to use Ariba,
- CAD drawing techniques,
- PLM software usage,
- R&T Test request procedure,
- VPI & VPC processes,
- Design process all the way to validation,
- All Lab Ops / Applied tech testing,
- Lab Ops and Business unit's knowledge transfer.

- In the comments section that has been shown how useful do you feel this tool would be to ask for clarifications or to challenge a knowledge contribution?

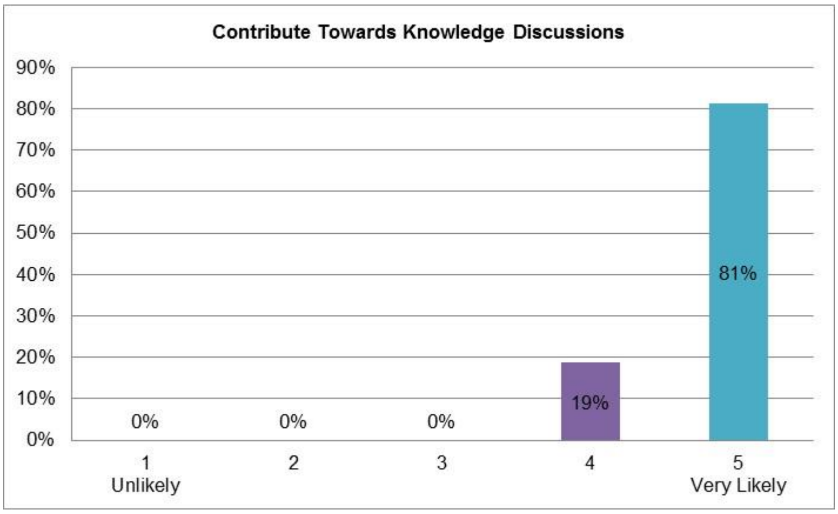


Figure 141. Likeliness to Contribute Towards Knowledge Discussions

- Would you use a system like this to search for certain knowledge?

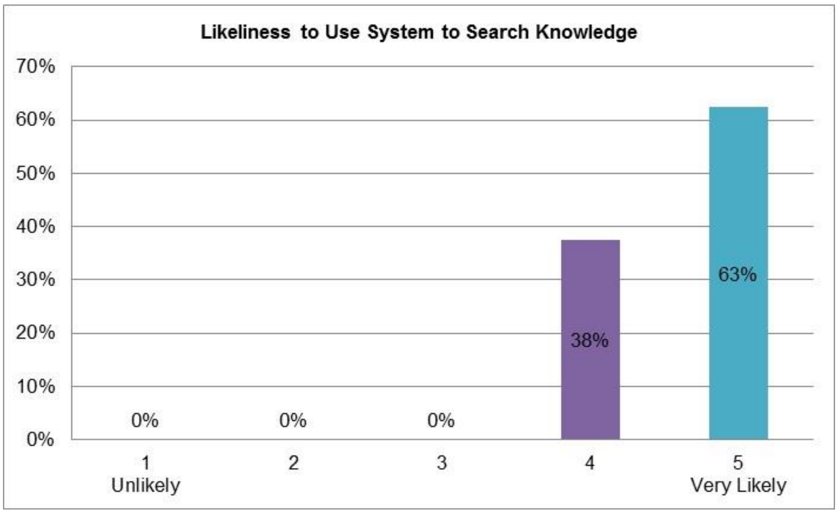


Figure 142. Likeliness to Use System to Search Knowledge

- Would you consider contributing to the system?

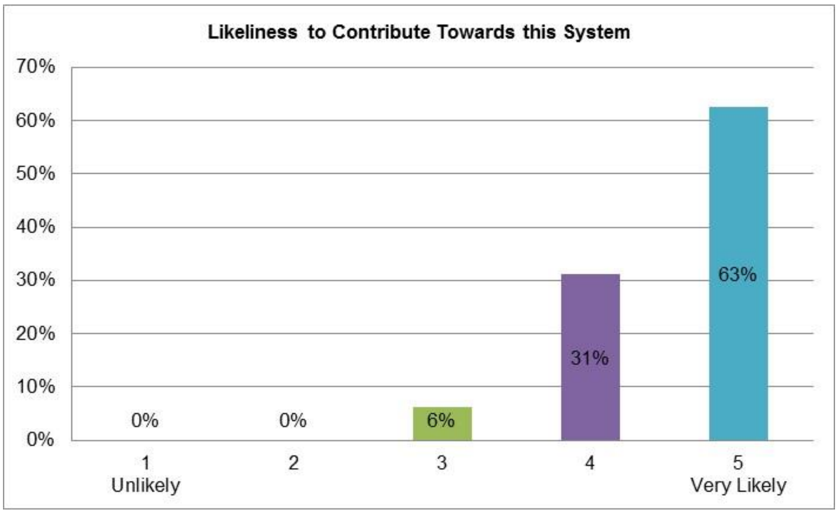


Figure 143. Likeliness to Contribute Towards this System

Appendix L: New Metrics Sheet Overview Presentation

This appendix contains instruction in the use of the implemented utilisation metric.

Figure 144. New Metrics Sheet Overview Slide 1

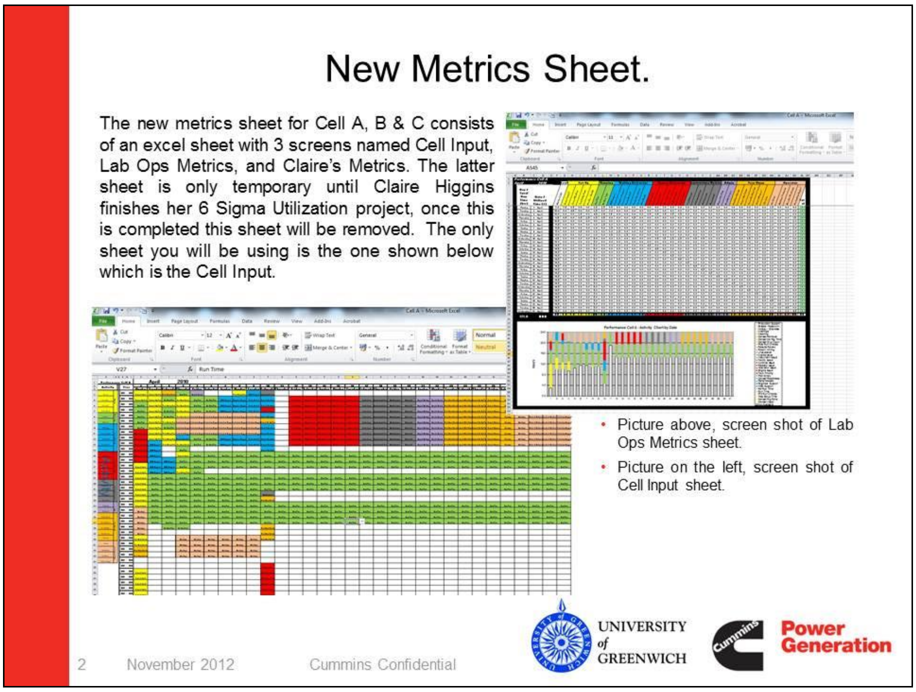


Figure 145. New Metrics Sheet Overview Slide 2

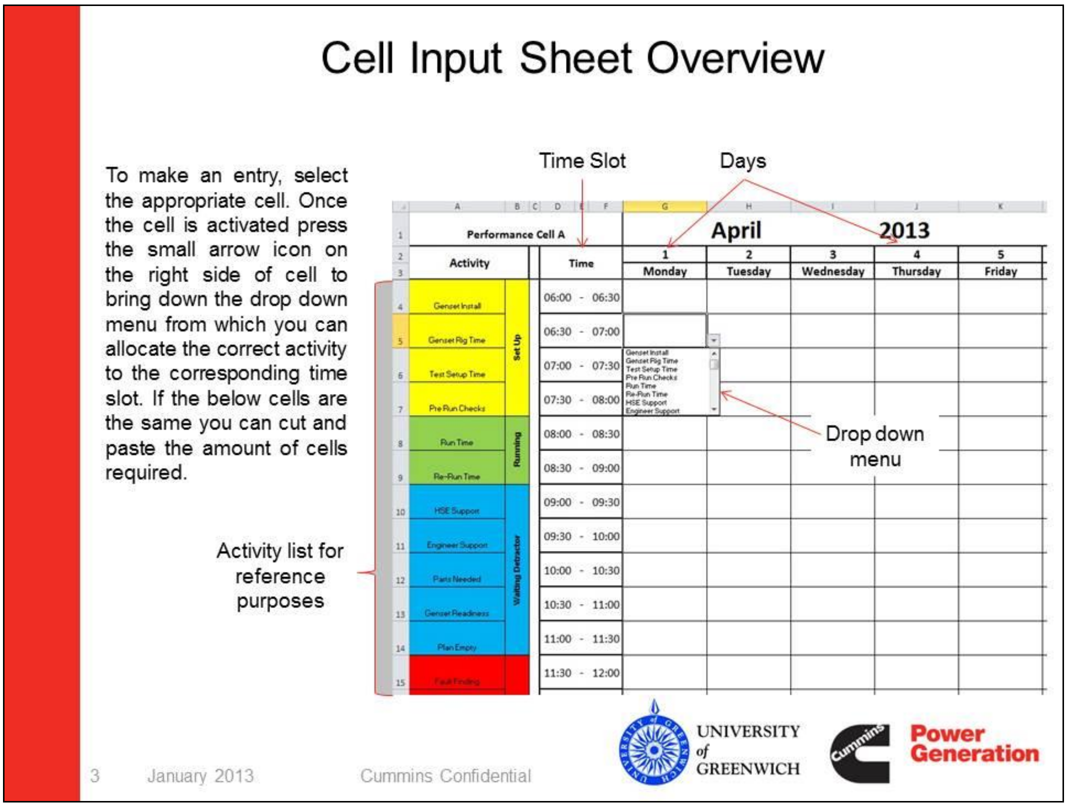


Figure 146. New Metrics Sheet Overview Slide 3

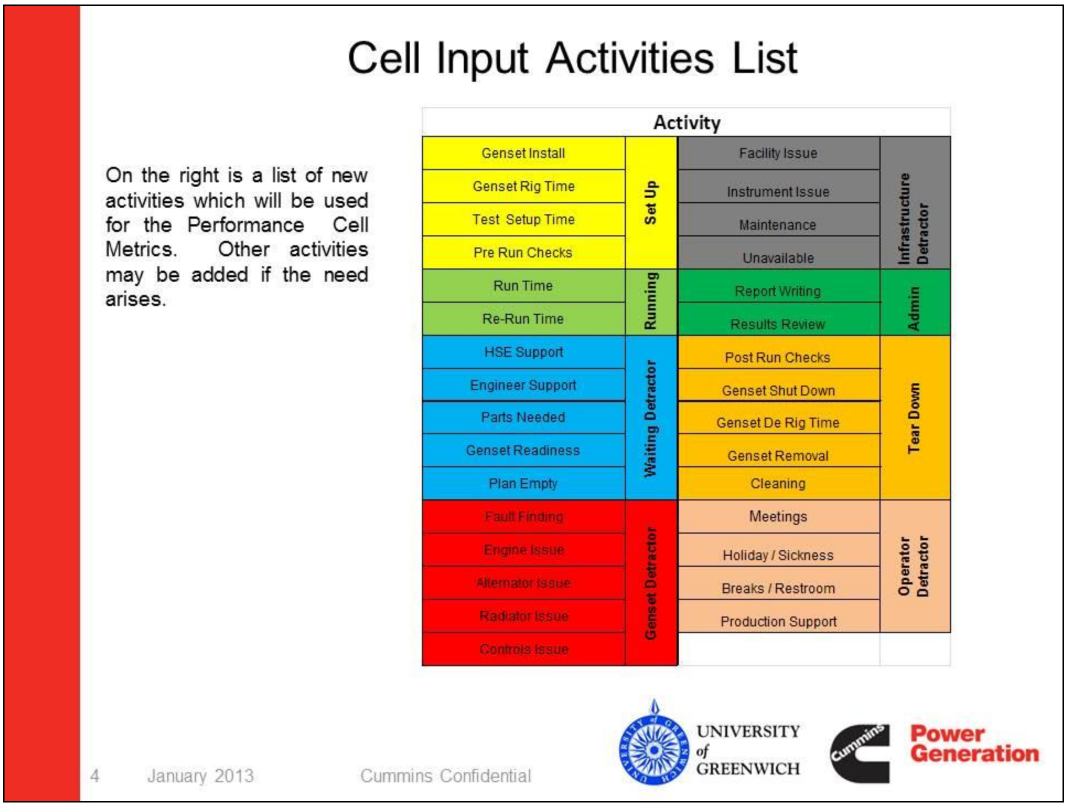


Figure 147. New Metrics Sheet Overview Slide 4

Figure 148. New Metrics Sheet Overview Slide 5

Appendix M: Intro to CPG-Knowledge Sharing Platform

This appendix contains instruction in the use of the CPGK-Knowledge Sharing Platform.

Figure 149. Intro to CPG-Knowledge Sharing Platform Slide 1

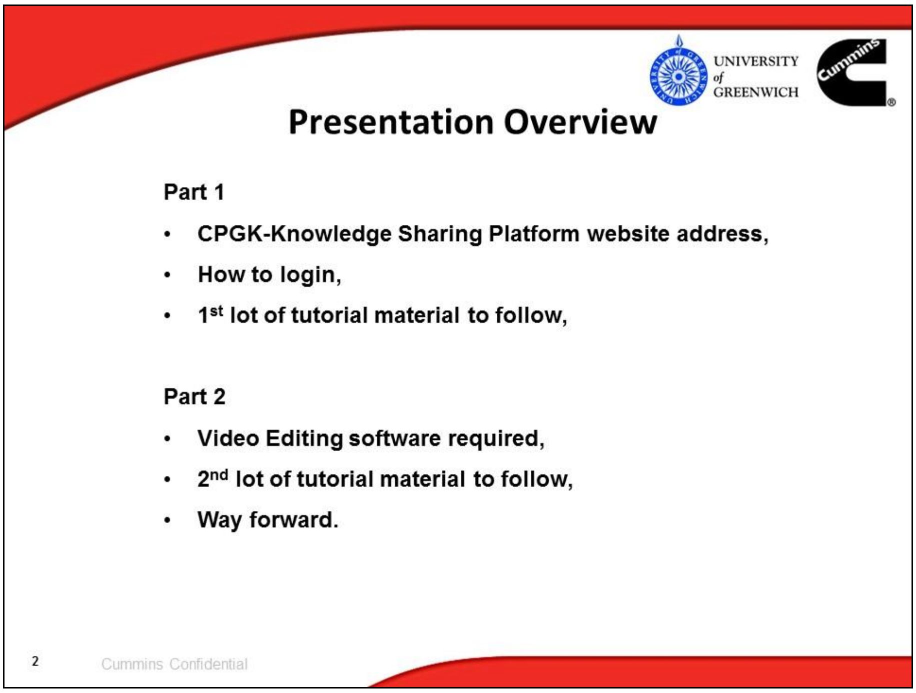


Figure 150. Intro to CPG-Knowledge Sharing Platform Slide 2

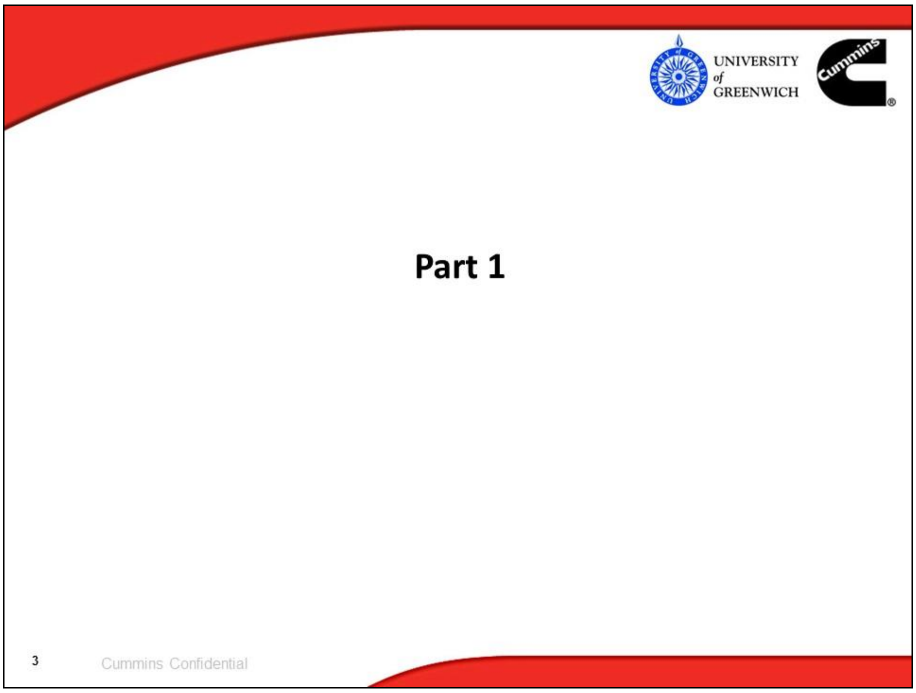


Figure 151. Intro to CPG-Knowledge Sharing Platform Slide 3

Figure 152. Intro to CPG-Knowledge Sharing Platform Slide 4

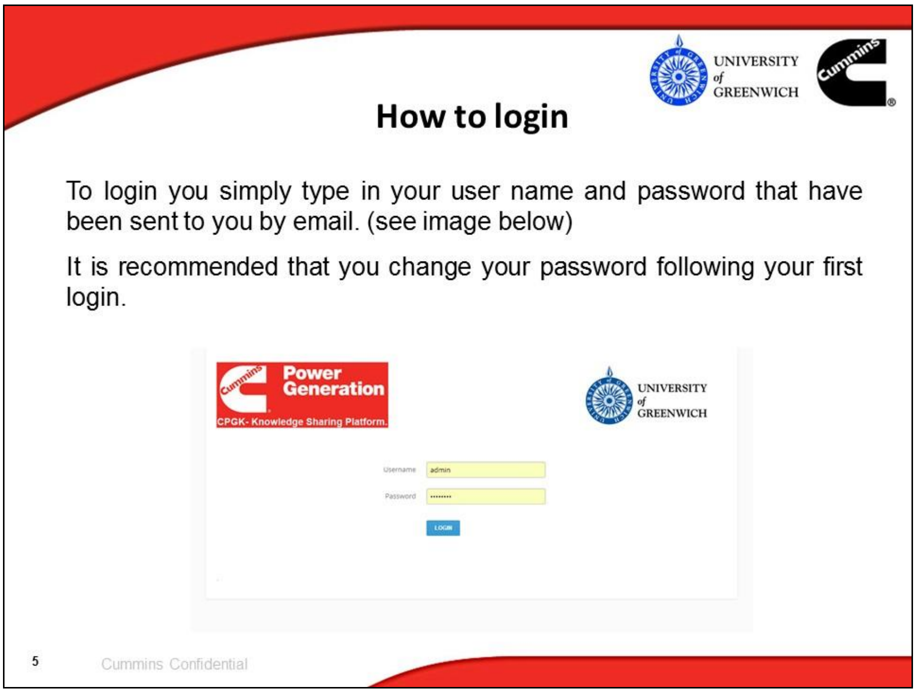


Figure 153. Intro to CPG-Knowledge Sharing Platform Slide 5

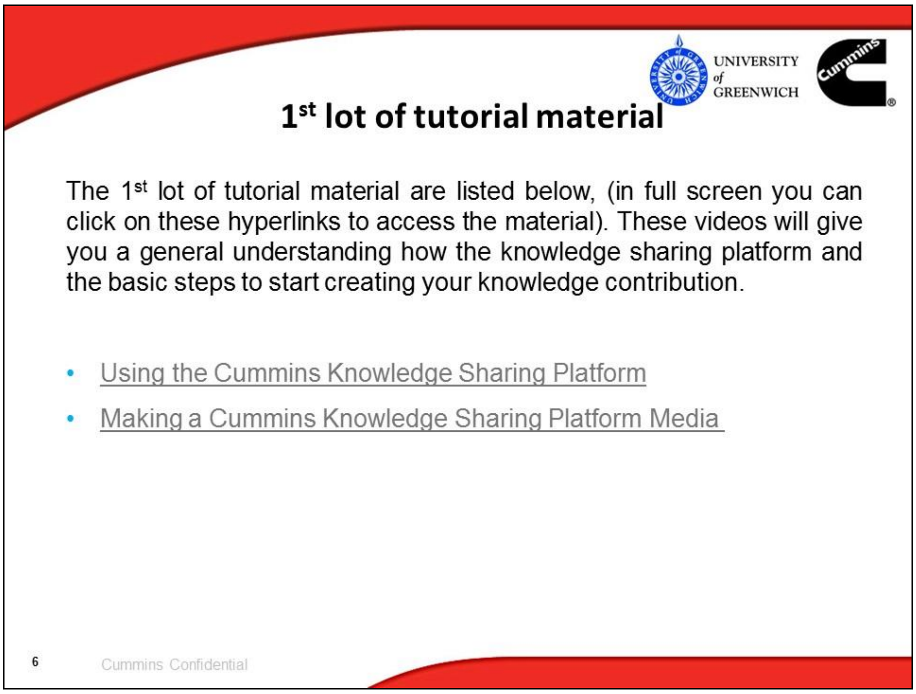


Figure 154. Intro to CPG-Knowledge Sharing Platform Slide 6

Figure 155. Intro to CPG-Knowledge Sharing Platform Slide 7

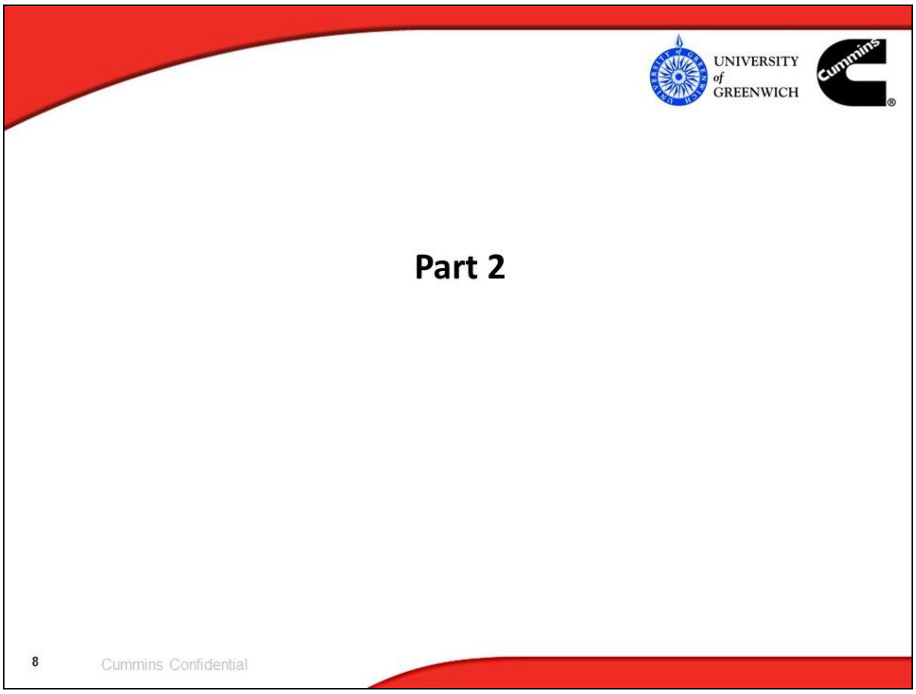


Figure 156. Intro to CPG-Knowledge Sharing Platform Slide 8

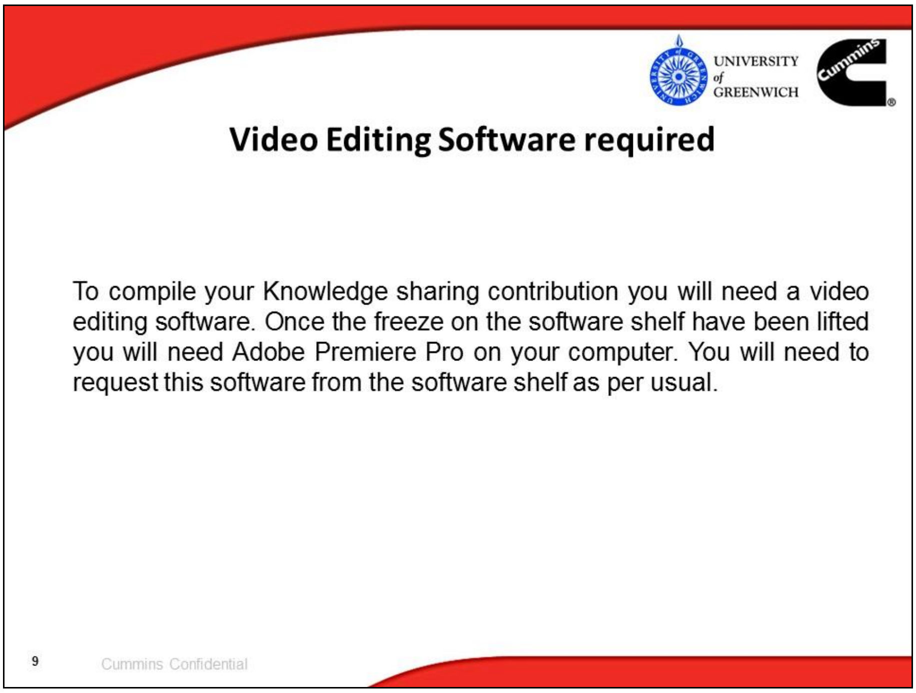


Figure 157. Intro to CPG-Knowledge Sharing Platform Slide 9

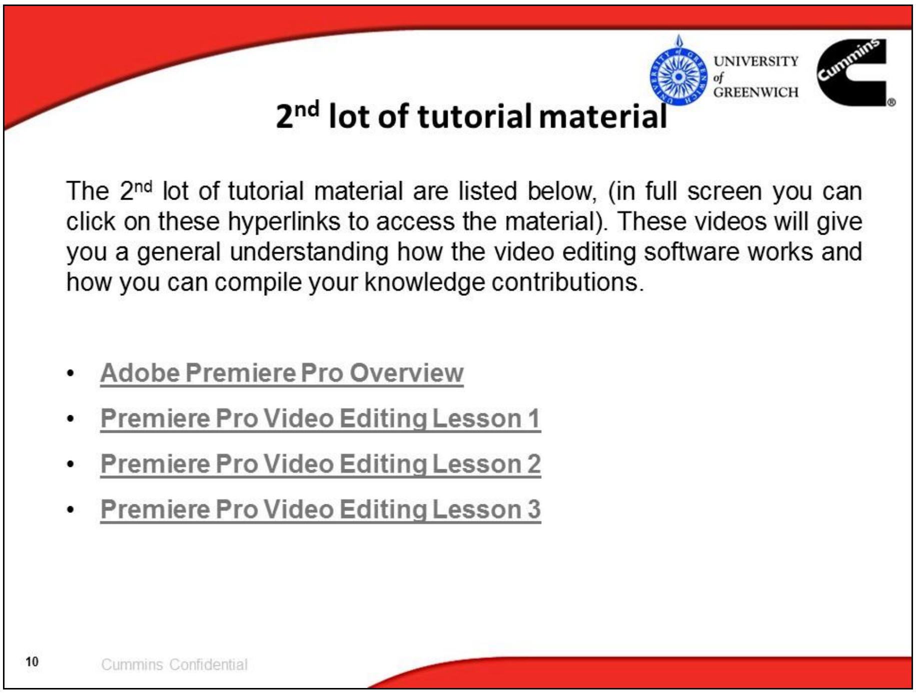


Figure 158. Intro to CPG-Knowledge Sharing Platform Slide 10

Figure 159. Intro to CPG-Knowledge Sharing Platform Slide 11

Figure 160. Intro to CPG-Knowledge Sharing Platform Slide 12

Figure 161. Intro to CPG-Knowledge Sharing Platform Slide 13

Appendix N: Knowledge Contribution: Example 1

This appendix contains screen shots of a knowledge contribution example created during the project.

Figure 162. Knowledge Contribution: Example 1 Screen Shot 1

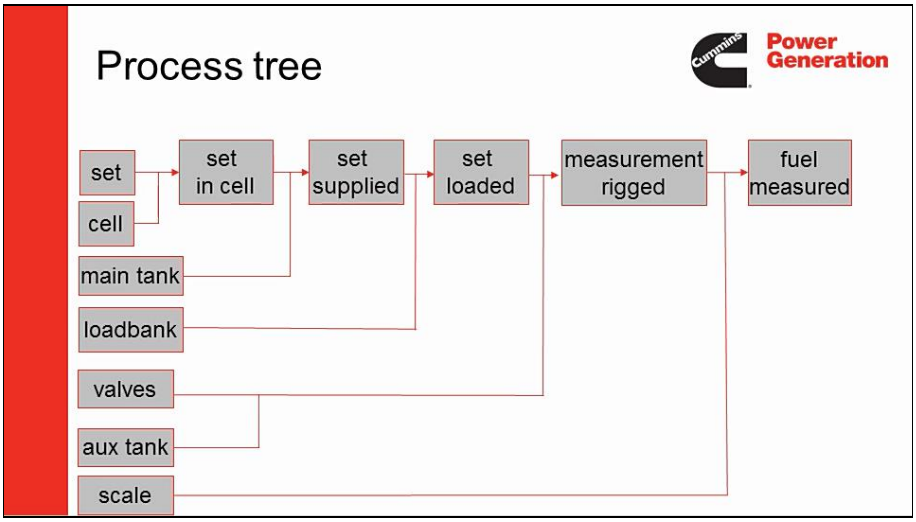


Figure 163. Knowledge Contribution: Example 1 Screen Shot 2

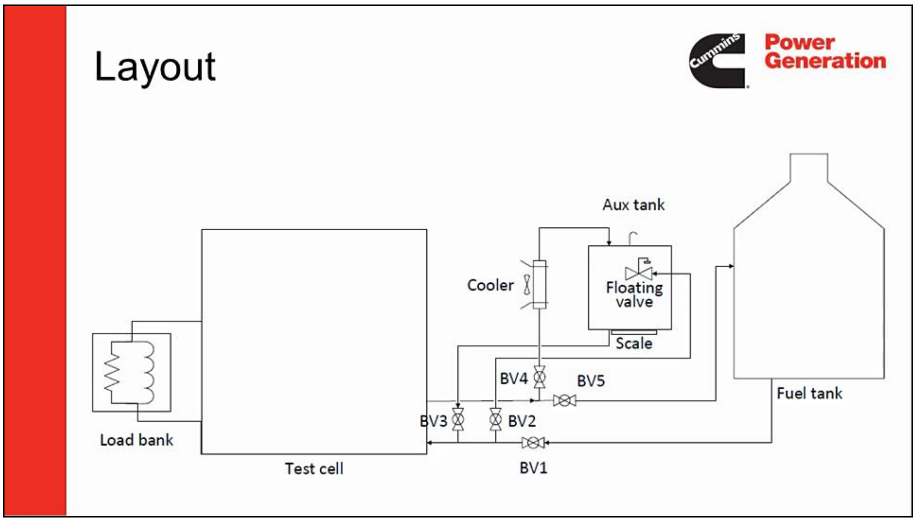


Figure 164. Knowledge Contribution: Example 1 Screen Shot 3

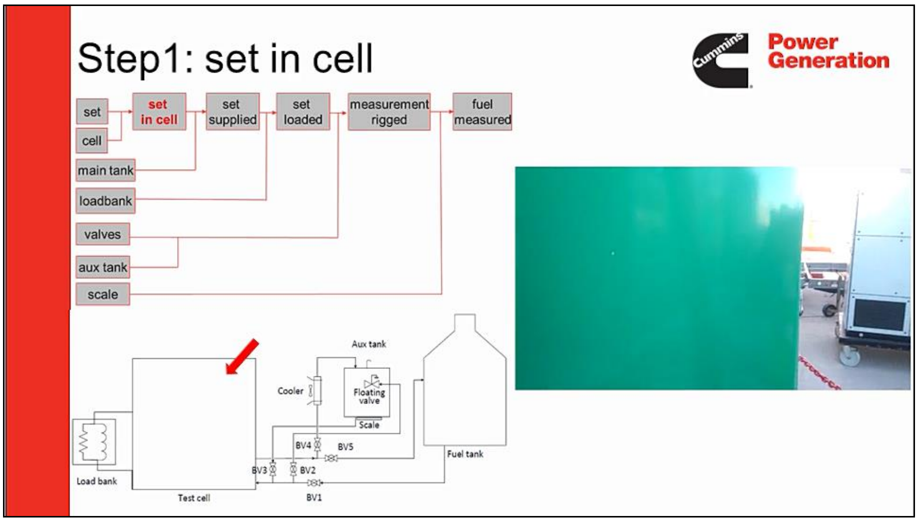


Figure 165. Knowledge Contribution: Example 1 Screen Shot 4

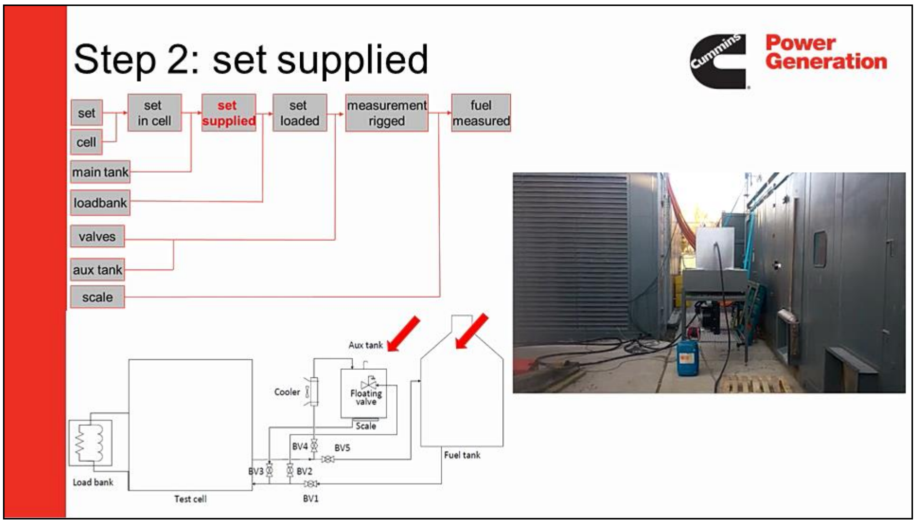


Figure 166. Knowledge Contribution: Example 1 Screen Shot 5

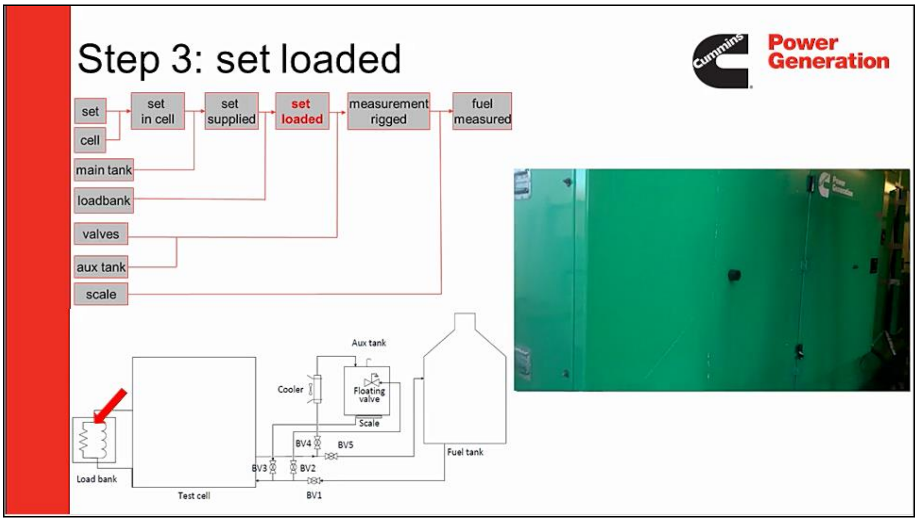


Figure 167. Knowledge Contribution: Example 1 Screen Shot 6

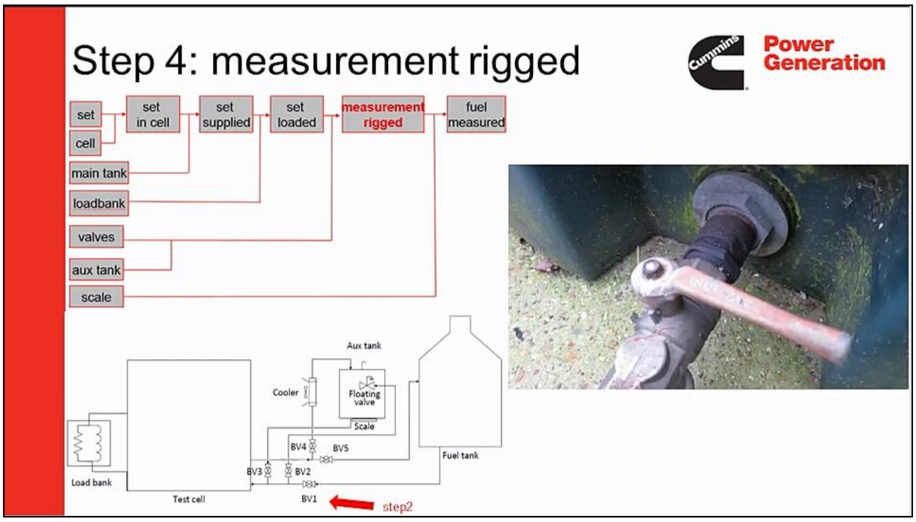


Figure 168. Knowledge Contribution: Example 1 Screen Shot 7

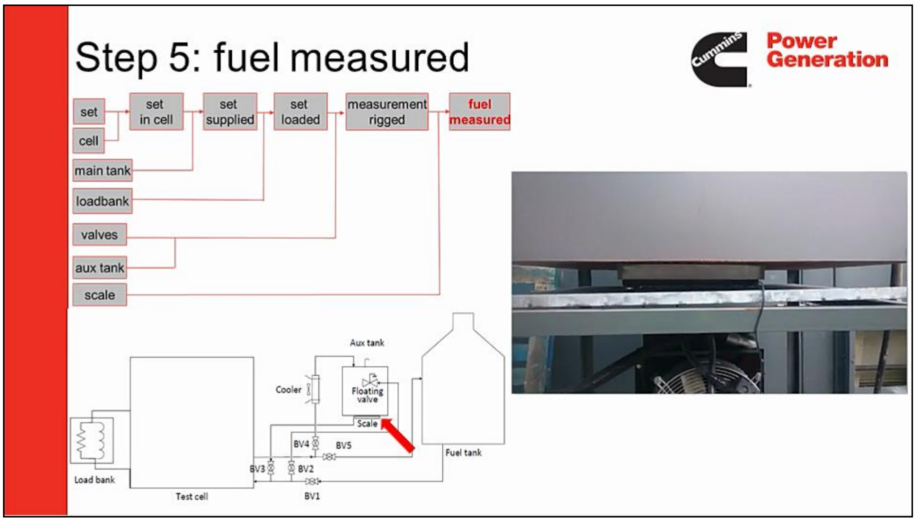


Figure 169. Knowledge Contribution: Example 1 Screen Shot 8

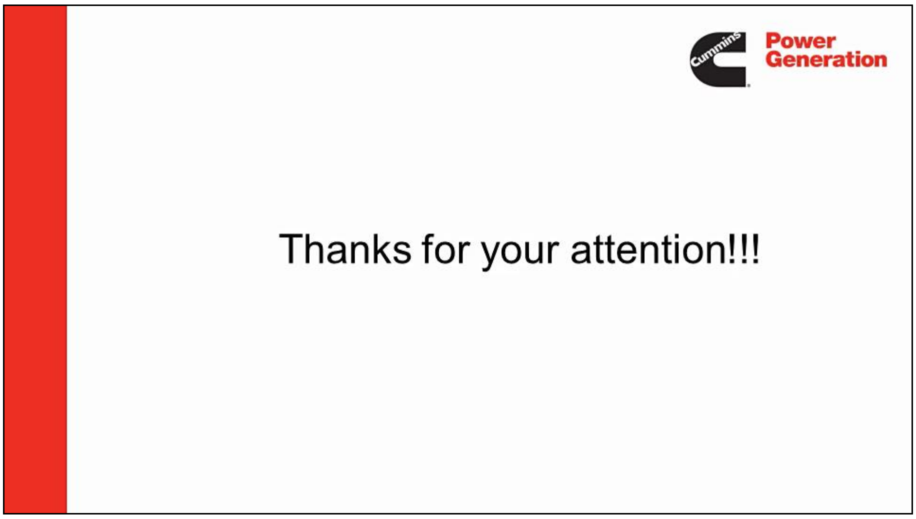


Figure 170. Knowledge Contribution: Example 1 Screen Shot 9

Appendix O: Knowledge Contribution: Example 2

This appendix contains screen shots of a knowledge contribution example created during the project.

Figure 171. Knowledge Contribution: Example 2 Screen Shot 1

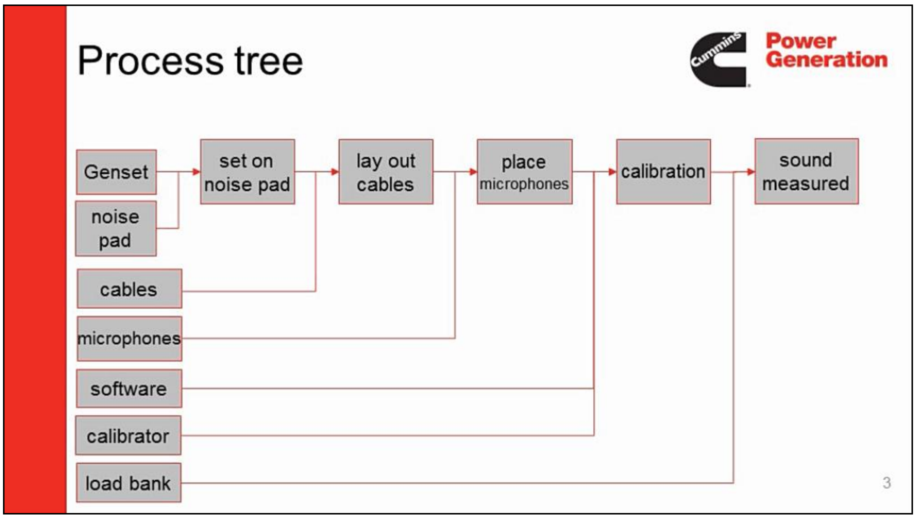


Figure 172. Knowledge Contribution: Example 2 Screen Shot 2

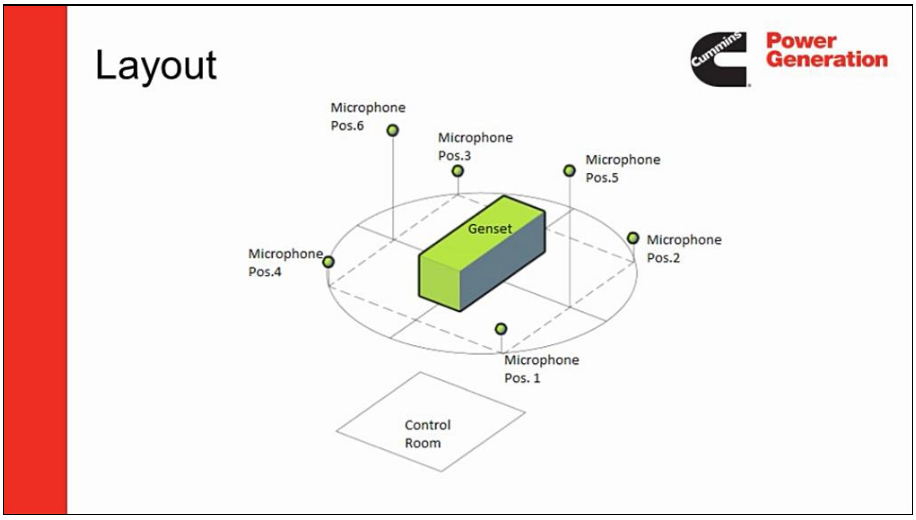


Figure 173. Knowledge Contribution: Example 2 Screen Shot 3

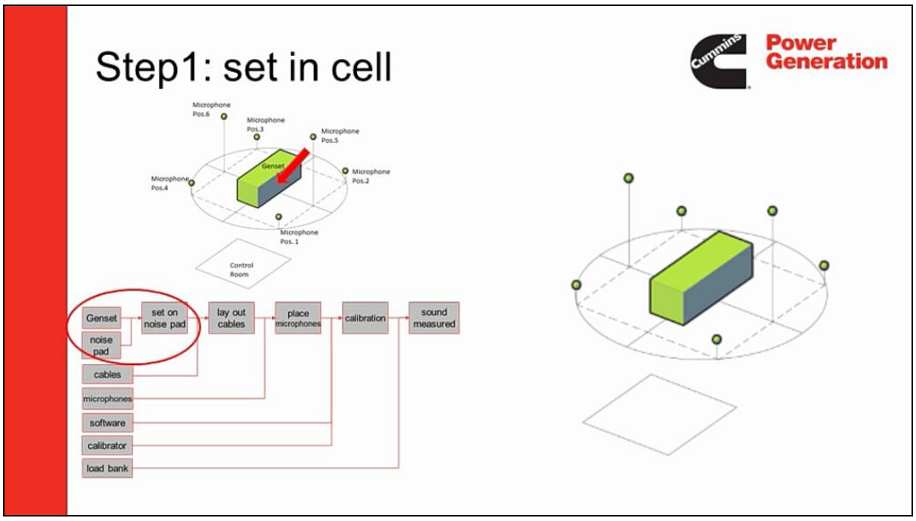


Figure 174. Knowledge Contribution: Example 2 Screen Shot 4

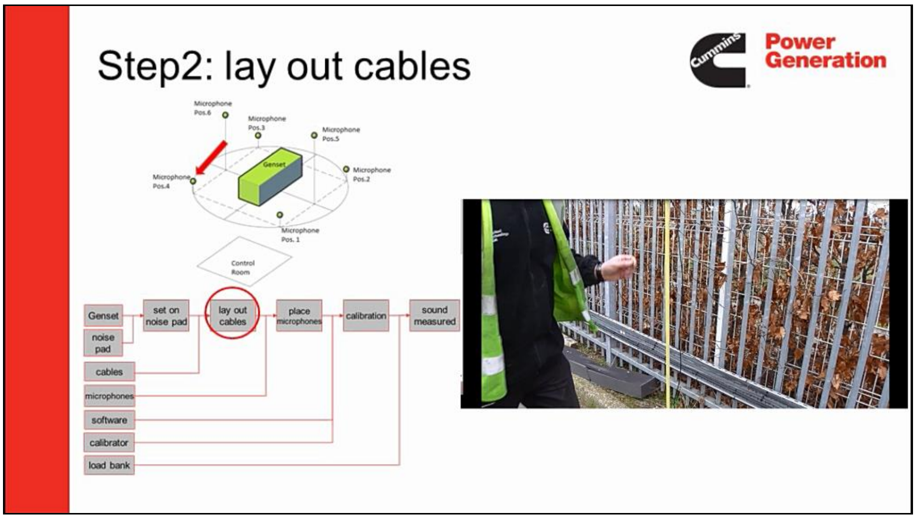


Figure 175. Knowledge Contribution: Example 2 Screen Shot 5

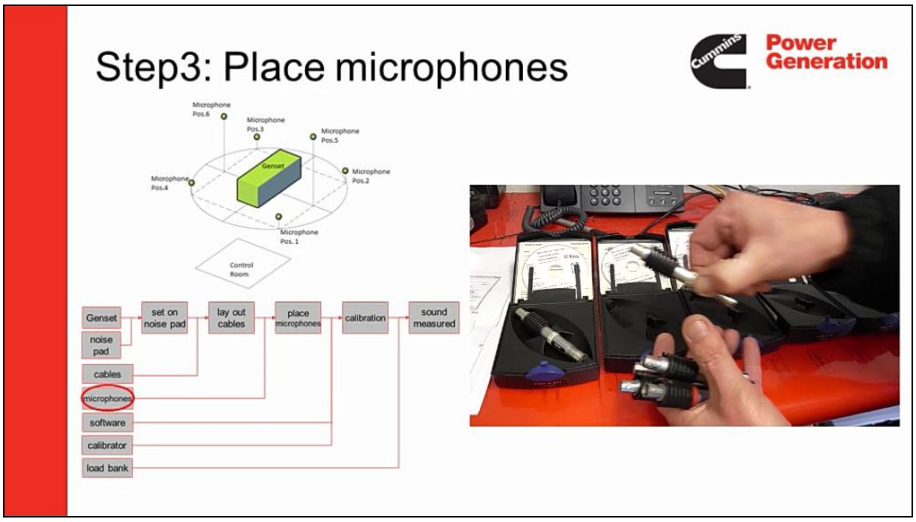


Figure 176. Knowledge Contribution: Example 2 Screen Shot 6

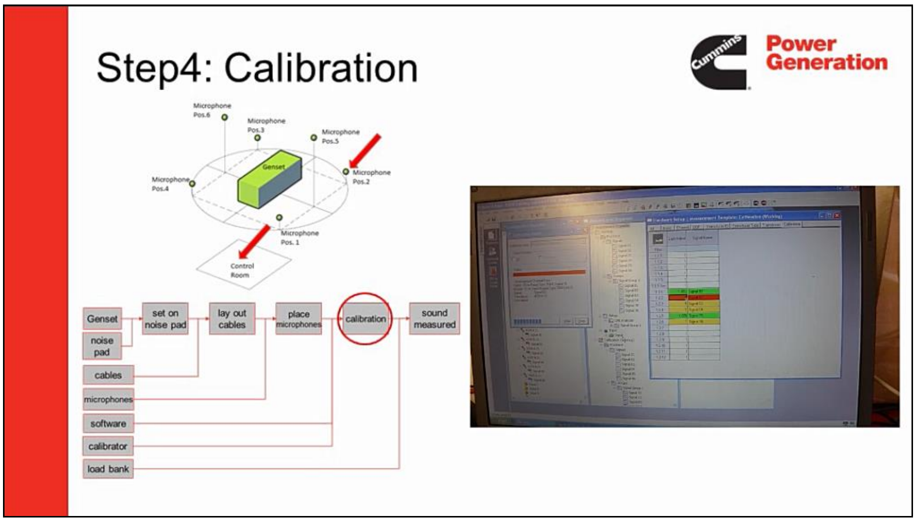


Figure 177. Knowledge Contribution: Example 2 Screen Shot 7

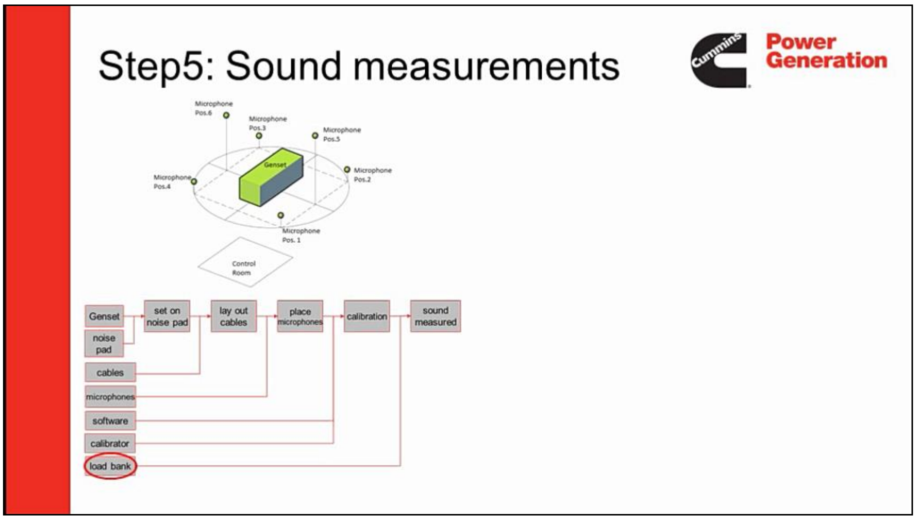


Figure 178. Knowledge Contribution: Example 2 Screen Shot 8

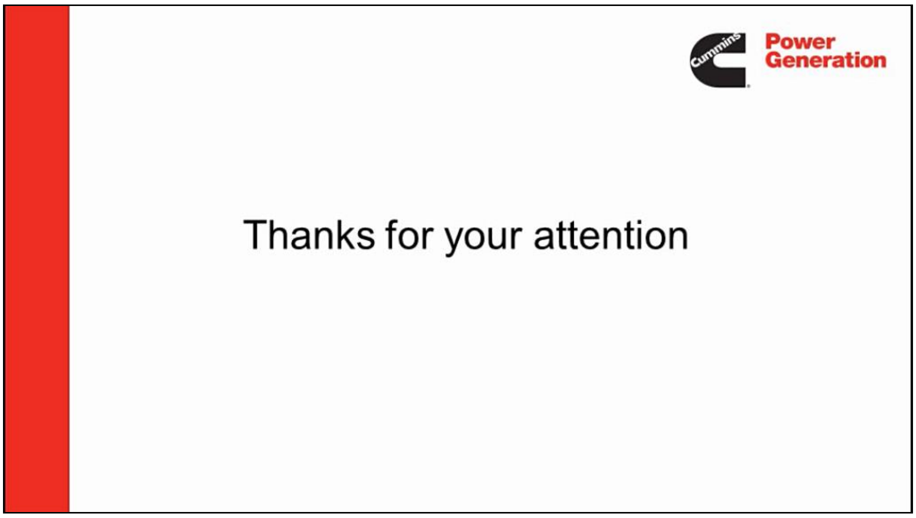


Figure 179. Knowledge Contribution: Example 2 Screen Shot 9

Appendix P: Developed Utilization Metrics Iterations

This appendix contains figures to explain the developed utilization metrics.

WK 1

	Cell C					
	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
07:00 - 07:30	/	/	/	/	/	
07:30 - 08:00	18	5	4	5	23	
08:00 - 08:30	7	18	4	18	23	
08:30 - 09:00	7	13	4	17	23	
09:00 - 09:30	21	21	4	17	23	
09:30 - 10:00	21	21	4	17	23	
10:00 - 10:30	19, 4	21	4	21	23	
10:30 - 11:00	4	4	4	21	23	
11:00 - 11:30	4	4	4	21	23	
11:30 - 12:00	4	10	4	21	23	
12:00 - 12:30	20	10	4	20	23, 11	
12:30 - 13:00	19, 22	10	4	21		
13:00 - 13:30	19, 22	10	4	21		
13:30 - 14:00	19	10	4	21		
14:00 - 14:30	19	10	4	21		
14:30 - 15:00	19	10	4	21		
15:00 - 15:30	1	10	4	21		
15:30 - 16:00	1	10	4	19		
16:00 - 16:30	/	/	/	/		

No.	Task
1	Cleaning
2	EBU Testing
3	Engineering
4	Equipment Issue
5	Facilities
6	Genset Install
7	Genset Issues
8	Get Equipment
9	Logistics
10	Materials / Parts
11	Meetings
12	Holiday / Sickness
13	Paperwork
14	Prod Test Support
15	QSI / inpower
16	Re-Test
17	Rigging
18	Set Check
19	Set Shut Down
20	Tea/Bathroom Break
21	Testing
22	Fault finding
23	Waiting for info from other depts

Figure 180. Utilization monitoring time sheet with categories issues list.

Detractor	Activity
Set Up	Genset Install
	Genset Rig Time
	Test Setup Time
	Pre Run Checks
Running	Run Time
	Re-Run Time
Waiting Detractor	HSE Support
	Engineer Support
	Parts Needed
	Genset Readiness
	Plan Empty
Genset Detractor	Fault Finding
	Engine Issue
	Alternator Issue
	Radiator Issue
	Controls Issue
Infrastructure Detractor	Facility Issue
	Instrument Issue
	Maintenance
	Unavailable
Admin	Report Writing
	Results Review
Tear Down	Post Run Checks
	Genset Shut Down
	Genset De Rig Time
	Genset Removal
	Cleaning
Operator Detractor	Meetings
	Holiday / Sickness
	Breaks / Restroom
	Production Support

Figure 181. Initial list of waste detractors for utilization time sheet

Performance Cell A

Activity		Running	Waiting Detractor	Genset Detractor
Pre Run Checks				
Run Time		Running		
Re-Run Time		Running		
HSE Support			Waiting Detractor	
Engineer Support			Waiting Detractor	
Parts Needed			Waiting Detractor	
Genset Readiness			Waiting Detractor	
Plan Empty			Waiting Detractor	
Fault Finding				Genset Detractor
Engine Issue				Genset Detractor
Alternator Issue				Genset Detractor
Radiator Issue				Genset Detractor

Week 15

Time	Sunday 7	Monday 8	Tuesday 9	Wednesday 10	Thursday 11	Friday 12	Saturday 13	Sunday 14
07:30 - 08:00								
08:00 - 08:30					Genset De Rig Time	Genset De Rig Time	Genset De Rig Time	Genset De Rig
08:30 - 09:00		Engineer Support	Test Setup Time	Engine Issue	Genset De Rig Time	Genset De Rig Time	Genset De Rig Time	Genset De Rig
09:00 - 09:30		Engineer Support	Run Time	Engine Issue	Genset De Rig Time	Genset De Rig Time	Genset De Rig Time	Genset Rem
09:30 - 10:00		Test Setup Time	Run Time	Engine Issue	Run Time	HSE Support	Genset De Rig Time	Genset Rem
10:00 - 10:30		Test Setup Time	Run Time	Engine Issue	Run Time	Genset De Rig Time	Genset De Rig Time	Genset Rem
10:30 - 11:00		Test Setup Time	Run Time	Engine Issue	Run Time	Genset De Rig Time	Genset De Rig Time	Cleaning
11:00 - 11:30		Test Setup Time	Test Setup Time	Engine Issue	Instrument Issue	Genset De Rig Time	Genset De Rig Time	Cleaning
11:30 - 12:00		Run Time	Engine Issue	Engine Issue	Instrument Issue	Genset De Rig Time	Genset De Rig Time	Genset Inst
12:00 - 12:30		Breaks / Restroom	Breaks / Restroom	Engine Issue	Breaks / Restroom	Breaks / Restroom	Genset De Rig Time	Genset Inst
12:30 - 13:00		Meetings	Engine Issue	Engine Issue	Run Time	Meetings	Genset De Rig Time	Genset Inst
13:00 - 13:30		Engineer Support	Run Time	Engine Issue	Run Time	Meetings		
13:30 - 14:00								

Figure 182. Automated utilization timesheet - Cell input sheet

Performance Cell A April 2013		Lead	Set Up				Running		Waiting Detractor					Genset Detractor					Infrastructure Detractor				Admin		Tear Down					Operator Detractor				
Day / Total Run Time (hrs)	Date / Utilized Time (%)	Not Available	Genset Install	Genset Rig Rime	Test Setup Time	Pre Run Checks	Run Time	Re-Run Time	HSE Support	Engineer Support	Parts Needed	Genset Readiness	Plan Empty	Fault Finding	Engine Issue	Alternator Issue	Radiator Issue	Controls Issue	Facility Issue	Instrument Issue	Maintenance	Unavailable	Report Writing	Results Review	Post Run Checks	Genset Shut Down	Genset De Rig Time	Genset Removal	Cleaning	Meetings	Holiday / Sickness	Breaks / Restroom	Production Support	Total
Monday	1 April	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5
Tuesday	2 April	1.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.0	8.5
Wednesday	3 April	1.0	0.0	0.0	2.5	0.0	1.5	0.0	0.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	8.5
Thursday	4 April	1.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	8.5
Friday	5 April	1.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	5.5
Saturday	6 April																																	
Sunday	7 April																																	
Monday	8 April	1.0	0.0	0.0	2.0	0.0	3.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	8.5
Tuesday	9 April	1.0	0.0	0.0	1.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	8.5
Wednesday	10 April	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5
Thursday	11 April	0.5	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.5	0.0	8.5
Friday	12 April	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.5	0.0	0.5	0.0	5.5
Saturday	13 April																																	
Sunday	14 April																																	
Monday	15 April	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	8.5
Tuesday	16 April	1.0	0.0	2.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.5	1.0	8.5
Wednesday	17 April	1.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	8.5
Thursday	18 April	1.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	8.5
Friday	19 April	0.5	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5
Saturday	20 April																																	
Sunday	21 April																																	
Monday	22 April	0.5	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5
Tuesday	23 April	0.5	0.0	0.0	3.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5
Wednesday	24 April	0.5	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5
Thursday	25 April	0.5	0.0	0.0	2.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	8.5
Friday	26 April	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.5	0.0	0.5	0.0	5.5
Saturday	27 April																																	
Sunday	28 April																																	
Monday	29 April	0.5	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5
Tuesday	30 April	0.5	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	8.5
34.0	19.43%	23.5	0.0	12.5	31.0	0.0	34.0	0.0	0.5	9.5	22.0	0.0	0.0	0.0	14.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	11.0	0.0	1.0	5.5	0.0	8.0	1.0	175.0

Figure 183. Automated utilization timesheet - Automated summation

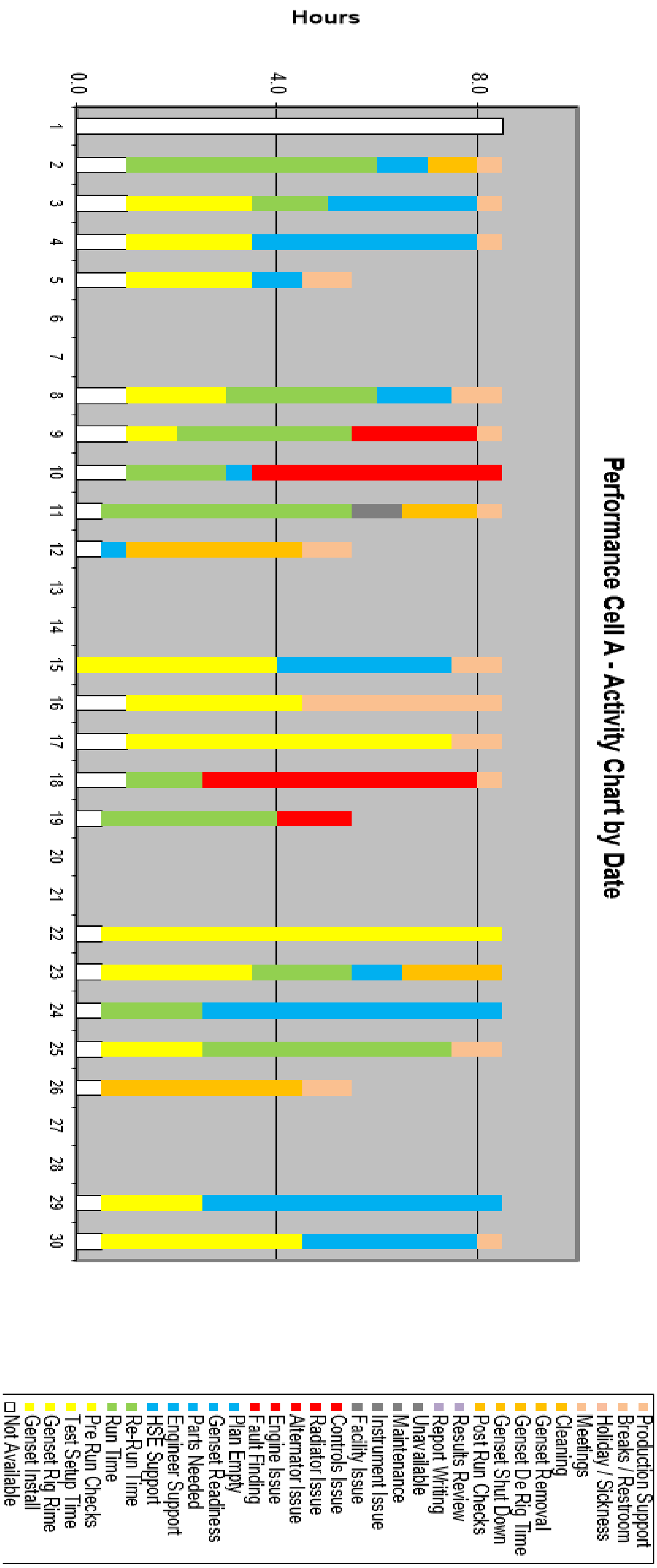


Figure 184. Automated utilization timesheet - Graphical presentation of monthly activities

Appendix Q: End User Guide

This section presents an end user guide for the developed knowledge sharing framework. The main functionality and operating parameters to use this knowledge sharing framework are broken down into easy to follow steps and explained in detail. The user guide forms part of the framework and is also a proof of the developed methodology and tools for real applications.

Extensive training material to use the knowledge sharing framework has already been created using the developed methodology and stored in the knowledge repository, which has been adopted by knowledge contributors during the proof of concept phase. This section will supplement this pre-existing training material.

Introduction to End User Guide

This Chapter provides an end user guide for the knowledge sharing framework. The following steps in the developed methodology have been identified as key points required to search the system for knowledge and create knowledge contributions that can be shared with the engineering community at the collaborating company.

An extensive user guide has been created using the developed methodology in the form of knowledge contributions under training material. These can be accessed by visiting the knowledge sharing platform at www.CPGK-knoweldgesharing.com. This training material was utilized by the selected knowledge contributors during the system case study. The end user guide instructions are only a brief supplement of this training material.

The identified steps that will be described in this Chapter are:

- Logging into the Knowledge Sharing Platform;

- Accessing the Knowledge Sharing Platform training material;
- Creating a knowledge request;
- Creating a knowledge request form;
- Creating a knowledge contribution;
- Knowledge contribution approval and upload to the knowledge sharing platform process;
- Searching the knowledge sharing platform; and
- Knowledge discussions.

Logging onto the Knowledge Sharing Platform

To access the CPGK – Knowledge Sharing Platform users need to open their internet browsers and navigate to the website: www.cpgk-knowledgesharing.com. A log in page, shown in Figure 185, will be displayed in which the user must fill in their user name and password. This log in information has been created by the administrator has been sent out to users, with a brief presentation providing instructions on how to access the knowledge sharing platform and instructions to reach the training material uploaded on to the site.

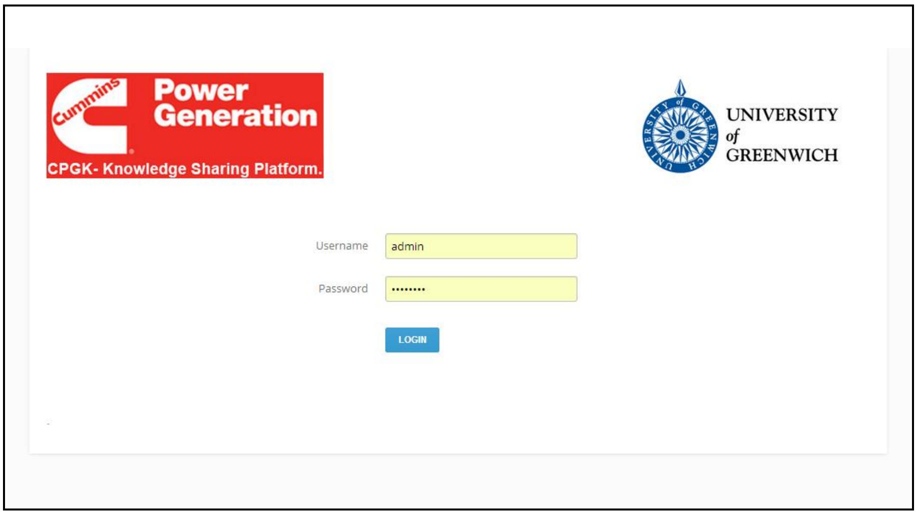


Figure 185. CPGK - Knowledge Sharing Platform Log in page

Once logged in, the user will be redirected to the main page shown in Figure 186, where the main functions of the knowledge repository can be found. These include a search bar, user settings, menu bar, providing the main storage categories and functions of the site, a randomly selected video, a list of top videos, and any new videos which have been recently uploaded onto the system.

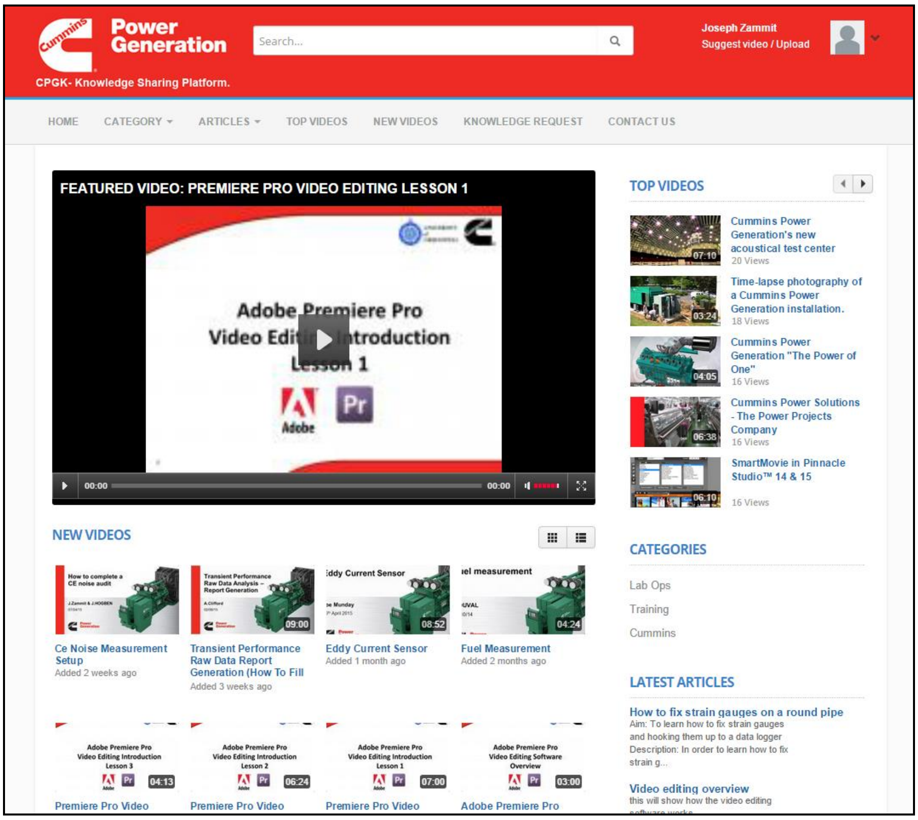


Figure 186. CPGK - Knowledge Sharing Platform main page

It is advised that the user should follow the training material provided before continuing use.

Accessing the Knowledge Sharing Platform Training Material

The provided training material can be accessed by selecting from the menu bar category > training. This will list all training material. Alternatively, users can type in ‘training’ in to the search facility and all material tagged as ‘training’ will be listed, as shown in Figure 187 and Figure 188.

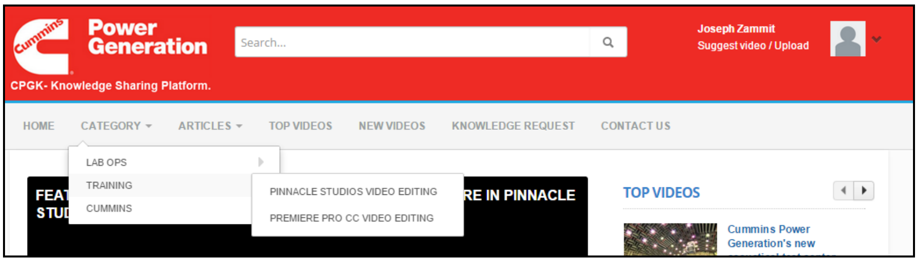


Figure 187. CPGK - Knowledge Sharing Training Material

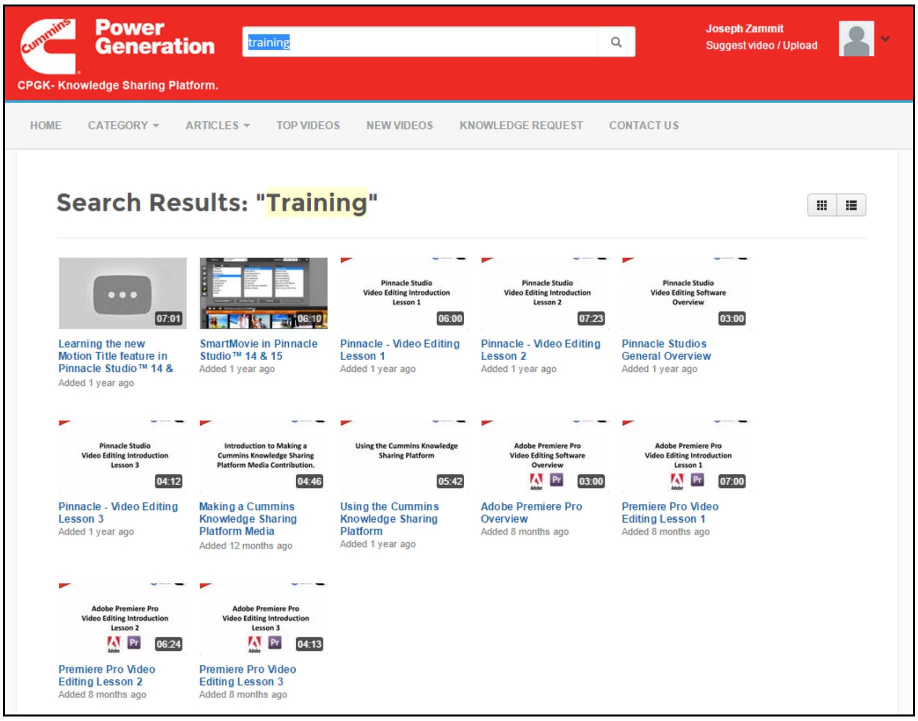


Figure 188. GPGK - Knowledge Sharing Platform training search results

The training material identified is as follows:

- Using the Cummins knowledge sharing platform;
- Making a knowledge sharing platform media contribution;
- Using a video camera;
- Video editing - Premiere Pro Overview;
- Premiere Pro Video Editing Lesson 1;
- Premiere Pro Video Editing Lesson 2;
- Premiere Pro Video Editing Lesson 3; and
- Snap it – computer desktop video grab.

The selection of training material provides basic training for the use of the platform. Training in how to structure and build a knowledge contribution, using the supplied video camera purchased for the project, and basic training for the video editing software and computer desktop screen grab software are also provided.

Creating a Knowledge Request

The initial knowledge request has been implemented into the knowledge sharing platform. On the main page of the system the user has the option, on the top bar menu, to select a knowledge request. During early trials of the system, feedback from a senior manager was received stating that an extra dialog pop-up box should be added, asking users if they have already checked the database for the knowledge they have requested. This feedback was implemented and is shown in Figure 189.

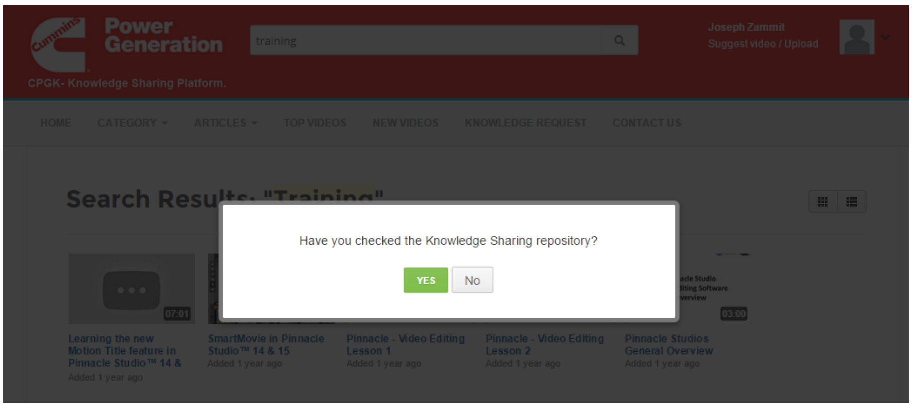


Figure 189. CPGK - Knowledge sharing platform knowledge request

Once a user selects 'No' confirming that they have checked the knowledge sharing repository, they are forwarded to the knowledge request form, in which the knowledge request originator needs to fill in the information of the required knowledge. In order to provide structure and commonality to the system, a specific structure was created with all of the mandatory fields in order, to avoid users submitting partially completed requests. The fields used in the knowledge request form are: Title, Category, Aim, Description and Learning outcomes. It was determined that, as a user submitting a request, they must understand the reason and the outcomes from capturing the knowledge they are requesting. If they cannot determine or justify a reason for the request it would not be of substance. Once submitted, the system administrator receives an email with all required information. An example of this is shown in Figure 190 and Figure 191.

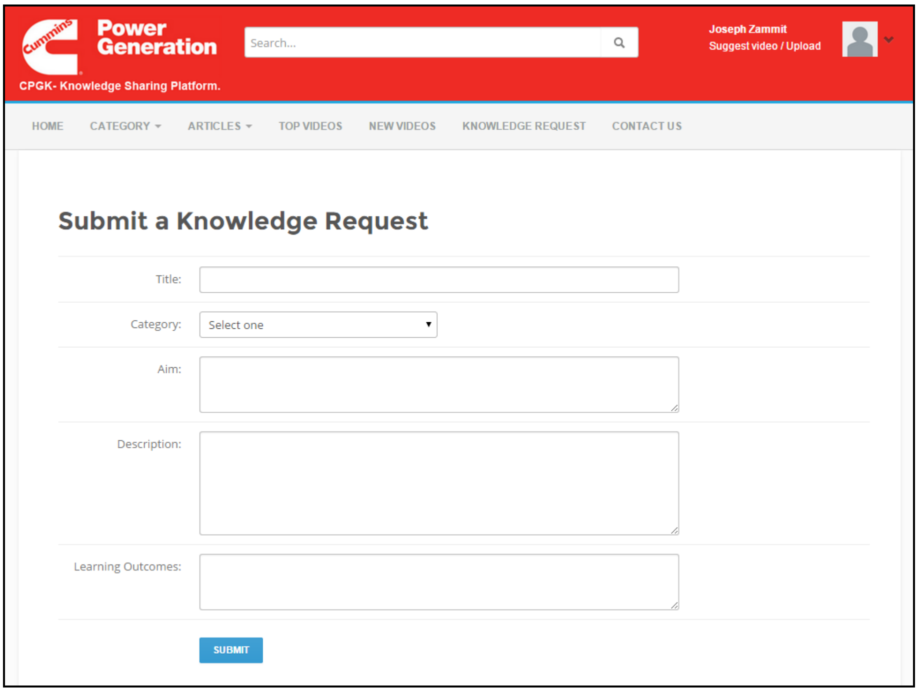


Figure 190. CPGK - Knowledge Sharing Platform knowledge request form

Hello,

You have a new request from CPGK-Knowledge Sharing.

Here are the details of the submission:

Title: How to fix strain gauges on a round pipe
Category: Sample Sub-cat
Aim:
To learn how to fix strain gauges and hooking them up to a data logger
Description:
In order to learn how to fix strain gauges onto a round pipe, in which orientation should they be attached, how to connect them to a data logger and how to check the set-up.
Learning Outcomes:

1. The different types of stain gauges used at Lab Ops.
2. How to attach them to a test piece,
3. How to hook them up to a data logger and check the set-up.

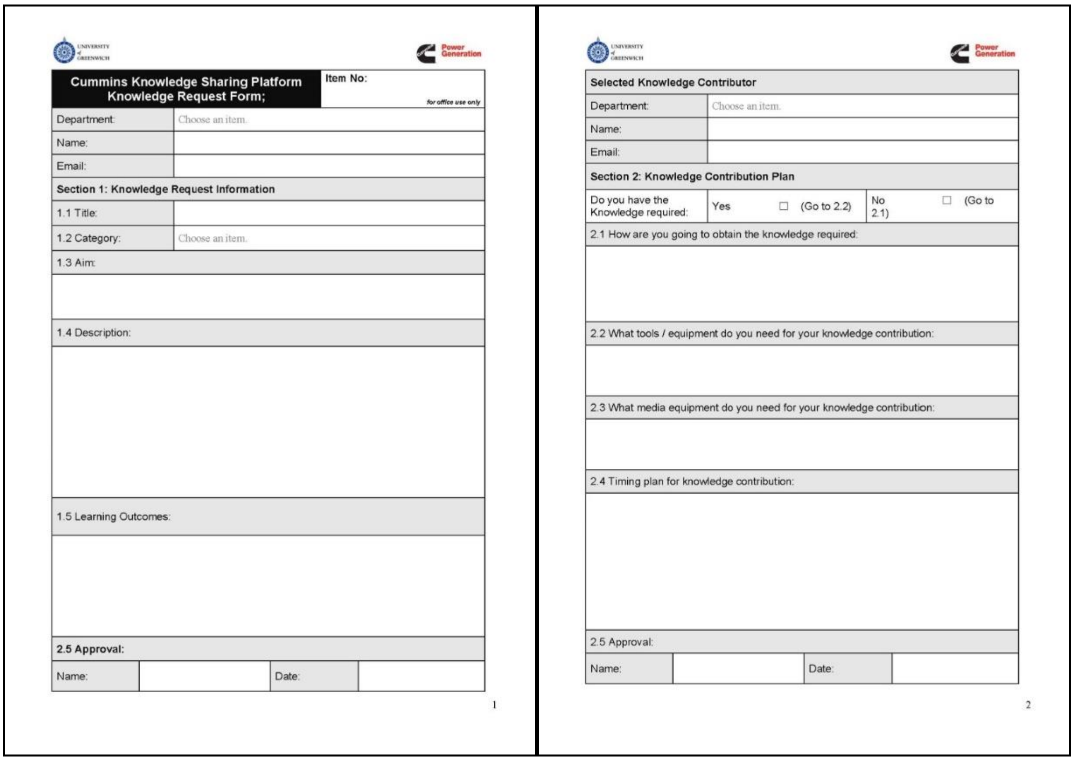
This request has been submitted form IP: 92.251.5.39

Figure 191. Knowledge request Admin email

At this point, the administrator will evaluate the content of the request and will determine if it should be processed or not.

Creating a Knowledge Request From

Once a knowledge request has been approved, the submitted information is inserted into a Knowledge Request Form (KRF), shown in Figure 192, and submitted by email to the knowledge contributor. The KRF is a template, provided in word processing format, divided into two sections. Section one contains the information from the knowledge request, while section two contains the information that the knowledge contributor needs to complete as part of the effort to document the plan of how they will create and capture the knowledge contribution.



Cummins Knowledge Sharing Platform Knowledge Request Form;	Item No: *for office use only*		
Department:	Choose an item.		
Name:			
Email:			
Section 1: Knowledge Request Information			
1.1 Title:			
1.2 Category:	Choose an item.		
1.3 Aim:			
1.4 Description:			
1.5 Learning Outcomes:			
2.5 Approval:			
Name:		Date:	

1

Selected Knowledge Contributor			
Department:	Choose an item.		
Name:			
Email:			
Section 2: Knowledge Contribution Plan			
Do you have the Knowledge required:	Yes ☐ (Go to 2.2)	No ☐ (Go to 2.1)	
2.1 How are you going to obtain the knowledge required:			
2.2 What tools / equipment do you need for your knowledge contribution:			
2.3 What media equipment do you need for your knowledge contribution:			
2.4 Timing plan for knowledge contribution:			
2.5 Approval:			
Name:		Date:	

2

Figure 192. Knowledge request form example (KRF)

The key element to be determined by the knowledge contributor which need to be filled in on the knowledge request form are:

- What knowledge is required;
- What tools / equipment is required;
- What media equipment is required; and
- Timing plan to create knowledge contribution.

Once these have been determined and input into the form, these are then sent to the administrator for approval. If not approved, the document will go through a number of iterations until the content has been approved by the administrator.

Creating a Knowledge Contribution

The creation of a knowledge contribution consists of 3 basic steps: planning the knowledge contribution, capturing the required knowledge, and finally, compiling the captured knowledge into a single organised knowledge contribution.

The planning of the knowledge contribution consists of creating a flow diagram of how a user is going to capture and explain their knowledge topic. The diagram, shown in Figure 193, displays two examples of knowledge capture process plan. The first example is hand written while the second example is created using Ms. Visio shown in Figure 194.

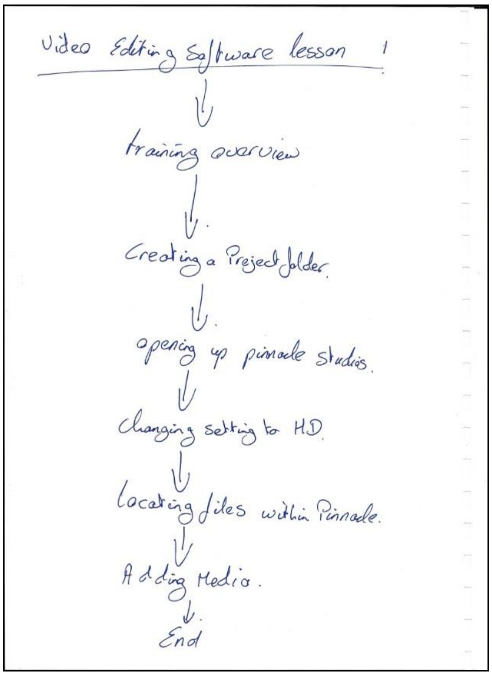


Figure 193. Knowledge Contribution Process Plan Example 1

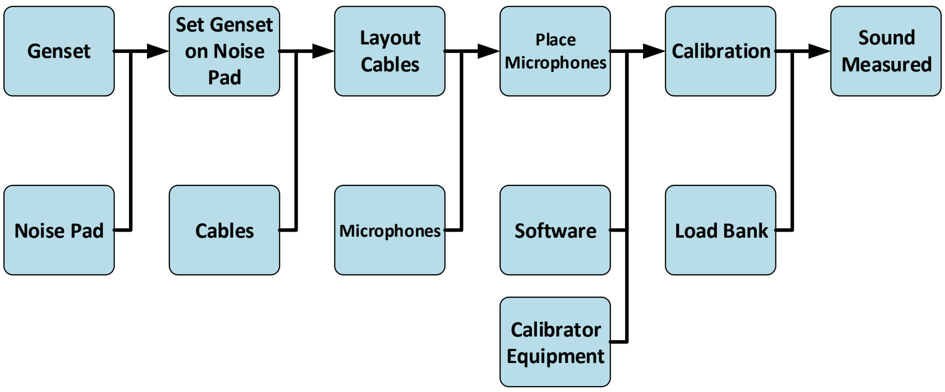


Figure 194. Knowledge Contribution Process Plan Example 2

The aim of this process plan is to provide a logical order of how the knowledge is going to be explained to the knowledge receiver, while also providing a logical map of the knowledge steps required to be captured in order to construct the final knowledge contribution. It is also advised that a voice over script is prepared at this stage, in order to determine the length of time required to explain a specific portion of the knowledge being captured. Once the voice over time required is determined, this can be used to plan the video footage duration in order to simplify knowledge contribution editing later on in the process.

Once the knowledge video footage segments have been captured using the provided video camera equipment, it is time to compile the knowledge contribution. In order to obtain a common knowledge contribution format, the user needs to download the knowledge contribution template from the knowledge repository. The template consists of a number of slides which are the basic building blocks required for the knowledge contribution. The template created consists of a title page, physical layout page and the process tree page; these pages provide the opportunity for the knowledge contributor to explain these various items in detail prior to the knowledge video portion. Examples of these pages are shown in Figure 195 to Figure 197.

Figure 195. Knowledge contribution template – title screen example

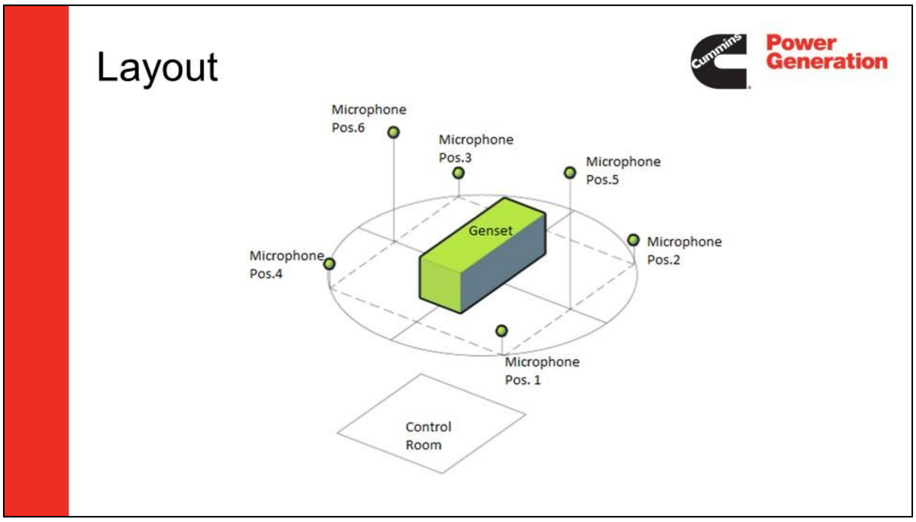


Figure 196. Knowledge contribution template – system layout example

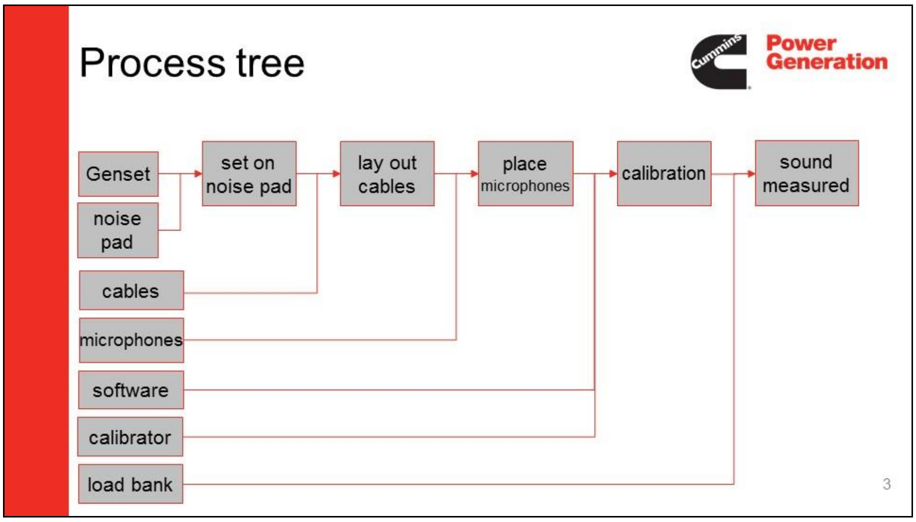


Figure 197. Knowledge contribution template – process tree example

These introduction screens are followed by the knowledge video. Instead of showing the video in full screen, this is combined with the process flow and layout which are shown on the side. The intention is to highlight the location, both in the layout and process flow, depending on what stage of the video presentation the user is at. This combination allows the user to make links and connections to what they are observing in the video in relation to the physical location and the order in the process tree. Figure 198 shows an example of a noise measurement process setup. Lessons and examples of how to edit a knowledge contribution video are covered in detail in the training material created for this project, and will not be covered in this section. For more information relating to this, please visit www.CPGK-knowledgesharing.com and follow the training material provided.

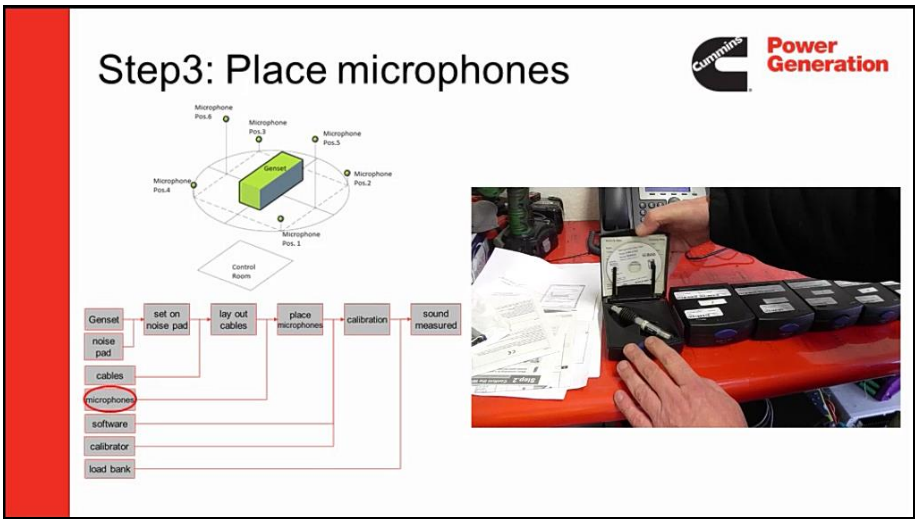


Figure 198. Knowledge contribution template – complete example

Knowledge Contribution Approval and Uploading

Once a knowledge contribution has been created, it needs to be submitted to the administrator for content and quality approval. The contributor needs to upload the video file on to the knowledge sharing platform by selecting the upload option located in the top right hand corner of the knowledge repository, under the user login name. This will forward the user to the upload video dialogue, shown in Figure 199.

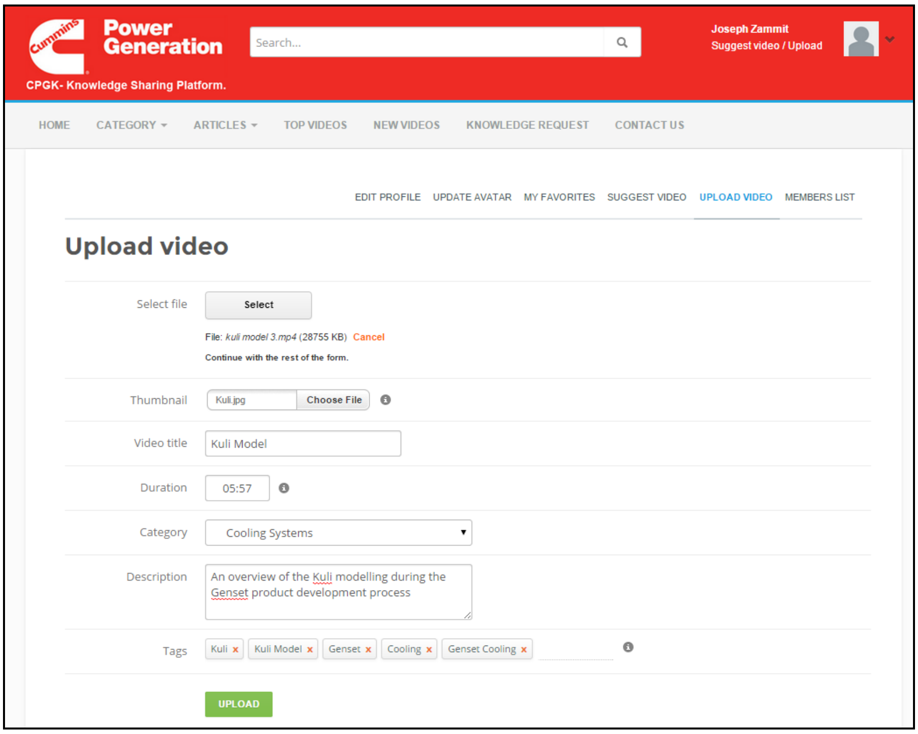


Figure 199. CPGK - Knowledge Sharing Platform Content Upload

Once the knowledge contributor selects the video file and completes the information describing the knowledge contribution they must upload the contribution. The upload might take a few minutes depending on the internet connection speed and the size of the file the user is uploading. Once the file is uploaded successfully, a message will appear stating that the user has successfully uploaded their video, as can be seen in Figure 200.

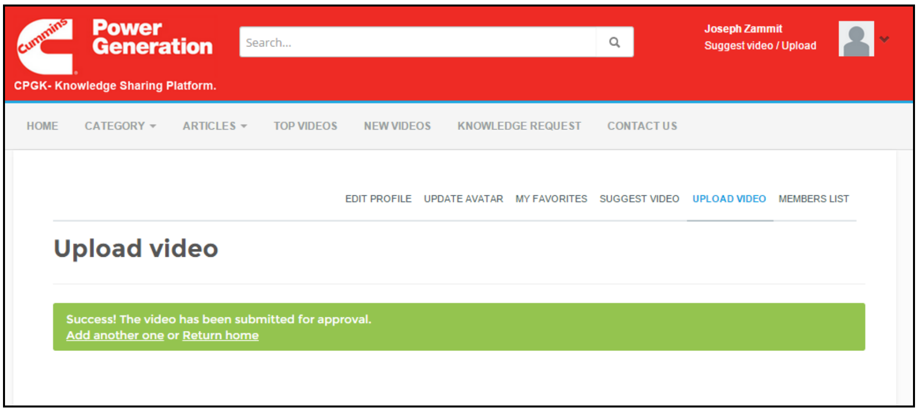


Figure 200. CPGK - Knowledge Sharing Upload Completion Message

Once the video is uploaded, it does not mean that the knowledge contribution is accessible to other users, because it has not been yet approved by the administrator. Once a video has been uploaded, the administrator will receive an automated email informing them of the upload. At this point, the administrator is required to log into the knowledge repository and access the administration backend of the knowledge repository, as shown in Figure 201.

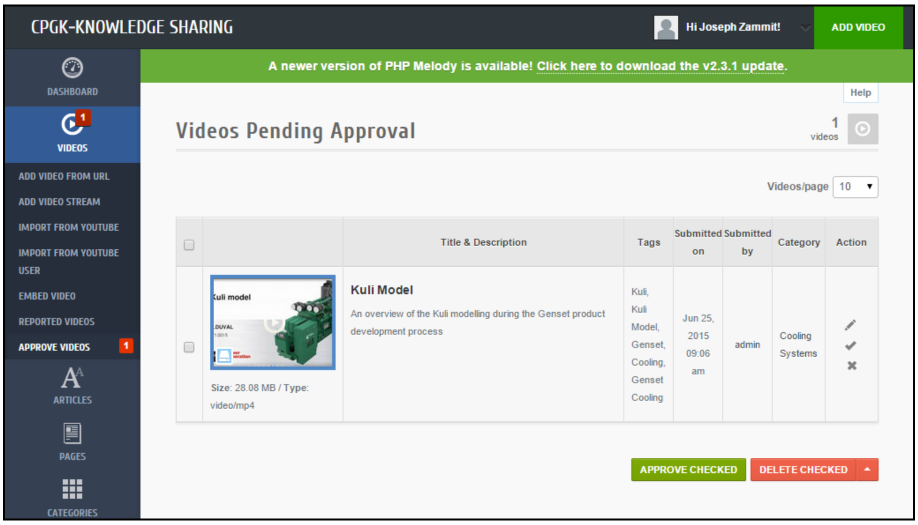


Figure 201. CPGK - Knowledge Sharing Platform Admin View

At this point, the administrator needs to check the quality and content of the contribution and edit any information pertaining to the knowledge contribution, such as title, description or tagging, as shown in Figure 202. If the administrator is not competent on the subject matter, they might ask for assistance from either the knowledge contributor or other experts in the company to check that all technicalities are correct and meet engineering standards.

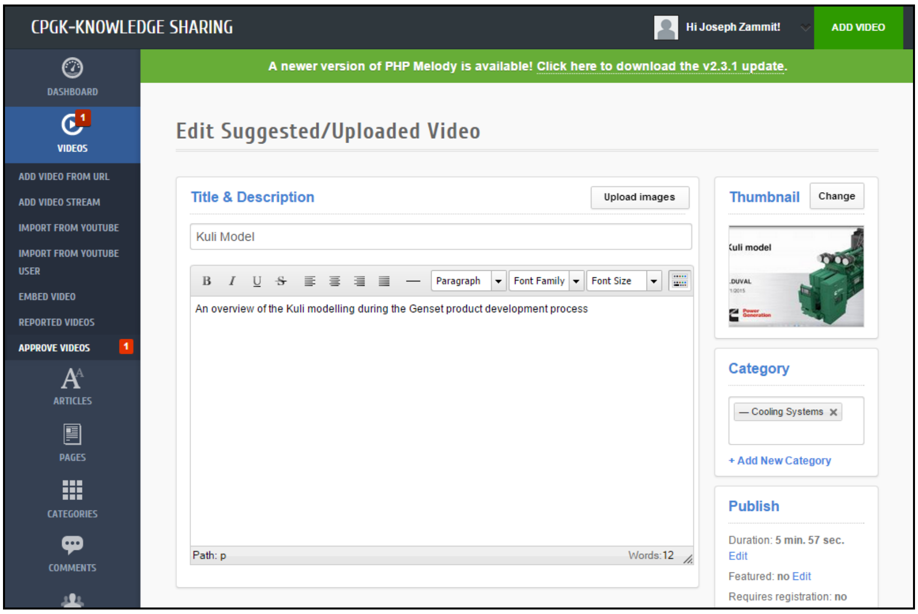


Figure 202. CPGK - Knowledge Sharing Admin Content Editing Window

Once all the quality and content checks are completed the administrator either approves or rejects the knowledge contribution. If it is approved the knowledge contribution will be instantly activated in the knowledge repository and accessible by other users. On the contrary, if it is rejected, the originator will receive an automated email informing them that their contribution is rejected and will need to be revised and re-submitted.

Searching the Knowledge Sharing Platform

Searching the knowledge sharing platform for knowledge is similar to the explanation provided in previous section accessing the Knowledge Sharing Platform Training Material. There are five main methods to search for knowledge within the repository. Users may run a keyword or a tag search from the search bar, searching knowledge through the different categories available in the menu bar for the different knowledge classifications, run a search of contributions submitted by a user, view top ranked videos and through the new videos listed in the main page. Figure 203 shows all of these search options.

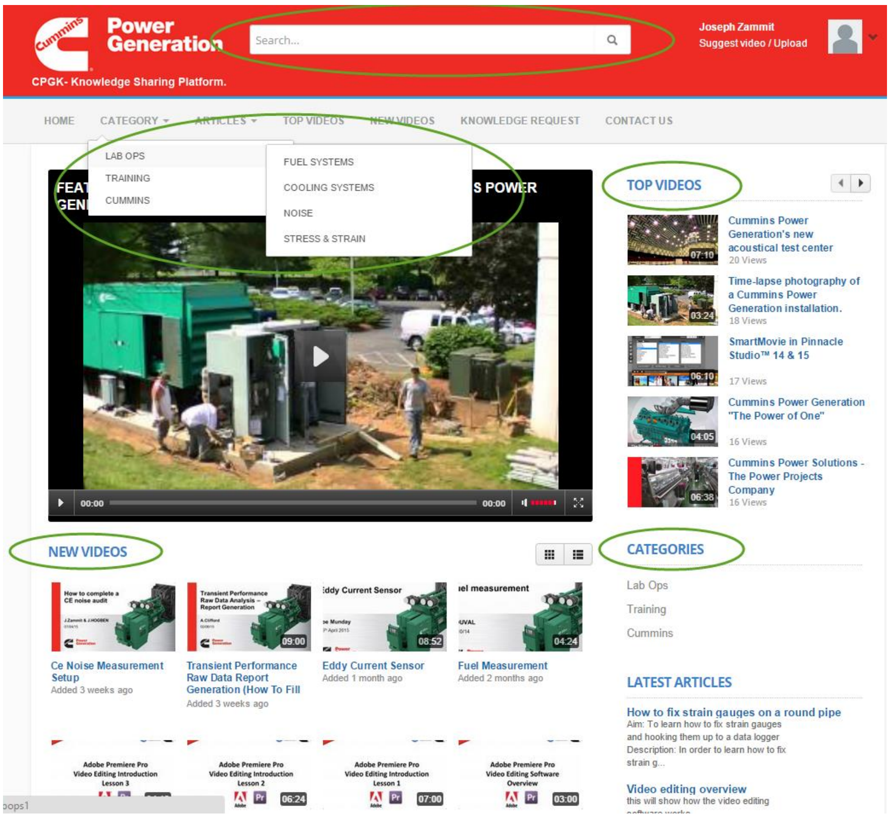


Figure 203. CPGK - Knowledge Sharing Platform Main Search Tools