Making the Implicit Explicit: A Case Study of the Implementation of Technology Management in a Group of Companies

by

Jacobus Christiaan Visser

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Supervisor: Mr K.H. von Leipzig

Co-supervisor: Prof S.S. Grobbelaar

December 2019

DECLARATION

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Date: December 2019

ABSTRACT

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J.C. Visser

Department of Industrial Engineering,

University of Stellenbosch,

Private Bag X1, Matieland 7602, South Africa.

Thesis: MEng. (Industrial Engineering)

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Technology management is an established field of study, which is concerned with the management of the various capabilities, resources and knowledge which make up the technology portfolio of organisations. Over time technology management has proven an effective link between the technological capability of an organisation and its business strategy. Effective technology management allows an organisation to dynamically and continually realign and reorganise its technological capabilities. By dynamically managing its technology, an organisation can counter external and market pressures to ensure that it continually leverages its competitive advantage in innovative ways and markets. This research study investigates how technology management can be

implemented in an existing holding company with a number of subsidiaries grouped together in a complex hierarchical structure.

An inductive and qualitative research process is employed to approach the problem in stages. First, specific research questions are defined to address different aspects of the larger research problem. A structured literature review is then conducted on both established and recent literature to determine what possible solutions are already available within the scientific literature. The most relevant solutions are then reworked into a reproducible set of instruments. These instruments are then uniformly applied to each of the subsidiaries of the holding company. The results of these instruments produce a complex and connected web of interrelationships between the various subsidiaries and their vested technologies. The final stage of the method is to map this complex web into a technology management framework, which can support the analysis and decision-making of technology management within the organisation.

A local South African technology group of companies is used as a case study to test the research method. The technology group's combined technology portfolio is diverse, yet containing significant overlapping technologies vested in the different subsidiaries. With the already established technology portfolio, some technology management processes are already in place, though informal and implicit in nature. A further aim of this research is then to, through the application of this research, develop the implicit and informal technology management processes of this company into explicit and formal technology management structures. Furthermore, it aims to develop a set of tools and frameworks to assist the company to maintain its technology management structures, while also serving as a long-term strategic decision-making tool.

Other than illustrating an effective process for implementing technology management uniformly between different entities of an organisation with a complex and hierarchical structure, this study also explores other elements concerning technology management. First, a structured literature review investigates various aspects of technology management in both established and recent studies. Second, the study explores how

technology audits can be reliably and uniformly conducted at different entities. Finally, a conceptual technology management framework is developed, which serves as both an at-a-glance view of the current state of technology within an organisation, and as a strategic planning device.

OPSOMMING

Maak die Implisiet Eksplisiet: 'n Gevallestudie vir die Toepassing van Tegnologiebestuur op 'n Groep van Maatskappye

J.C. Visser

Departement Bedryfsingenieurswese,
University van Stellenbosch,
Privaatsak X1, Matieland 7602, Suid Afrika.

Tesis: MIng. (Bedryfsingenieurswese)

Desember 2019

Die bestuur van tegnologie is 'n gevestigde studieveld wat handel oor die bestuur van die verskeie vaardighede, hulpbronne en kennis wat die tegnologie portefeulje van organisasies uitmaak. Met tyd is tegnologiebestuur bewys om 'n effektiewe skakel tussen die tegnologiese vaardighede van 'n organisasie en sy besigheidstrategie te wees. Effektiewe bestuur van tegnologie laat 'n organisasie toe om op 'n dinamiese en voortdurende wyse sy tegnologiese vaardighede te herbelyn en te herorganiseer. Deur op 'n dinamiese wyse sy tegnologie te bestuur, kan 'n organisasie eksterne en mark-verwante druk teenstaan om te verseker dat dit voortdurend sy kompeterende voordeel uitoefen op innoverende wyses en markte. Hierdie navorsingstudie ondersoek hoe

tegnologiebestuur ingestel kan word in 'n bestaande beheermaatskappy met filiale wat saam gegroepeer is in 'n komplekse hiërargiese struktuur.

'n Induktiewe en kwalitatiewe navorsingsproses is gebruik om die probleem in fases te benader. Eerstens word spesifieke navorsingsvrae gedefinieer om verskillende aspekte van 'n groter navorsingsprobleem aan te spreek. 'n Gestruktureerde literatuuroorsig word dan gedoen op beide gevestigde, sowel as onlangse literatuur om te bepaal watter moontlike oplossings daar reeds bestaan in die huidige, beskikbare wetenskaplike literatuur. Die relevantste oplossings word dan verwerk in 'n herproduseerbare stel instrumente. Hierdie instrumente word dan eenvormig toegepas op al die filiale van die beheermaatskappy. Die resultate van hierdie instrumente ontbloot 'n komplekse en verbinde web van interverwantskappe tussen die verskeie filiale en hul gevestigde tegnologieë. Die finale fase van dié metode is dan om hierdie komplekse web in 'n tegnologiebestuursraamwerk te omskep wat die analise en besluitneming van tegnologiebestuur binne die organisasie kan ondersteun.

'n Plaaslike Suid-Afrikaanse tegnologie groep van maatskappye word as gevallestudie gebruik om hierdie navorsingsmetode te toets. Die tegnologie groep se gekombineerde tegnologie portefeulje is baie divers, maar bestaan wel uit 'n beduidende aantal oorvleuelende tegnologieë wat gevestig is in die verskillende filiale. Met die reeds gevestigde tegnologie portefeulje is sommige tegnologiebestuurprosesse reeds in plek, hoewel dit slegs informeel en implisiet van aard is. 'n Verdere doelwit van hierdie navorsing is om, deur die toepassing van hierdie navorsing, die informele en implisiete tegnologiebestuursproses van hierdie maatskappy in eksplisiete en formele tegnologiebestuurstrukture te omskep. Verder beoog dit om 'n stel gereedskap en raamwerke te ontwikkel om die maatskappy te help om sy tegnologiebestuurstruktuur te onderhou, en om as langtermyn strategiese besluitnemings hulpmiddel te dien.

Afgesien daarvan dat die studie 'n effektiewe proses vir die eenvormige implementering van tegnologiebestuur tussen verskillende entiteite van 'n organisasie met 'n komplekse en hiërargiese struktuur daarstel, verken hierdie studie ook ander elemente rakende

tegnologiebestuur. Eerstens ondersoek 'n gestruktureerde literatuuroorsig verskeie aspekte van tegnologiebestuur in beide gevestigde sowel as onlangse studie materiale. Tweedens verken die studie hoe tegnologie oudits op 'n betroubare en eenvormige manier vir verskillende entiteite uitgevoer kan word. Laastens word 'n konseptuele tegnologiese bestuursraamwerk ontwikkel wat dien as beide 'n op-die-oog-af oorsig van die huidige toestand van tegnologie binne die organisasie sowel as 'n strategiese beplanningshulpmiddel.

ACKNOWLEDGEMENTS

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- Finally, to my new-born son, Ian Visser; I hope this body of work will serve you one day as a source of pride and motivation to follow your dreams regardless of the obstacles.

The Author, December 2019

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LIST OF ACRONYMS AND ABBREVIATIONS

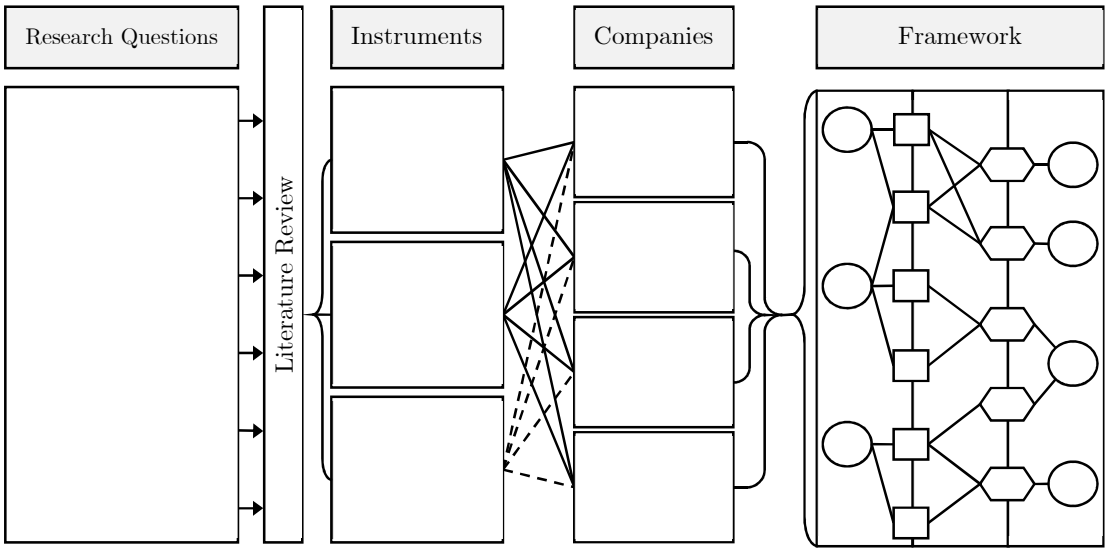
Alphawave MNP	Alphawave Mobile Network Products
Alphawave MNS	Alphawave Mobile Network Services
CPUT	Cape Peninsula University of Technology
EM	Electromagnetics
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Fields
EMI	Electromagnetic Interference
EMSS	Electromagnetic Software and Systems
ExCo	Executive Committee
HF	High Frequency
HR	Human Resources
IoT	Internet of Things
MOT	Management of Technology
RF	Radio Frequency
RFI	Radio-frequency Interference
SKA	Square Kilometre Array
SKA-SA	Square Kilometre Array – South Africa
SME	Small and Medium-sized Enterprises
TBS	Technology Balance Sheet
TM	Technology Management

CHAPTER 1

BACKGROUND

This chapter will provide introductory background on the study as well as the individual components of the study, including:

- An introduction to what this research aims to achieve
- Background on the Alphawave group of companies, which will serve as a case study for this research
- Introduction to technology and the field of technology management
- Framing of the research's problem statement, outcomes and rationale
- The below diagram is described as a visual map of the research process, which will also serve as a roadmap to this document:



1.1 Introduction

The ever-expanding and dynamic nature of technology place constant pressure on companies to remain relevant in a fast-changing world. Companies are constantly challenged by competitors or new entrants in their markets. New entrants have been argued to be more agile than bigger companies and can exploit specific market needs faster and more accurately than larger firms. [1], [2] New disruptive technologies can eliminate a company's competitive advantage and thereby reduce its market share.

These two possible challenges are merely some of the increasing number of external challenges facing companies. [1]–[4]

Innovation is key to a company's survival. The use of technology, for its part, is a major driver and enabler of innovation. A company needs to remain aware of advances in the technological landscape to ensure that its market offerings can remain or become competitive. By regularly evaluating its technology base and that of its competitors, a company would be able to challenge its competitors, or at least mitigate the impact of competitors on their own operations. In addition, the identification of new technological prospects can create new opportunities in new markets or challenge entrenched competitors in established markets. Care should be taken to ensure that a company's technology base remains relevant and up to date while expanding their technology base to ensure that their products remain at the forefront of technological excellence.[1]–[3]

Technology is not an easy concept to define, but, as it will be discussed in more depth later, it is chiefly a collection of created technological capabilities within an organisation. These capabilities are vested within the respective people, procedures and equipment present in the organisation. How these capabilities are directed and employed will impact how well the technology base of an organisation is exploited. A company's competitive advantage is then dependent on its own understanding of its technological capabilities and shortcomings, along with its ability to leverage its capabilities to obtain and sustain a competitive advantage over its competitors. [5], [6]

Technology is dynamic, as such, its management should also be dynamic. It is critical for companies to constantly evaluate its technology portfolios to not just determine their current technological capabilities, but to also determine which technology would be required to sustain the growth of the company. Indeed, many studies have highlighted the positive impact of linking technology management with the overall strategic planning of an organisation. By strategically linking long-term business goals with forecasted technology planning, the organisation can effectively ensure that

innovative and technologically advanced products are delivered strategically to both established and innovative markets. Based on available and potential capabilities, as well as its overall business strategy, a company should continually search for new and innovative ways to package their technology for current and new markets. [3], [7]–[10]

The management of technology should therefore not only be concerned with the current situation of the company, but also the strategic goals of the company. This study will at the hand of a case study of the *Alphawave* group investigate how a successful technology company manages its technology. It will also investigate how established technology management principles can assist the company to continue to leverage its competitive advantage in new and innovative ways and markets. [10]

Although the *Alphawave* group has a history of successful implementation of technology, its business strategy is not supported by a formal and integrated technology management process. That said, technology is managed within the group and its subsidiaries, but in an implicit and informal manner. While exploring ways to implement a formal technology management process is the main aim of the study, it will also – in the investigative process – develop aids to promote the formal and effective management of technology within the group and its subsidiaries.

1.2 History of the Alphawave Group of Companies

Before an expansive rebranding process starting in 2017, the *Alphawave* group of companies were known as the *EMSS* group. A timeline of this evolution is shown in Figure 1-1. This timeline shows the origins of the *EMSS* group as the founding of *Electromagnetic Software and Services* (*EMSS*) in 1994 specialising in electromagnetic software design and services. The electromagnetic software simulation package, *FEKO*, was developed by *EMSS* and quickly became internationally recognised software, widely used in the automotive and aerospace industries of Europe, Asia and America. [11]–[15]

While steadily developing *FEKO* into a world-renowned software tool, *EMSS* continued consulting and research work in the assessment of electromagnetic fields. Following various government and military research projects, a major cellular operator

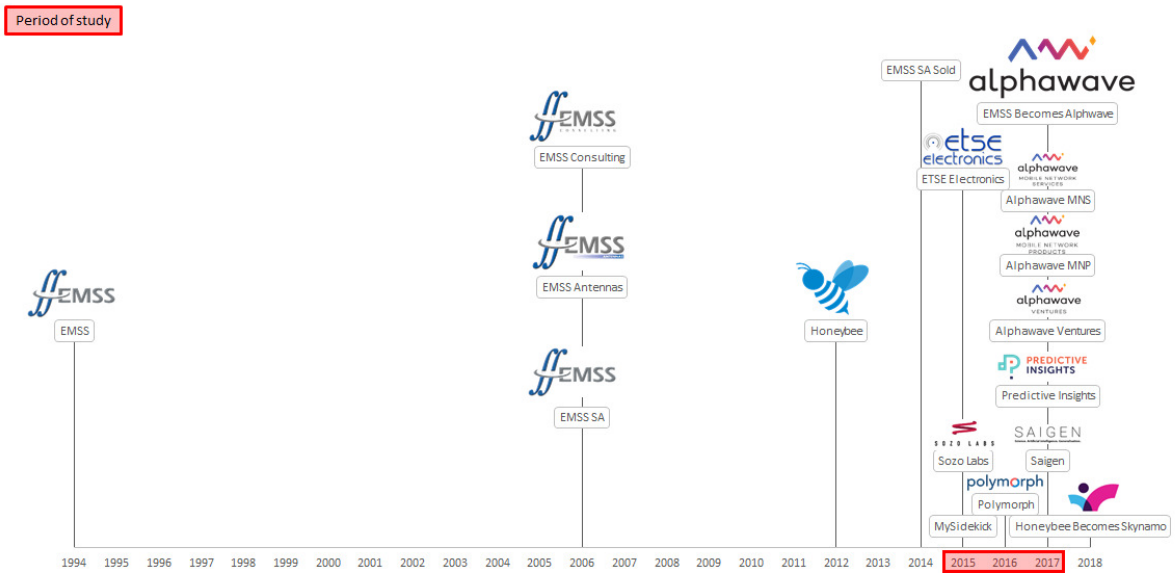


Figure 1-1: Timeline of the evolution of the *Alphawave* group, also indicating the period the current study takes place.

in South Africa approached *EMSS* to research the effect of cellular signals on human beings. This research formed the basis of long-standing contracts between *EMSS* and various cellular operators, where *EMSS* assesses and certifies cellular base stations in terms of international guidelines. *EMSS Consulting* was established as a separate company in the *EMSS* group to specifically focus on the assessment and measurement of electromagnetic fields, while a separate company in the group, *EMSS-SA* would continue the development, marketing and sales of *FEKO*. [12], [16]

The assessments of cellular base stations are performed using either computer simulations or in-situ field measurements. In order to assess cellular base stations efficiently, *EMSS Consulting* produced a new software package that combines the management of a database of base stations, the assessment of the base stations and a 3D modelling tool (based on *FEKO*) to perform assessments on complex sites. This software package, *IXUS*, was expanded into a commercial product that is utilised in-house for local contracts, and by international clients based in various countries, including Australia and Canada.[16], [17]

A later addition to the *IXUS* package was an electromagnetic measurement module. This module managed and automated various labour-intensive tasks associated with large-scale field measurement projects. Included in the module was automated reporting services yielding easy-to-create, yet professional reports that adhere to

international standards. The reporting services simplified the process of converting measured data into easily relatable reports.[18]

Although electromagnetics was at the core of the projects and products of *EMSS* at this stage, the group was also emerging as a capable software design house. To alleviate the logistical burden of gathering large amounts of information during site surveys, *EMSS Consulting* developed an Android application to replace paper notes with electronically stored data gathered during site surveys. This significantly improved the efficiency of site surveys and subsequent processing of data. This departure from electromagnetics proved that *EMSS* could develop software outside of the narrow scope of electromagnetics. [19]

The success of the survey application led to the creation of a new Android application that tracks, manages and assists sales representatives while visiting clients. The application was an almost immediate success and also spawned a new company, *Honeybee* (which has since been rebranded to *Skynamo*). *Honeybee* was founded to develop the application and drive the sales and marketing of the new application. [15], [20]

A separate company in the group, *EMSS Antennas*, was founded to design antenna receivers for the radio astronomy project, *MeerKat*, which was a precursor for the multi-national *Square Kilometre Array* (*SKA*) project. Over the course of its ten-year existence, *Antennas* grew from a small antenna design firm to a large antenna solution firm, which incorporates its own high-tech manufacturing plant and test facilities. During this process, the company developed capabilities in not only the design of high-tech antennas, but also in the fields of radio astronomy, cryogenics, control systems, manufacturing and quality assurance.[13]

As a joint venture between *EMSS Consulting* and *EMSS Antennas*, the companies developed and manufactured a compact and relatively inexpensive personal safety monitor, *fieldSense*. This monitor helps RF workers identify areas where it is safe to work around RF transmitters. The success of the monitor can directly be traced from the combined capabilities utilised by the two separate companies, namely, measurement experience, antenna design, market knowledge and production. The second version of *fieldSense* has already been released and has made a significant impact in the international market, especially in North America.[21]

In 2014, *EMSS-SA*, along with the software package *FEKO*, was sold to the US-based company, Altair. This event, along with the success of the *Honeybee/Skynamo* application, prompted the *EMSS* group to initiate continued expansion into areas outside of their core capabilities of electromagnetics. The *Alchemy-A Technology Accelerator* (now functioning as *Alphawave Ventures*) was conceived to fund smaller start-up projects and companies in different technology sectors. The technology accelerator also attempts to combine the different capabilities within and outside the *EMSS* group. [13]–[15], [22], [23]

Since 2015 the *EMSS* group invested in companies that grow their technology portfolio, especially in companies whose vested technological capabilities add significant growth potential to the group as a whole. The first major investment was in *ETSE Electronics*, a company whose focus historically was on the design and development of bespoke electronic solutions for a diverse range of clients.[15], [24]

The second major investment was in *Polymorph*, an experienced mobile and IoT design and development company. Although *Polymorph* has extensive software experience and knowledge, it combines its technical skill with strong design capabilities. [15], [25]

Other smaller investments through the *Alchemy-A Technology Accelerator* were made in innovative start-ups. Two notable examples are *Sozo Labs* and *MySidekick*. *Sozo Labs* is a Virtual- and Augmented Reality development lab. *MySidekick* is a mobile shopping application that notifies a user of available nearby deals. [15], [23], [26], [27]

In 2017 the *EMSS* group started an expansive rebranding process and from 1 May 2017 became *Alphawave*. Although most of the entities in the group remained unchanged, the *EMSS Consulting* and *Alchemy-A* entities underwent a restructuring process. *EMSS Consulting* was separated into three different entities. *Alphawave Mobile Network Services* (*MNS*) continues to deliver electromagnetic simulation, measurement and assessment services to various mobile network operators. *Alphawave Mobile Network Products* (*MNP*) focuses on the development, marketing and sales of the two main products inherited from *EMSS Consulting*, i.e., *IXUS* and *fieldSense*. Lastly, the software development team of *EMSS Consulting* was merged with *Alchemy-A* to form *Alphawave Ventures*. This new entity gives software development support to the various entities within the *Alphawave* group and also assists new start-ups outside the group. [12], [15], [23]

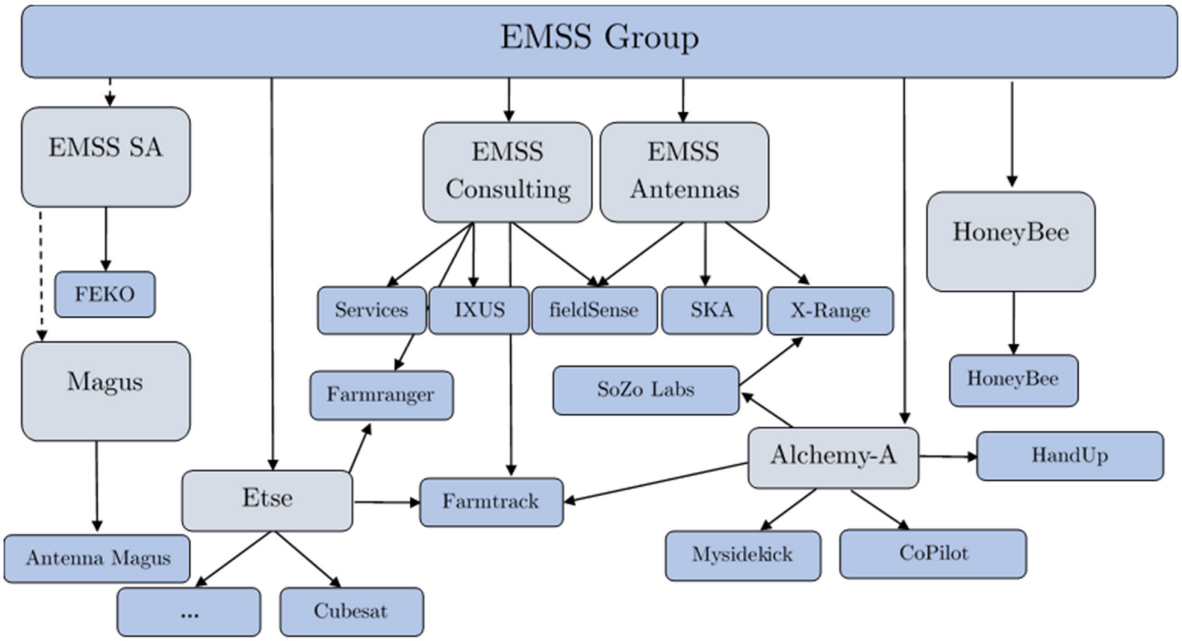


Figure 1-2: Simplified organogram of the various entities and products of the *EMSS* group at the start of the study

Following the restructure and rebranding, the *Alphawave* group has continued to grow. *Alphawave Ventures* along with *Polymorph* invested in two Data Science start-ups, *Predictive Insights* and *Saigen*, thus expanding their knowledge base even further.[15]

Throughout its history technology has played an important role in the group of companies. The group has, through internal development and external acquisitions, built up an impressive technology portfolio, while on multiple occasions also successfully transferred technology from one entity or product to the next. The rebranding of *EMSS* to *Alphawave* in itself is partly to emphasise that the group has significantly expanded on their initial niche electromagnetics technology base.[14], [15], [19]

This study aims to determine how technology is being managed and utilised within the *Alphawave* group. Due to the dynamic nature of the group multiple changes in the makeup of the group occurred during the course of the study. An oversimplified organogram showing the then *EMSS* group and the various entities and products that formed part of the group at the start of this study is shown in Figure 1-2. Note that broken lines indicate companies that were no longer part of the *EMSS* group already at the start of the study. Both Figure 1-1 and Figure 1-2 show the hierarchical structure

and complexity of the *Alphawave* group and the interrelationships between its subsidiaries. Discounting the many expansions since the commencement of this study, even then the group had a complex structure.

Effective technology management could thus be an efficient way for the *Alphawave* group to ensure that they exploit their technological capabilities effectively. This study is then a real-world exercise to establish the technology base of an SME with multiple subsidiaries. Simultaneously, the study will attempt to make the potentially underlying and informal technology management strategy more explicit. By analysing the technology management structures in place, whether formal or informal, a greater understanding of how the overall technological capabilities of the group can be assessed. Finally, formal and explicit technology management structures and aids can be developed to sustain and expand the competitive advantage of *Alphawave*.

1.3 Technology and Technology Management

As can be seen, by the numerous different definitions available for technology, technology is not an easy term to define. Regardless, a common feature of these definitions is the fact that the concept of technology is not merely limited to physical equipment, such as computers or manufacturing machines. An adequate definition of technology for the field of technology management should then include all resources within an organisation that can be utilised to develop and produce products to satisfy market needs. [1], [9], [28], [29]

As per Van Wyk, "Technology is created competence. It is expressed in technological entities consisting of devices, procedures, and acquired human skills."[29] This definition of technology encompasses the diverse nature of what could be considered technology. First, technology is not a naturally occurring phenomenon, it is something that is created, established or learned. Second, technology is not merely related to physical machines, but any capability that is available to add value to the organisation. [1], [9], [28], [30]

If technology is a collection of capabilities, then technology management is concerned with how to develop and utilise these technological capabilities effectively within an organisation. Technological capabilities must be exploited to gain and sustain a competitive advantage. The task of managing technology is not simple, as it is an ever-changing environment; thus the manner in which technology, and therefore

capabilities, is managed, should be dynamic in nature. [10], [28], [29], [31]. Through the years, many studies have explored how different companies and organisations have managed to adequately leverage their technology, as well as how technology can be managed more efficiently. The study of technology management is thus an established field with verified research and results that are well documented within the scientific and corporate communities [3], [32].

Some of the most prominent researchers in the technology management field have developed models that identify the various aspects affecting how technology can be managed. Researchers such as Phaal, Cetindamar, Probert and Farrukh, in particular, have identified that the balancing and aligning of the different pressures exerted on a technological organisation is a core function of technology management. Especially important is the alignment of available and potential technological capabilities with corporate strategic goals. In particular the balance of technology push versus market pull, through structured technology management processes, is essential to ensure that the correct products are delivered to the corresponding markets. Technology management bridges the gap between business strategy (market pull) and technology development (technology push). [3], [9], [31], [33]

Over the years the *Alphawave* group has, through informal and implicit technology management, already developed a varied and substantial number of technological capabilities in the broader fields of science, engineering and management. Technology management links these different fields of study together. [3], [9], [33], [34] By formalising existing implicit management processes into explicit and formalised technology management structures, *Alphawave* will be able to expand more efficiently on its already available capabilities. Based on the current state of technology within the group and its subsidiaries, a set of tools and frameworks can be developed to make these implicit processes explicit. This will, in turn, assist *Alphawave* to implement efficient, explicit and formal technology management structures to sustain and expand its competitive advantage. [10]

The set of tools and especially the framework will also serve as a strategic planning tool. This will aid *Alphawave* to effectively manage and maintain its current technology portfolio, while simultaneously revealing new opportunities for expansion of its portfolio. This more active management of its technology portfolio will make it easier to align its strategic business planning processes with its technology portfolio. This

alignment will strengthen the competitive advantage of the group and its subsidiaries by ensuring that well-informed technology considerations are taken into account with long-term business decisions. [3], [9], [10], [35]

In summary, it is then the goal of this research to first, assist *Alphawave* to develop its implicit and informal technology management processes into explicit and formal technology management structures. Second, to develop a set of tools and frameworks to assist *Alphawave* to maintain its technology management structures, while also serving as a long-term strategic decision-making tool.

1.4 Research Problem

This study attempts to determine how technology management can be implemented in an existing holding company with a number of subsidiaries grouped together in a complex structure. In particular, the study investigates how technology management could be implemented within the *Alphawave* group of companies. The fundamental problem statement of this study can thus be summarised as "How can technology management be implemented in an existing group of companies, *Alphawave*, with a complex hierarchical structure?". This research problem statement, along with the, still to be discussed, related research questions, objectives and propositions, are shown in Figure 1-3.

The problem statement is understandably broad and requires a two-branched approach to be adequately answered. The one branch will investigate from a theoretical and academic background how technology management can and has been implemented in previous cases. The other branch will investigate, based on the knowledge gained from the first branch, how technology management can practically be implemented in the real-world situation of the *Alphawave* group.

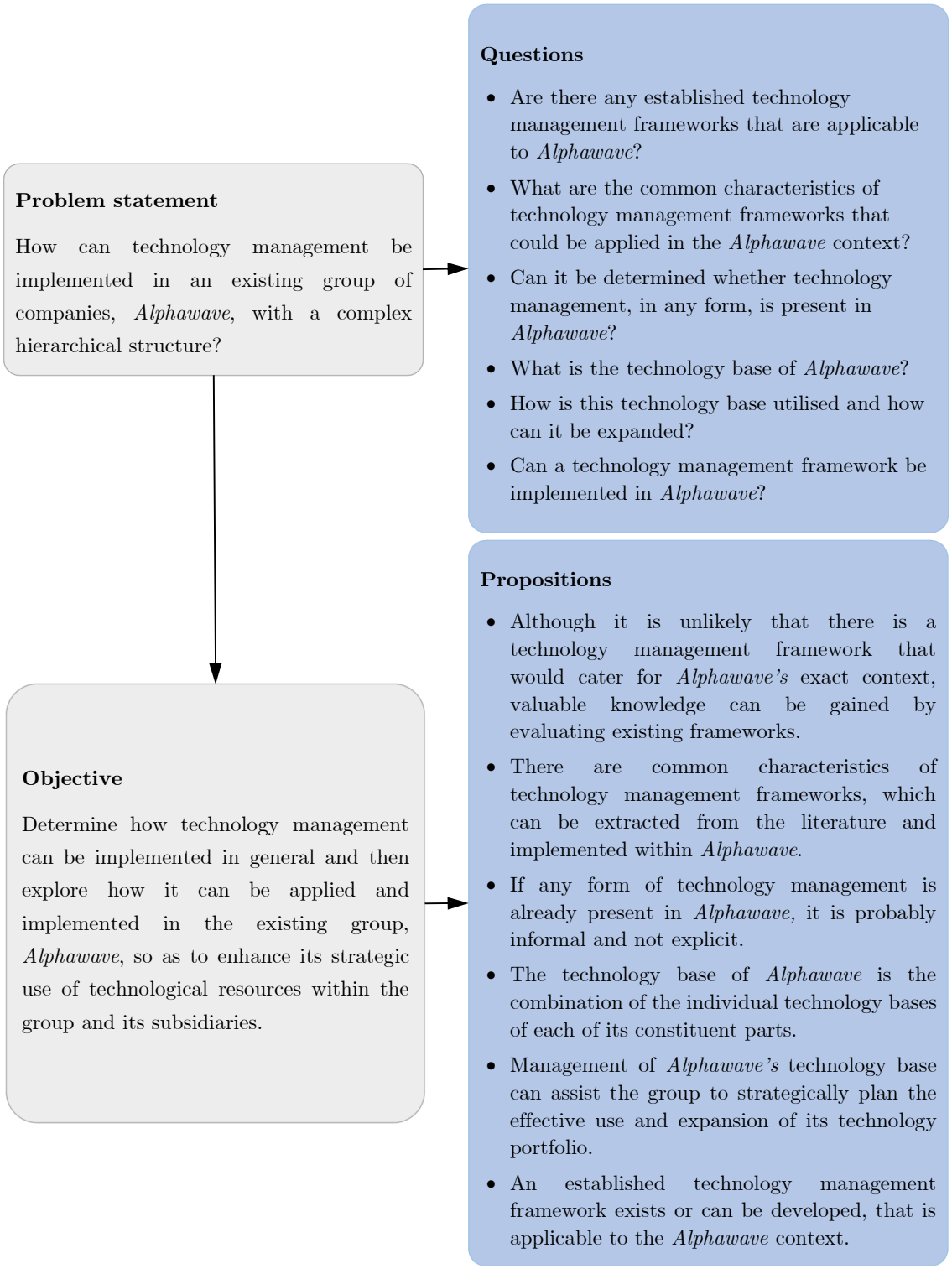


Figure 1-3: Research problem statement and objectives

The first branch of the study reviews already published research to ascertain how technology management has been implemented in a real-world situation. This branch of the study, therefore, attempts to answer the following questions from existing literature:

- Are there any established technology management frameworks that are applicable to *Alphawave*?
- What are the common characteristics of technology management frameworks that could be applied in the *Alphawave* context?

Building on the results of the theoretical and academic branch, the second branch investigates how technology management can be implemented within *Alphawave* and its subsidiaries.

As noted in the previous section regarding the background of *Alphawave*, the group consists of a dynamic group of companies with a number of key technological capabilities. Some of these capabilities are shared between the different companies in the group, others are unique to individual companies. This seems to indicate that some form of technology management might already be present within the group, although probably not explicit or formal. From this it follows that the second branch of the research tries to answer the below question related to how technology management can practically be implemented within the Alphawave group:

- Can it be determined whether technology management, in any form, is present in *Alphawave*?
- What is the technology base of *Alphawave*?
- How is this technology base utilised and how can it be expanded?
- Can a technology management framework be implemented in *Alphawave*?

1.5 Research objectives

Since the research problem will be solved by a combination of a theoretical and academic approach as well as a practical implementation, the objective is set to account for both situations. The theoretical and academic branch of the study has the objective to determine, in a general sense, how technology management is intended to be implemented. The practical implementation, while based on the theoretical background, will be more concerned as to how technology management can be implemented in the specific real-world situation of the *Alphawave* group.

To account for the dual outcomes the objective of the study is set as follows: "Determine how technology management can be implemented in general and then explore how it can be applied and implemented in the existing group, *Alphawave*, so as to enhance its strategic use of technological resources within the group and its subsidiaries."

The research propositions of the study are focused on how general technology management principles can be tailored to be implemented into a specific organisation, in this case, the *Alphawave* group. Although the propositions, and most of the study for that matter, refer to a specific organisation it is expected that the rationale of this study can be reapplied in other cases as well. The following research propositions are then made to effectively investigate the validity of applying general technology management principles on individual organisations:

- Although is unlikely that there is a technology management framework that would cater for *Alphawave's* exact context, valuable knowledge can be gained by evaluating existing frameworks.
- There are common characteristics of technology management frameworks that can be extracted from the literature and implemented within *Alphawave*.
- If any form of technology management is already present in *Alphawave,* it is probably informal and not explicit.
- The technology base of *Alphawave* is the combination of the individual technology bases of each of its constituent parts.
- Management of *Alphawave's* technology base can assist the group to strategically plan the effective use and expansion of its technology portfolio.
- An established technology management framework exists or can be developed, that is applicable to the *Alphawave* context.

The objective of the study can duly be summarised as trying to determine what principles of technology management might be implemented at an organisation with multiple subsidiaries and then investigating how these principles might be implemented in a real-world situation.

1.6 Rationale for the study

Effective technology management can assist organisations to create long term strategies to manage its current capabilities and technology effectively and thus ensure that these organisations remain competitive in current and future markets. This effective management of technology is established by knowing how and which capabilities and technologies can best be utilised and expanded to enter new markets to ensure it maintains or expands its competitive advantage. [3], [9], [10], [31], [33]

While the development of a framework and resultant tool for considering and developing long-term strategies is a goal of this research, this study's main goal is to determine how well-established and traditional tools of technology management (e.g. technology audits and technology balance sheets) can be applied to an organisation that consists of multiple subsidiaries. As will also be noted in the literature review, many previous studies highlight the lack of practical methods to implement in technology management. Through the use of this specific case, this study will investigate how these principles can successfully be implemented within a real-world organisation with a complicated hierarchical structure, whilst documenting the process with which it can be implemented.

The case of *Alphawave* has certain characteristics that makes it a valuable example for other similar organisations to follow. The *Alphawave* group of companies are a diverse group of companies sharing mostly similar yet still different technology portfolios and strategic aims. How the different company's technology portfolios are shared or individually developed are important considerations and could affect the long-term success of the group as a whole.

An inductive and qualitative research process is employed to solve the research problem statement and is illustrated in Figure 1-4. The method approaches the problem in stages. The first stage has already been highlighted in this chapter, notably identifying the research questions that need to be resolved by this study. The following stage takes the form of a literature review, where broader solutions for general, non-specific, cases

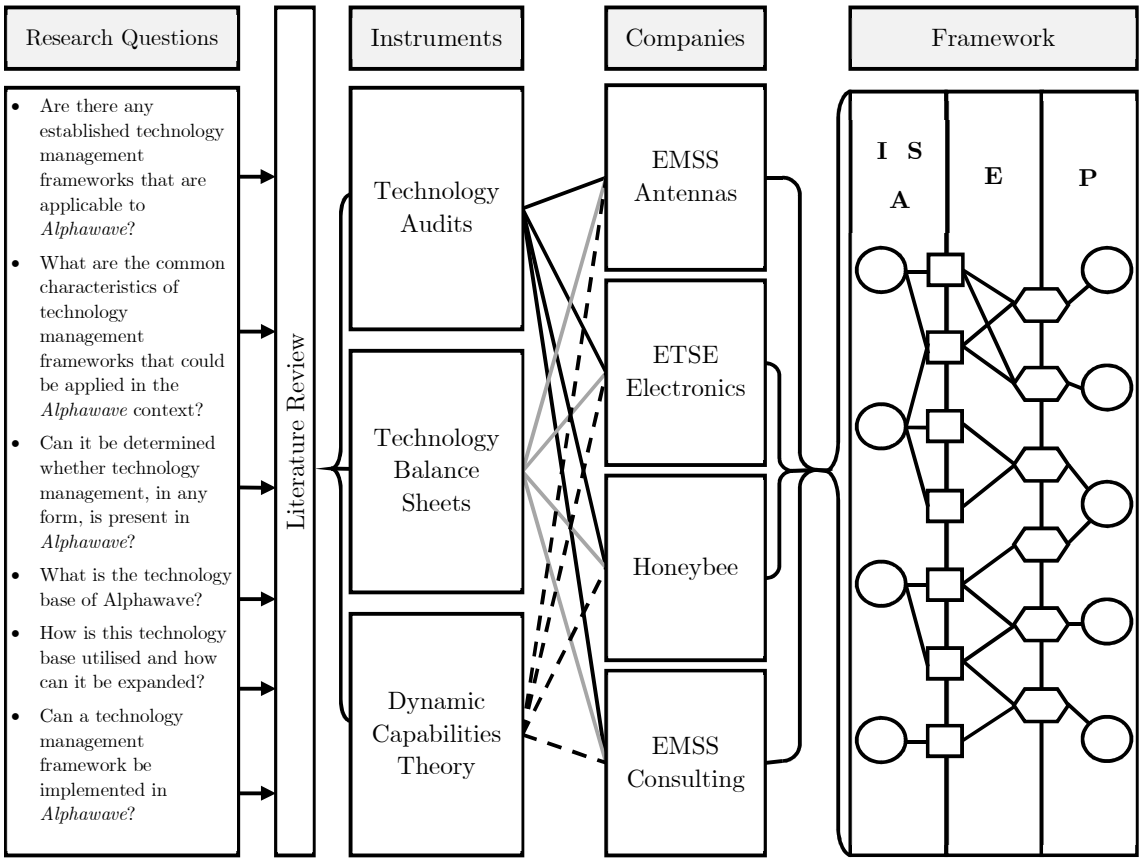


Figure 1-4: Research process flow

are identified. These solutions are then reworked into a reproducible set of instruments that can be reliably applied to each of the different companies making up the *Alphawave* group. The goal of these instruments is to investigate the status of technology and technology management within each of the *Alphawave* entities.

The investigation into each of the group's different entities results in a complex web of both shared and independent technology lodged in the various companies. This complex web is then mapped into a framework visually illustrating how the various interrelationships are connected between the various different companies. This framework then not only serves as a map of the current technological situation within the group but also as a visual planning tool to assist with strategic decision-making. Visually illustrating the state of technology in the individual companies as a subset of the overall state of technology in the group makes this framework useful as a strategic tool both at group and company level. Although developed for a specific case, this

framework should be useful to map any collection of independent, yet still related parts, to visually assist with high-level strategic decision-making.

As with the developed framework, it should be possible to apply the same research process to other organisations or cases, regardless of whether it was developed for a particular case. Some of the elements would have to be reworked; for instance, other instruments might have to be identified from the literature to be applied to each of the entities of that particular case, however, the core investigation remains the same.

This research study follows a structured and reproducible process to determine how technology is managed within a group of companies. Applicable instruments are identified from relevant literature and applied uniformly to each of the entities of the organisation. The interrelationships between the different entities are then mapped in a visual framework to assist with strategic decision making within the organisation and the various entities.

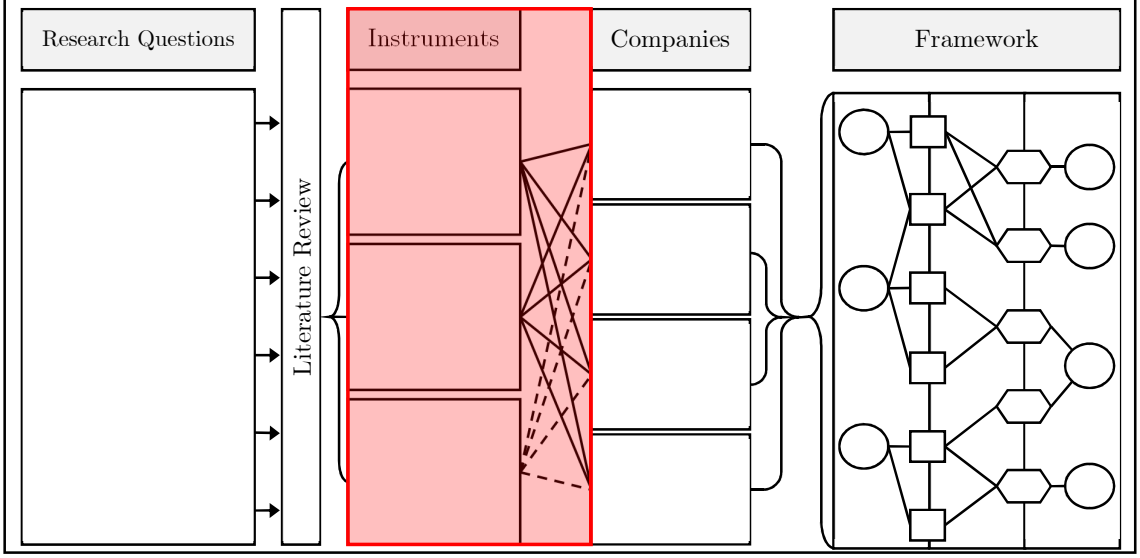
With its firm base in literature, this process aims to facilitate the implementation of technology management frameworks in real-world situations, and in particular in the case of the *Alphawave* group of companies. The use of frameworks, such as these, are intended to promote the effective linkage of technology and business strategy, and thus assisting organisations to effectively leverage their technology for maximal competitive advantage.

CHAPTER 2

RESEARCH DESIGN AND METHODOLOGY

This chapter gives an overview of this research document and describes the research methods and instruments adopted for this study:

- The research strategy describes the different aims of the various chapters of this study and how the aims combine for the strategy as a whole.
- The research method establishes the research as a qualitative, inductive and functionalist study and describes the dual theoretical and practical branches of the study.
- The primary research instruments of the study, i.e. technology audits through semi-structured interview, are outlined.
- The elements discussed in this chapter forms part of the overall research process as illustrated below:



2.1 Research Strategy

The aim of this study is to determine how (mostly academic) technology management principles can be applied in practice by organisations. In particular, how technology management principles can be applied within a group of companies assembled in a complex hierarchical structure. To achieve this aim, the research can be divided into

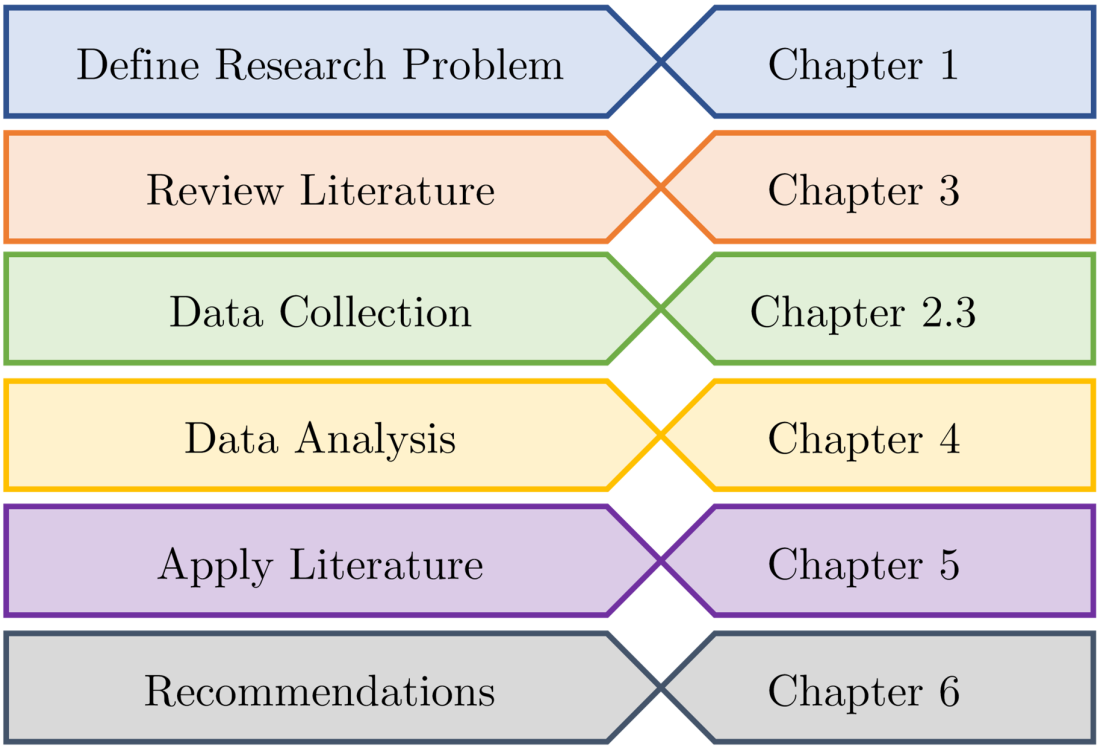


Figure 2-1: Research Strategy

six different sections. These different sections and corresponding chapters are shown in Figure 2-1. The research problem is defined as part of the background in Chapter 1. The research problem is based on the real-world context of a South African SME with a large and diversified technology portfolio spread over the different companies in the hierarchical and complex structure of the *Alphawave* group. By exploring how technology management principles can be implemented in this context, it is hoped that the study will also reveal how the *Alphawave* group can better exploit and expand their technological capabilities.

Chapter 3 of this study focuses on a structured literature review undertaken to establish the scientific basis of technology management. Also included in this chapter are selected further literature reviews of principles that require further examination beyond the scope of the structured literature review.

Data for this study was collected through a series of semi-structured interviews with relevant role-players from the different companies that make up the core of the

Alphawave group. The development and content of these interviews are discussed in Section 2.3 and serve as a technology audit of the technological capabilities available within the group and various companies. These audits are based on the *Dynamic Capabilities Theory* approach and utilise technology balance sheets. This section also details the reports wherein the results of the interviews, and resultant audits were summarised, all these reports are included in full in Addendum B.

The information and data collected and summarised during the interview and audit process are then analysed in Chapter 4. This chapter will investigate how technology is managed, regardless of how informal, within the group and its respective companies. Based on these results the potential benefits of implemented further technology management structures are explored.

A conceptual framework is developed and discussed in Chapter 5 and is intended to help the *Alphawave* group to effectively manage their technological capabilities and thus, in turn, enhance their technology management processes. The framework is developed based on the prevalent principles, themes and characteristics highlighted as part of the literature review of Chapter 3.

Finally, Chapter 6 will summarise the conclusions of this study, while also exploring how future research or practical implementation could enhance the outcomes of this study. These outcomes are not only evaluated for implementation within the *Alphawave* group but also how the same framework or principles can be implemented in different contexts and situations.

In summary, this study evaluates a real-world problem by firstly researching established scientific literature. Thereafter the real-world context is explored and, based on these results, a conceptual framework is developed to enhance the technology management within the *Alphawave* group. The study thus encapsulates both the theoretical and practical implications of implementing technology management.

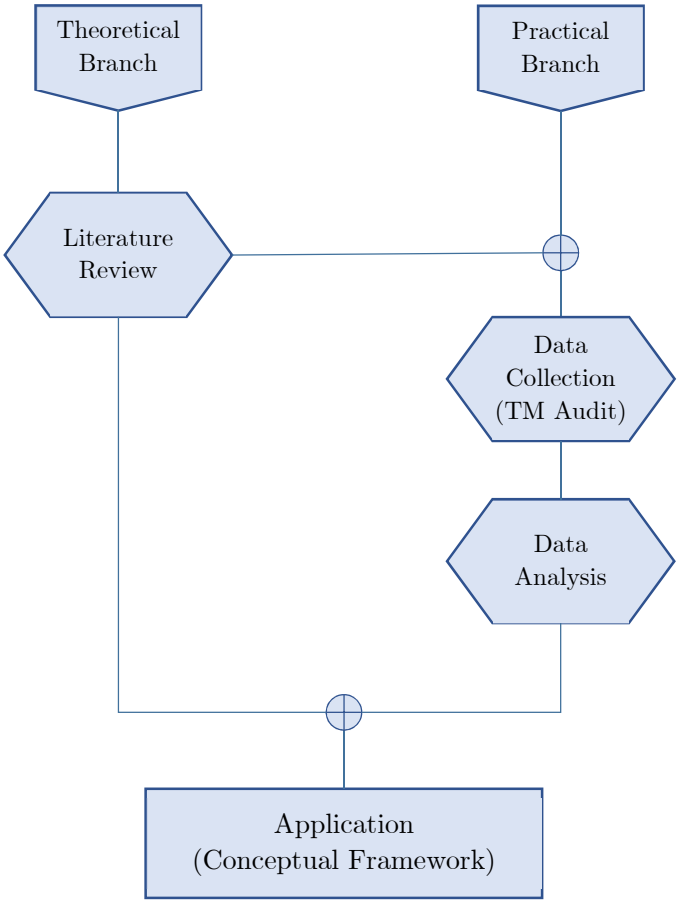


Figure 2-2: Two branches of the research study

2.2 Research methodology

To effectively study both the theoretical and practical facets of implementing technology management, this study can broadly be divided into two branches. The first branch sets out to determine the theoretical principles of technology management from already established academic literature. The second branch attempts to apply the principles of technology management in an actual organisation, the *Alphawave* group.

The study and its two branches are visually presented in Figure 2-2. As indicated in this figure the theoretical and practical branches of the study interlink at two different occasions. The first occasion is when the required tools and techniques to analyse the technology management situation in the *Alphawave* group are developed based on the results of the literature review. The second occasion is when a conceptual framework

is developed by applying the principles identified during the literature review on the resulting data from the analysis of the *Alphawave* situation.

This two-branched strategy should be effective in ensuring that correct data and information is collected during the study and that the resultant framework is based on well-established and academically sound principles. At the same time, as the data is collected from a real-world situation, the methods, analysis and results should be suited to be applied in practice.

As the study makes no attempt to hypothesise a theory to be tested against the gathered data, the study is inductive of nature. Conclusions, generalisations and principles are drawn from its observations, whether from the literature review or the practical audits. These observations are then used to create a conceptual framework encapsulating the theories of how the different elements of technology management interact and can be managed in a real-world situation. [36]

Whenever an organisation is researched certain assumptions are made on the fundamental nature of organisations and how to research them. As will be seen in the results of the literature review in Chapter 3 and in the implementation of the literature later on, this study takes an objectivist view of organisations. This view assumes that an organisation is a collection of real processes and structures, rather than a social construct created by individuals. As such, based on the objectivist view, an organisation can best be researched from an objective and external position. [36]

Similar assumptions are made regarding the role and function of organisational research. This study takes the regulatory approach and attempts to describe the workings of an organisation and suggest incremental improvements rather than radical and fundamental changes. This approach fits the later-mentioned function of alignment in technology management, which attempts to better align different processes within an organisation rather than fundamentally transforming the processes.[36]

As illustrated in Figure 2-3 these two views and approaches place the research paradigm of the study as functionalist. The study is concerned with solving problems

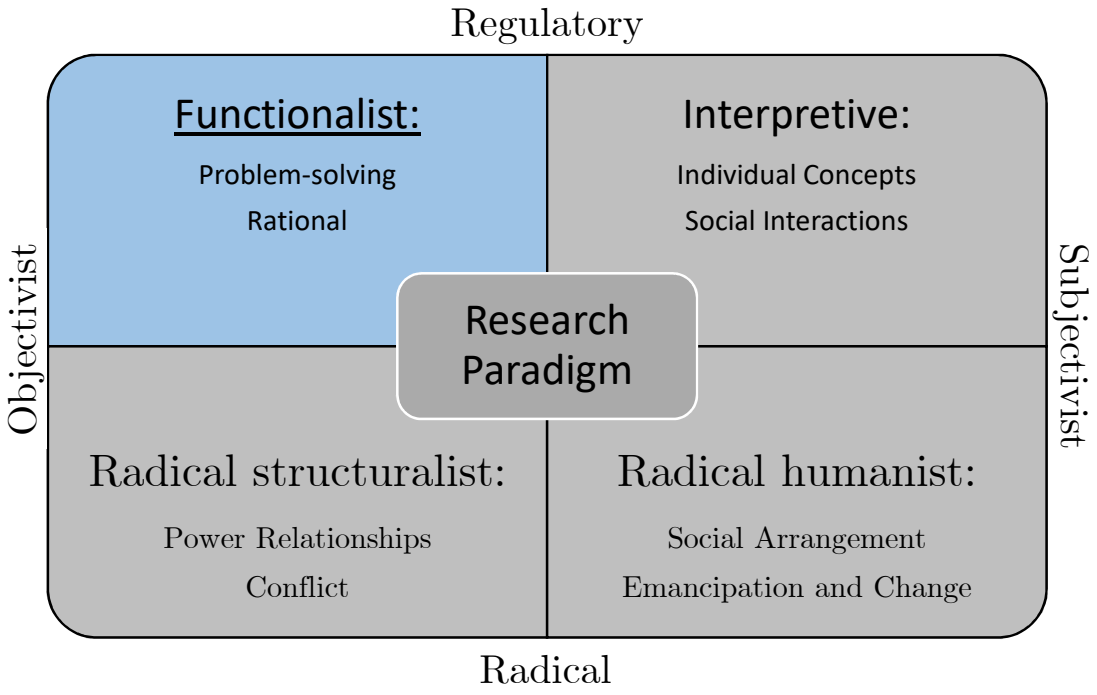


Figure 2-3: Paradigms for the study of organisations (Reproduced from A. Bryman, et al [36])

within an organisation and attempts to provide rational measures to correct them. The study thus takes an objective view of an organisation and, rather than effecting radical transformations, explores how the better alignment of the various processes and aspects of the organisation can improve the general well-being of the organisation.[36]

This study is of a qualitative nature. Qualitative research is used in technology management literature as a common method to research how technology management can be applied within an organisation. Qualitative research generally attempts to understand how the various actors within an organisation interacts by analysing formal and informal processes within the organisation. How these processes change and evolve other time is a cornerstone of qualitative research. This type of research will assist to explore how technology has been managed in the past and at the same time help to determine how the relevant processes can be optimised to enable even more efficient management of technology. [36] The research generally followed the general steps of qualitative research as stipulated in Figure 2-4.

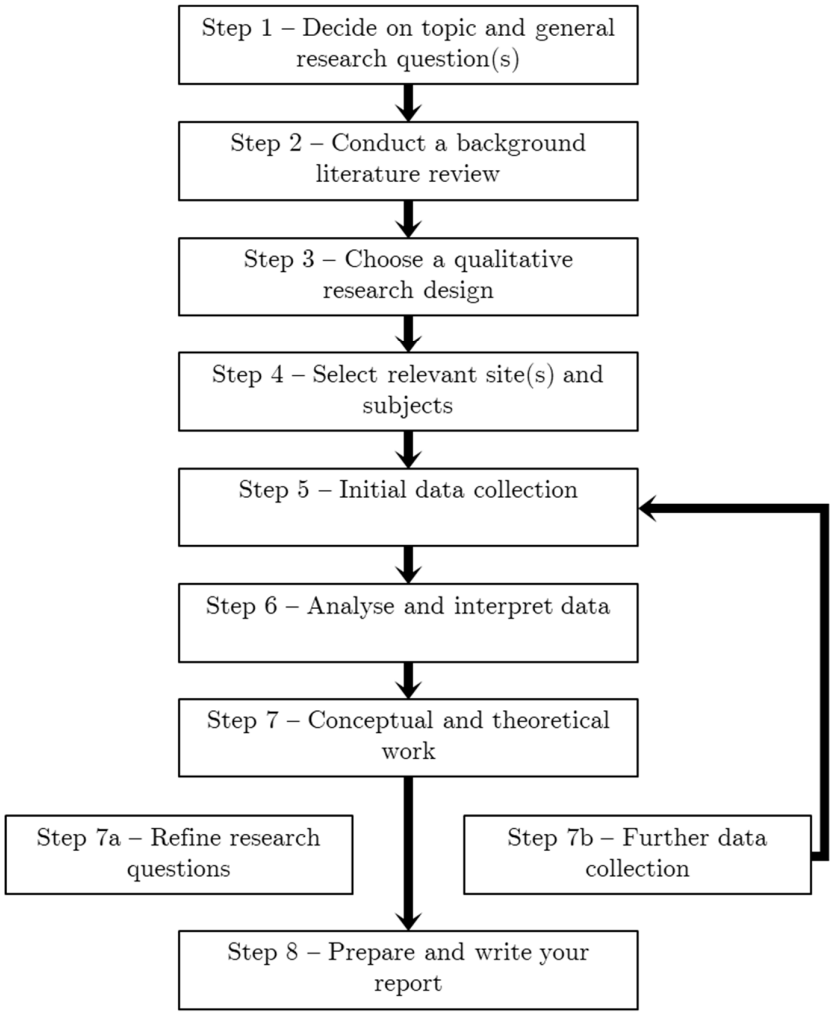


Figure 2-4: General outline of the main steps involved with qualitative research (Reproduced from A. Bryman, et al [36])

The method of data collection is a critical part of any study and for this reason, specific care was taken to develop an appropriate research instrument to effectively gather information from the relevant participants. As described in more detail in the following section, the research instrument decided upon was a series of qualitative interviews where research subjects could answer questions in semi-structured interviews allowing both interviewer and subject to explore various topics in-depth as needed. The results of these interviews were analysed using a combination of coding and narrative analysis to establish the context and extent of the information gathered. [36]

2.3 Research Instrument Design

A core outcome of this study is to determine what the current state of technology is as well as how technology is currently managed in the *Alphawave* group. To determine the state of technology and technology management within the group and its subsidiaries a technology audit is designed to form part of a series of semi-structured interviews with key role-players of the *Alphawave* group. During these interviews, the state of technology and technology management is audited based on the *Dynamic Capabilities Theory* approach with the help of technology balance sheets. The results of these audits are then summarised in a *Technology Management Analysis* report. This report highlights the structures and state of technology management within each of the companies in the *Alphawave* group.

From the results of these technology audits in the various companies in the *Alphawave* group, the broader state of technology management in the *Alphawave* group is analysed.

2.3.1 Selection of Alphawave Role-players

Based on initial discussions with the upper management of the *Alphawave* group, the various managing directors (or similar) of the different companies that make up the *Alphawave* group was identified as the ideal subjects to represent each company as part of the interview process. Due to the nature and complexity of the different companies, these representatives coordinate technology management within the different companies, although not always in a formalised manner.

The different representatives also form part of the *Alphawave* group's management structure and, through this, are also involved in the process to share technology between the different companies. The director level in the *Alphawave* group is then responsible to steer the direction of technology development in their respective companies as well as sharing technology between the different entities.

Table 2-1: Company representatives partaking in study

Participants	**Company**	**Role**
Participant A	*EMSS Antennas*	Incoming Managing Director
Participant B	*EMSS Antennas*	Outgoing Managing Director
Participant C	*ETSE Electronics*	Managing Director
Participant D	*Honeybee*	Chief Executive Officer
Participant E	EMSS Consulting	Managing Director

The representatives from each of the four entities included in this study are listed in Table 2-1.

As indicated in this table, every company had one representative as part of the interview process, except for *EMSS Antennas*. As will be covered in more detail in the discussion of the technology audit of this particular company, *EMSS Antennas* was in a transition phase at the time of these interviews. As part of this transition, a new managing director had been appointed. Both the incoming and outgoing directors were interviewed simultaneously to ascertain both how technology was managed in the past and how it will be managed going forward.

Each representative took part in a semi-structured interview of approximately two hours each. The structures of these interviews are detailed in the following section.

2.3.2 Interview Structure

Each of the representatives was interviewed in their own offices. The interviews followed a semi-structured approach, with questions prepared beforehand to give guidance to the discussion rather than to be answered in a specific order. The aim of the interviews was to learn as much as possible about the various companies and their respective technology management policies through conversation.

Each interview started with a short introduction to the principles of technology management. There was also a discussion of simple tools to be employed to establish specific relationships between different technological subjects during the course of the interviews. Some historical examples were presented to illustrate how technology had been managed in the *Alphawave* group before, and the potential benefits of more formal technology management. This introduction attempted to establish a mutual understanding and language of technology management as a foundation for the discussion between the interviewer and subject, while simultaneously ensuring that the subject is aware of the outcomes of the interview and study as a whole.

To establish some background of the company the initial questions were intended to guide the conversation to determine the environment of the company and how products and/or services are developed or delivered to different markets. Specifically, the questions related to how innovation is managed to develop new products and/or services.

After establishing the background and innovation systems of the company, the following questions related to how technological capabilities are managed within the company. Specifically, which formal and informal structures are in place to identify what capabilities can be developed into new products, what capabilities are available within the company and what capabilities are required by the company.

Finally, and based on the previous questions, the core competencies of the company are identified. Also identified are the capabilities that can be developed internally within the company and what capabilities should be acquired externally from the company. All the questions included as part of the interview are summarised in Figure 2-5.

The questions related to the current and planned capabilities and competencies of each company are specifically included to audit the current state of technology and the manner in which technology is managed within the company. The relationships

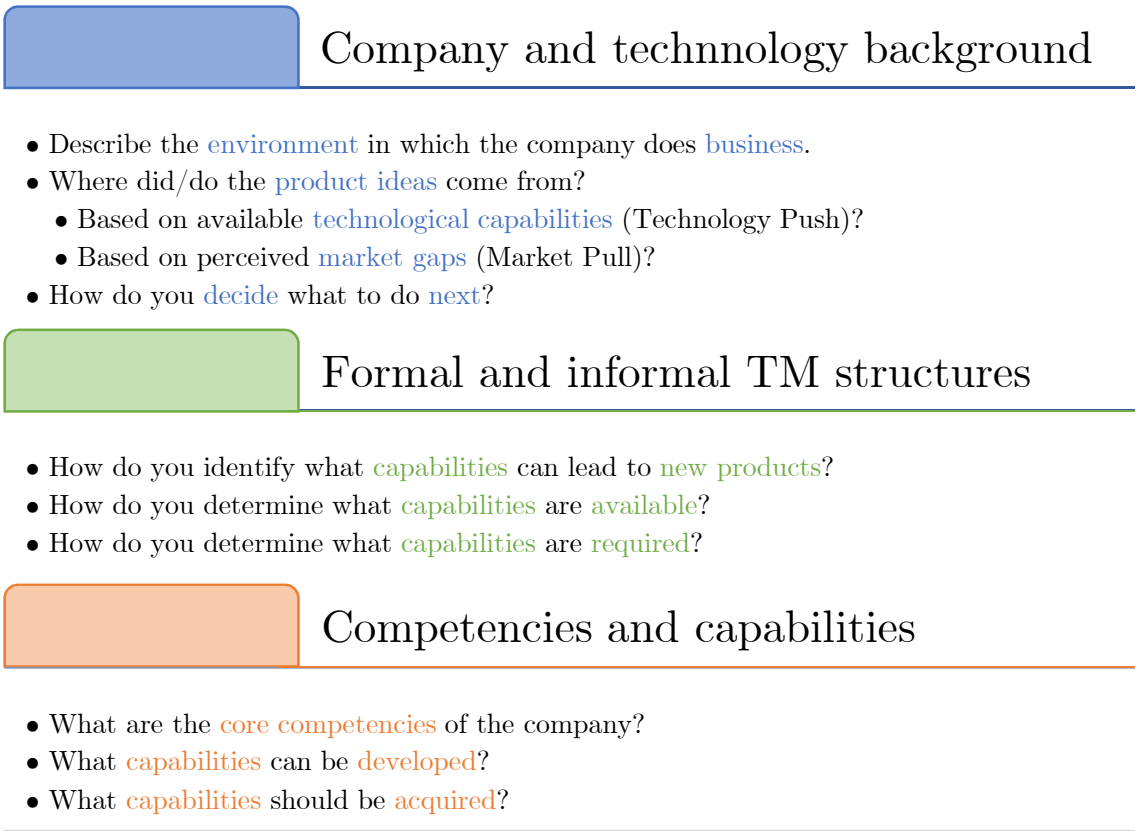


Figure 2-5: Summary of interview questions

between the different technologies are also evaluated and audited using technology balance sheets.

The graphical output of these balance sheets makes them ideal to summarise the results of the audit findings, both for the current situation as well as for forecasted planned situations. The balance sheets show how the different technologies, processes, products and markets are interlinked within the individual companies.

2.3.3 Resulting Audit Reports

During the interview, the interviewer makes notes of the discussion and specifically the answers related to the questions above. If agreed to by the subject, a voice recording of the interview is also made. Based on the notes and voice recording, if available, the interview is then summarised as a *Technology Management Analysis* report, written by the interviewer and edited by the subject of the interview. The report specifically

relates the findings of the technology audit, which takes place during the course of the interview.

By allowing each subject to edit the report, the subject of the interview has control over the information included in the report and the study as a whole. This ensures the accuracy of the report and that no confidential information is inadvertently divulged to outside parties. If needed, a second, and much shorter, follow-up interview is held to discuss and finalise the report.

The individual reports then become the main sources of research for the study. As the subject had the chance to screen the information for possible confidentiality issues and also correct any factual errors, the reports can easily be shared as part of the study. They cover general topics relating to the history and structure of the company, innovation processes and structures, as well as the results of the technology audit of the competencies, capabilities and processes present in the company.

Each report starts with a review of the business environment of the company, which also often includes a background of the technological and structural history of the company. This section explains the situation and circumstances of the company at present and how it came to be in that position.

The following section of the report investigates how the company manages innovation. Although the current innovation structures are important, other innovation structures historically applied are also investigated. Specific care is taken to identify both formal and informal innovation structures.

The next section identifies the core competencies entrenched in the company at present. These competencies should shed light on what gives, or could give, a competitive advantage to the company. Any competencies that may require further development or capabilities that need to be acquired by the company are also discussed in this section.

Based on the previous sections as well as the technology balance sheet derived during the interview, an audit of the current state of technology is performed. The results of

the audit are analysed and included in the report and attempt to describe both the current state of technology and its management within the company, as well as future risks or opportunities are made.

Following the audit, a final conclusion on the state of technology management ends off the report. This conclusion summarises the current state of the company and how it can be developed and grown in the future using technology management principles.

2.3.4 Management of Potential Conflict of Interest

The author of this research was employed full-time at one of the subsidiaries of the *Alphawave* group, *EMSS Consulting* (later known as *Alphawave Mobile Network Services*) during the course of the study. Although this employment enabled access to the *Alphawave* group and the various role-players, it also created a potential conflict of interest to exist. As the study includes audits of the technology and processes within the various companies, due care was required not to skew the results of these audits, and especially for the subsidiary where the author was employed.

The potential conflict of interest was mitigated, in part, by the fact that the author was employed as a project manager in the subsidiary. The project managers of this subsidiary are not involved with strategic planning at group level, nor active with the sharing and possible management of technology between the different subsidiaries. Also, the project managers have very little professional contact with the directors or employees of the other subsidiaries. The level of management level at which the author was employed seems to be adequately separated from the level of investigation of the study.

The potential conflict of interest was further managed by conducting the semi-structured interview, including technology audit, for *EMSS Consulting* only after the interviews for all the other subsidiaries had already been conducted. Reserving this interview until last ensured that the author could form a broader overview impression of technology management in the group as a whole before conducting the interview.

The interview was thus conducted from the context of the group, rather than from the context of *EMSS Consulting*.

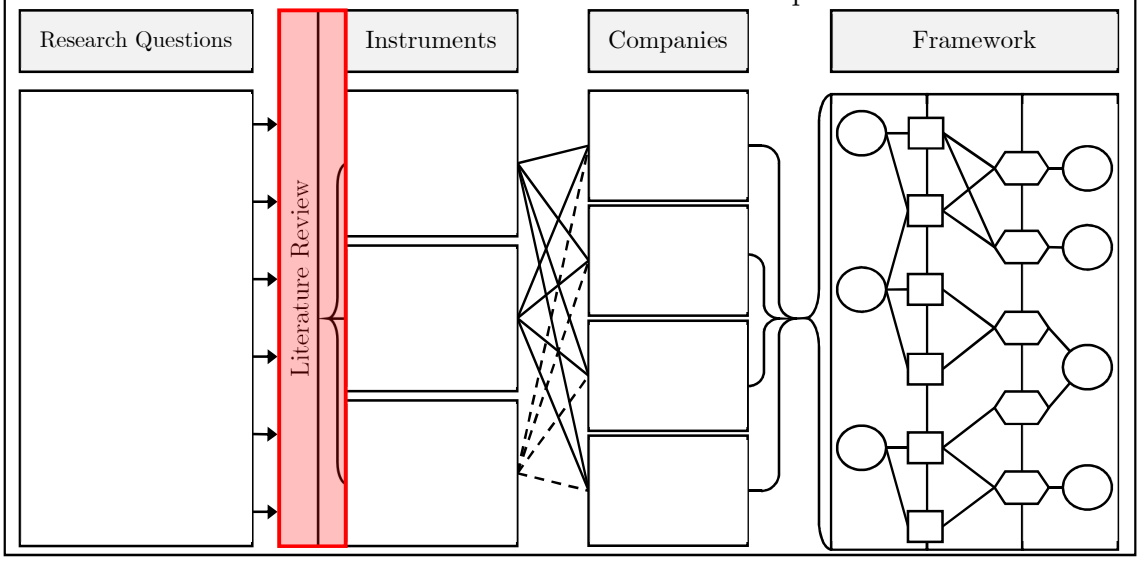
Finally, the reporting process assisted in mitigating the effect of the potential conflict of interest. As the interviewees had the opportunity to edit the final *Technology Management Analysis* report of their respective subsidiary, any unintentional bias from the author could be removed by the subject of the interview.

CHAPTER 3

LITERATURE REVIEW

This chapter will detail the literature review conducted to form the scientific foundation for this research, including:

- A structured literature review of 50 studies to research relevant trends in the field of technology management, especially with regards to frameworks.
    - The studies included are a blend of well-established literature, as well as a selection of more recent studies.
- Based on the structured literature review, some of the concepts identified in the review is expanded on to obtain a deeper understanding of them.
- The instruments to be applied to the various companies are derived from the conclusions of this review.
- The literature review fits into the overall research process as below:



3.1 Introduction

The literature review of this study predominantly focuses on the different aspects of technology management. This includes, but is not limited to, different types of technology management frameworks, tools and principles thereof. With this in mind, the literature review consists of two distinct, but related parts. This first part is a structured review of a selection of articles relating to technology management

frameworks. In turn, the second part is a selective review of relevant key concepts in the greater technology management field.

In particular, already established principles and tools of technology management and how to apply them to existing organisations and businesses are explored. The manner in which these principles and tools have been implemented and the sectors where they have successfully been implemented will be investigated.

The literature review has the following two outcomes: (1) establish a broad understanding of the field of technology management and specifically technology management frameworks and (2) develop in-depth knowledge of the relevant key technology management concepts as identified during the structured literature review.

3.2 Structured Literature Review

Technology management is an established field of science and there are vast selections of resources available related to the field. [3], [31], [37], [38] In an effort to bound the scope of the structured literature review, the number of studies included in this literature review was limited as described below.

This literature review is not, and makes no claim to be, an exhaustive review of all the available literature available related to technology management. Instead, this structured review of a selection of articles in the field of technology management is intended to give a broad overview of a diverse and complex field.

3.2.1 Selection of Articles

To limit the scope of this literature review 50 articles were selected to form part of the review. Each of the articles were selected to fall into one of two categories of articles. The first category are the 30 most cited articles of all time regarding technology management frameworks. The second category is the 20 most relevant articles of recent years based on a review of their respective abstracts.

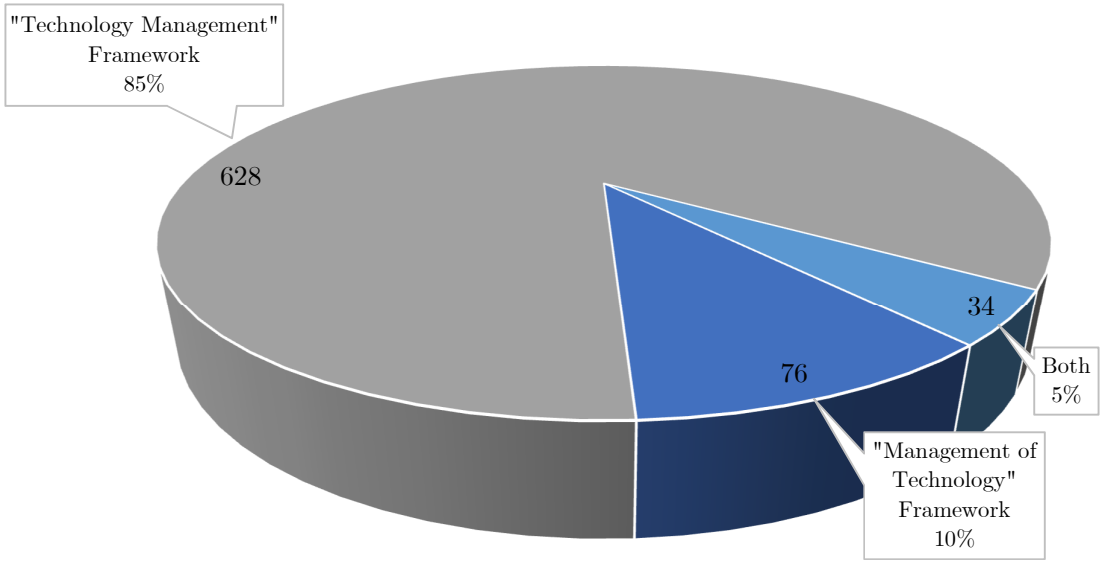


Figure 3-1: Number of results per search term

These two distinctive categories were selected to cover two different dimensions of the literature. The 30 most cited articles should address the fundamental principles of technology management frameworks and will ensure that the core knowledge of the field is explored during the review.

The selection of the 20 most relevant articles of recent years is an attempt to ensure that newer and potentially innovative studies are not excluded due to their relative newness. These 20 articles will then provide a review of the most recent research being done in the field and may potentially unearth innovative new ideas.

Both categories of articles were compiled by analysing search results of the Elsevier Scopus Database. Two search terms were used and the results collated into a list of 738 articles. The two search terms used were *"Technology Management" Framework* and *"Management of Technology" Framework.* These two search terms were selected to include a broad spectrum of articles of the entire field of technology management, also alternatively referred to as management of technology (MOT), while still specifically related to frameworks. The number of articles returned per search term is shown in Figure 3-1. The term *technology management* seems to be the more popular term resulting in 85% of the results. The term *management of technology* accounts for

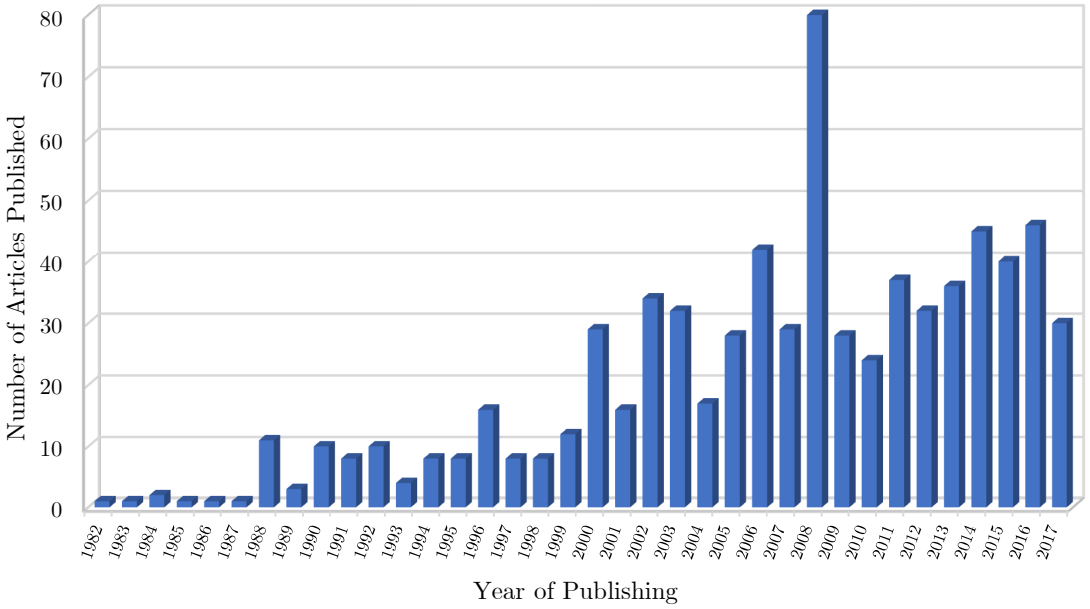


Figure 3-2: Total of search results per year published

about 10% of the results, indicating that the term, even though it is less widely used, is still relevant. Although relatively small, 5% of the results were returned from both of the search terms.

The list of articles returned from the Scopus search shows a general growing trend in the number of articles published per year in the field of technology management, as shown in Figure 3-2. The first article was published in 1982 and a steady number of articles were published until the late 1980s. In the late 1980s and early 1990s, the number of articles published per year increased considerably. Another considerable increase in the number of articles published per year is evident in the early 2000s and this number seems to have been constantly increasing since then.

The selection of 20 additional articles seems to be vindicated. As shown in Figure 3-3, no articles published after 2014 were adequately cited to be included in the list of 30 most cited articles. Indeed, if only the 50 articles were included in this literature review the most recent article included would have been published in 2014 and the most cited article since 2015 would only be 132rd on the list of most cited articles. As the number of articles published on this topic seems to be increasing yearly, a large body research would have been inadvertently excluded from this study if only the most cited articles

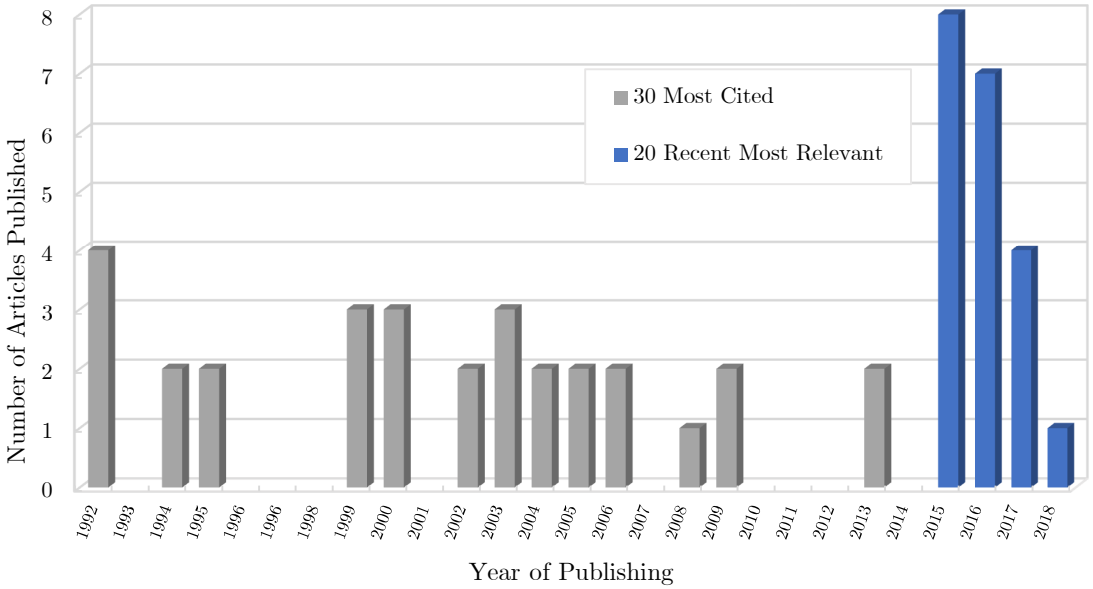


Figure 3-3: Total number of articles included in study published per year

were included. The decision then to add an additional 20 recent articles to the literature review adds more up-to-date research to the study and represents a large part of the total body of research already performed on this subject.

In the absence of a suitable metric, such as the number of citations, to empirically select the 20 most relevant recent articles, all the articles published between 2015 and 2017[1] were analysed on abstract level. The 20 most relevant articles were selected and included in the study based on the author's judgement of the relevance of the abstracts. Analysis at abstract level was also used to determine whether all the articles included in the 30 most cited articles were, in fact, relevant to the study at hand.

The 30 most cited articles included in this study are listed in Table 3-1 and the 20 most relevant articles of the past three years are listed in Table 3-2. These articles were then analysed to determine the leading trends in technology management. The results of this analysis are discussed in the next section with particular attention to

[1] One article was in print during the selection of articles for inclusion in 2017 and subsequently published in 2018 as indicated in Table 3-2.

Table 3-1: List of the 30 most cited articles included in study

The 30 most cited articles included in study			
Index	**Title**	**Authors**	**Year**
1	A framework for quality management research and an associated measurement instrument[65]	Flynn B.B., Schroeder R.G., Sakakibara S.	1994
2	Innovation in project-based, service-enhanced firms: The construction of complex products and systems[52]	Gann D.M., Salter A.J.	2000
3	Examining a model of information technology acceptance by individual professionals: An exploratory study[66]	Chau P.Y.K., Hu P.J.	2002
4	Using and validating the strategic alignment model[43]	Avison D., Jones J., Powell P., Wilson D.	2004
5	Patent information for strategic technology management[62]	Ernst H.	2003
6	Manufacturing flexibility: Defining and analyzing relationships among competence, capability, and customer satisfaction[67]	Zhang Q., Vonderembse M.A., Lim J.-S.	2003
7	Integrating environmental issues into the mainstream: An agenda for research in operations management[68]	Angell L.C., Klassen R.D.	1999
8	Collaboration and technology linkages: A strategic supplier typology[69]	Kaufman A., Wood C.H., Theyel G.	2000
9	Success factors and impacts of mobile business applications: Results from a mobile e-procurement study[70]	Gebauer J., Shaw M.J.	2004
10	Exploring the Limits of the Technology S-Curve. Part I: Component Technologies[1]	Christensen, Clayton M.	1992
11	Integration of market pull and technology push in the corporate front end and innovation management-Insights from the German software industry[60]	Brem A., Voigt K.-I.	2009
12	Business Models and Technological Innovation[71]	Baden-Fuller C., Haefliger S.	2013
13	Alignment Is Not Enough: Integrating Business and Information Technology Management with the Balanced Business Scorecard[44]	Van Der Zee J.T.M., De Jong B.	1999
14	Social Indicators for Sustainable Project and Technology Life Cycle Management in the Process Industry[72]	Labuschagne C., Brent A.C.	2006
15	Aligning information systems with business strategy[45]	Baets W.	1992
16	Technology management: a process approach[5]	Gregory M.J.	1995
17	Whose responsibility is IT (information technology) management?[46]	Boynton A.C., Jacobs G.C., Zmud R.W.	1992
18	A comparison of the views of business and IT management on success factors for strategic alignment[41]	Burn J.M., Szeto C.	2000
19	Understanding technology management as a dynamic capability: A framework for technology management activities[3]	Cetindamar D., Phaal R., Probert D.	2009
20	Technology management tools: Concept, development and application[42]	Phaal R., Farrukh C.J.P., Probert D.R.	2006
21	Implementing advanced manufacturing technology: An integrated planning model[63]	Chen I., Small M.	1994
22	Product technology transfer in the upstream supply chain[73]	Tatikonda M.V., Stock G.N.	2003
23	Knowledge inventories and managerial myopia[74]	Miller K.D.	2002
24	Manufacturing strategy, business strategy and firm performance in a mature industry[54]	Williams F.P., D'Souza D.E., Rosenfeldt M.E., Kassaee M.	1995
25	Information technology management: a knowledge-based perspective[75]	Bolisani E., Scarso E.	1999
26	An integrated framework for measuring product development performance in high technology industries[64]	Mallick D.N., Schroeder R.G.	2005
27	The joint influence of technology uncertainty and interorganizational interaction on external technology integration success[76]	Stock G.N., Tatikonda M.V.	2008
28	Information technology and business-level strategy: Toward an integrated theoretical perspective[55]	Drnevich P.L., Croson D.C.	2013
29	Linking knowledge transformation to Information Systems evaluation[30]	Irani Z., Sharif A.M., Love P.E.D.	2005
30	Exploring the Limits of the Technology S-Curve. Part II: Architectural Technologies[2]	Christensen, Clayton M.	1992

Table 3-2: List of the 20 most relevant articles of the past 3 years included in study

The 20 most relevant articles of the past 3 years			
Index	**Title**	**Authors**	**Year**
31	Customer and competitor insights, new product development competence, and new product creativity: Differential, integrative, and substitution effects[57]	Chuang F.-M., Morgan R.E., Robson M.J.	2015
32	Behavioral technology credit scoring model with time-dependent covariates for stress test[77]	Ju Y., Jeon S.Y., Sohn S.Y.	2015
33	Corporate-level technology strategy and its linkage with corporate strategy in multi-business companies: IKCO case study[7]	Arasti M., Khaleghi M., Noori J.	2017
34	Strategic roadmapping of robotics technologies for the power industry: A multicriteria technology assessment[8]	Daim T.U., Yoon B.-S., Lindenberg J., Grizzi R., Estep J., Oliver T.	2018
35	The patent portfolio value analysis: A new framework to leverage patent information for strategic technology planning[78]	Grimaldi M., Cricelli L., di Giovanni M., Rogo F.	2015
36	A fuzzy framework assessing corporate resource management for the mobile content industry[40]	Ghezzi A., Balocco R., Rangone A.	2015
37	A real options framework for R&D planning in technology-based firms[37]	Wang J., Wang C.-Y., Wu C.-Y.	2015
38	Technology alignment and business strategy: a performance measurement and Dynamic Capability perspective[39]	McAdam R., Bititci U., Galbraith B.	2017
39	Organizational Learning and Management of Technology[33]	Argote L., Hora M.	2017
40	Sources of technological innovation: Radical and incremental innovation problem-driven to support competitive advantage of firms[58]	Coccia M.	2017
41	Firms navigating through innovation spaces: a conceptualization of how firms search and perceive technological, market and productive opportunities globally[59]	McKelvey M.	2016
42	Analyzing the integration of technology platform strategies into the situational context of diversified companies[50]	Schuh G., Ryschka S., Rollmann A., Wetterney T.	2016
43	Evaluation of TOGAF as a management of technology framework[51]	Tambo T., Bargholz J., Yde L.	2016
44	Technology strategy framework for firms in growing economies[31]	Husain Z.	2016
45	Cybernetic Approach for Controlling Technology Management Activities[38]	Schuh G., Kramer L.	2016
46	Validity of business strategy as driver in technology management - A critical discussion[53]	Tambo T., Østergaard K.	2015
47	Integrated role of TQM and technology management in organizational sustainability[28]	Tasleem M., Khan N., Masood S.A.	2015
48	Strategy framework for technology platforms within the context of diversified companies[49]	Schuh G., Ryschka S.	2016
48	Technology selection between technology management and decision making: A case study from the Iranian automotive industry[47]	Ansari R., Soltanzadeh J., Tavassoli A.	2016
50	Towards a classification of technology strategy frameworks[56]	Santos C., Araújo M., Correia N.	2015

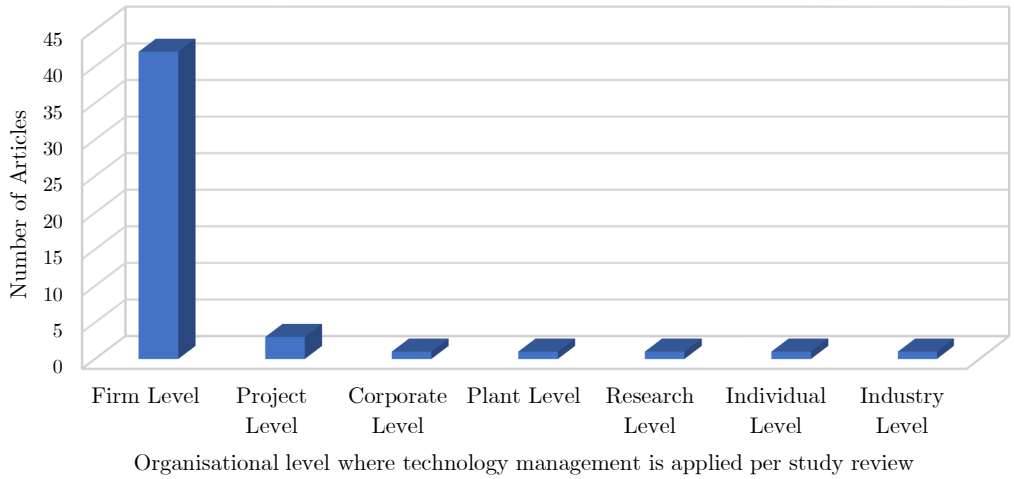


Figure 3-4: Bar chart illustrating the number of studies conducted at different organisational levels

how technology management frameworks have been implemented in real-world contexts.

3.2.2 Analysis and Classification of Articles

The 50 articles selected as part of the structured literature review were individually analysed and core information was extracted from each. This section will highlight the main trends found in the various articles and attempt to classify them accordingly.

The main focus of the literature review is to determine how technology management frameworks have been implemented in different situations. The analysis will then focus on different technology frameworks and tools implemented, while also identifying the contexts wherein these frameworks were applied.

The first definite conclusion that can be made from this literature review is that, based on the sample of articles included, the implementation of technology management takes place mainly at firm level. As illustrated in Figure 3-4, only eight out of the 50 articles included in this literature review is applied at a level other than the firm. When attempting to implement technology management in an organisation the firm seems to be the optimal level to at least start with the implementation of the required systems.

Notwithstanding the clear focus on using the firm as the basis for implementing technology management, from the onset identifying a single, all-encompassing framework for technology management seems an elusive goal. Various authors state that there is a need for a unified structure and framework in the technology management field [3], [5], [31], [38], [39], with most of the resulting frameworks being only conceptual and generally unproven in real-world situations [3], [39]–[41]. That said, the importance of technology management's role in linking technological capabilities with broader corporate and business strategies have been noted in various studies [3], [5], [7], [31], [39], [40], [42]–[46].

Technology management's origins lie in the large manufacturing companies of mostly the USA. Thus, as seen from the sample of articles used in this review, technology management has been predominantly applied in the manufacturing sector, followed by the ICT sector. It seems as if the potential advantages of technology management in other sectors have only become apparent fairly recently and thus fewer articles discuss the implementation of technology management in other sectors. Since the late 1990s, this has changed and with the increasingly rapid evolution of technology in all sectors, technology management has also become more and more important for companies to effectively leverage their competitive advantage [3], [38].

Technology management was also viewed as having only importance for large companies with separate R&D departments. This view has also been changing over the past few years and new studies are being published detailing the importance and implementation of technology management in SMEs in various industries. The understanding and utilisation of the technological resources of a company are fast being seen as a core characteristic of companies that are able to innovate in dynamic economies and contexts [3], [38].

By noticing how technology management has facilitated large corporations in developed economies to grow and flourish through turbulent economic times, many companies in developing economies are also trying to use technology management to

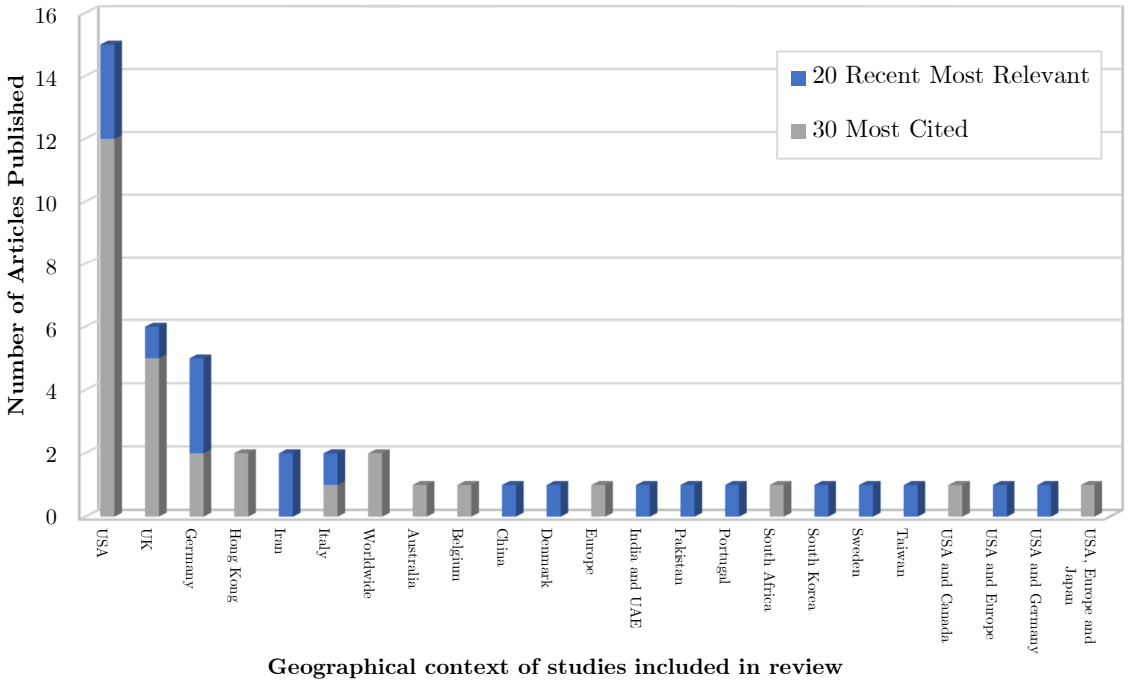


Figure 3-5: Number of articles published per geographic area

effectively leverage their unique technological capabilities [31]. Technology management seems especially important within economies where industrialisation is a priority.

By far the most articles included in this literature review were based on the context of the USA, as shown in Figure 3-5. As technology management evolved out of the USA's necessity to counter the rapid advances of the Japanese industry in the early 1980s, it is not surprising to see this trend. Following the USA is the UK and Germany, articles based on the context of various different European countries and the UK make up almost half of the articles included in this review. The skewness of this result is even more evident when analysing the articles included in the list of the top 30 most cited articles. Most of the articles included regarding developing countries were published in the past three years. This seems to show that technology management has been mostly studied and applied in industrialised countries, although there is some evidence that this has expanded to developing countries as well.

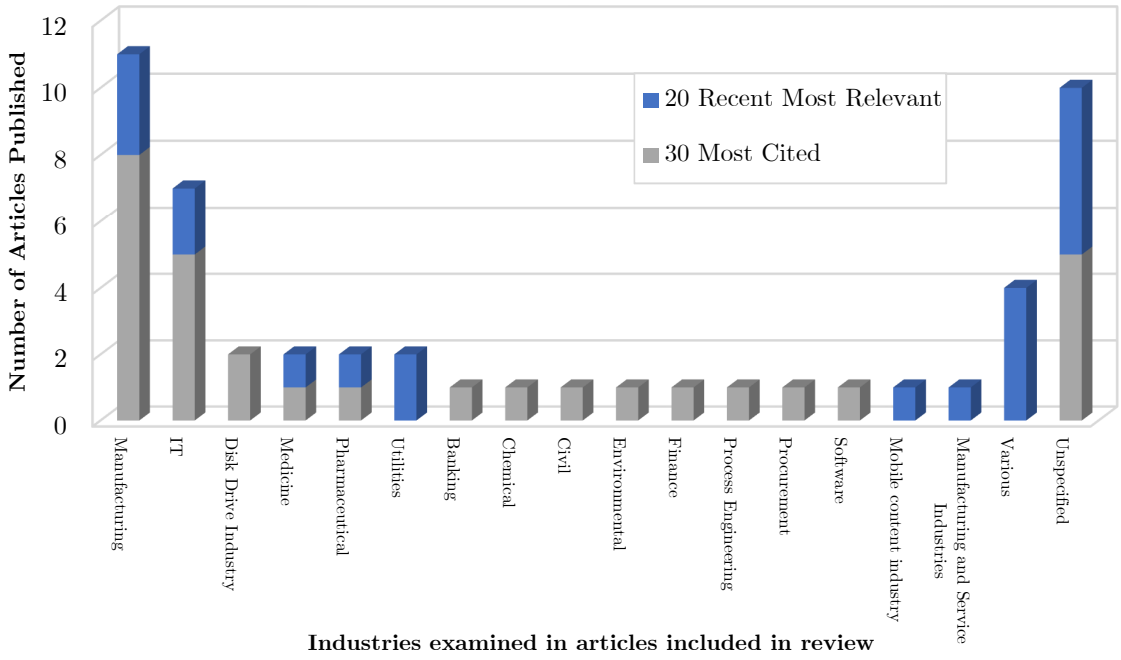


Figure 3-6: Summary of industries examined by the various articles included in the structured literature review.

Indeed, the articles published regarding technology management in Iran specifically [7], [47] discuss the importance of technology management to develop a country's industrial capacity. Although not included in this study, this same sentiment is expressed by De Wet [48] in an article describing how technology management should be used in developing countries trying to compete in technological markets. By incrementally developing their technological capabilities, companies in developing countries can increase their competitiveness on the global stage [47].

As with the shift of technology management to the developing world, so too has technology management been evolving out of its historical field of expertise. Figure 3-6 shows the different industries examined in the various articles included in the structured literature review. A large number of the studies included in the list of 20 most relevant recent studies has focused increasingly on applying technology management to various different fields rather than the traditional manufacturing and IT. There are, in particular, a few studies that examine different diversified companies

and attempt to show the particular relevance of technology management in ensuring that they manage and exploit their diverse capabilities effectively to ensure that they maintain their competitive advantage in various markets [7], [49], [50].

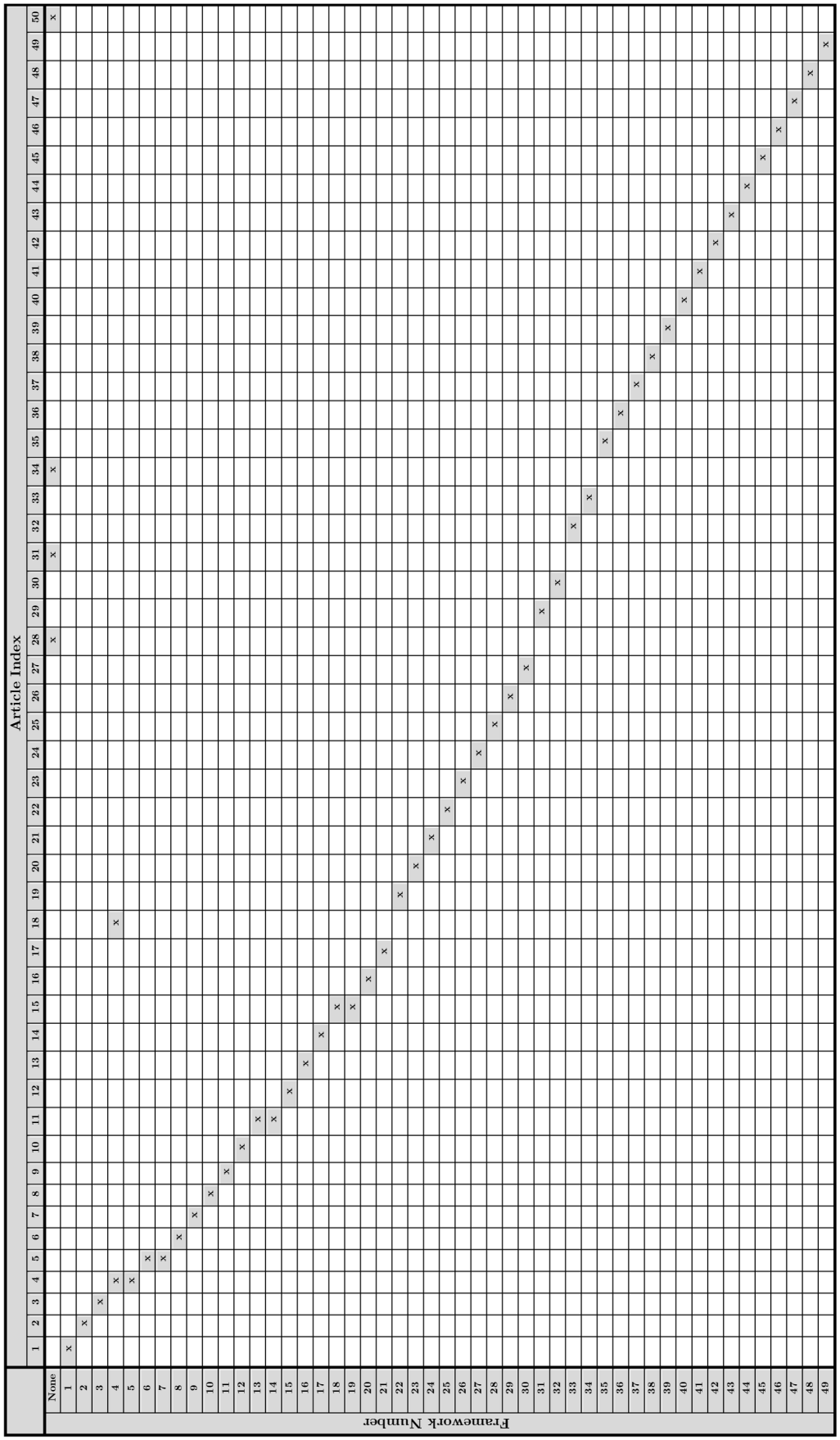
3.2.3 Core Outcomes of Structured Literature Review

The core outcome of this structured literature review is to determine what the leading concepts and principles are of technology management frameworks from established and reviewed scientific studies. The 50 selected studies are rich in information that covered various different aspects of technology management, as well as other related topics.

In an effort to collate the reviewed information the different aspects are grouped together in three main areas of investigation, namely technology management frameworks, tools and principles. The technology frameworks area of investigation includes the various frameworks discussed in the respective studies as well as features, development and validation techniques either employed by the frameworks or utilised to derive the respective frameworks. The tools area of investigation notes the tools described in the various studies, and also includes features of the tools in addition to measures used to apply and/or validate the respective tools. The principles area of investigation investigates the theoretical principles on which the various studies are based, the organisational traits recommended, technology and other management themes, as well as concerns regarding the natural environment.

To determine the prevalence of the various aspects or subjects, a collection of matrices is used to indicate when a study references or investigates a particular aspect or subject. An aspect's prevalence in the literature is then indicated by the number of studies that refer to it. By analysing these resultant matrices, the leading concepts and principles of technology management are identified and discussed. The entire collection of matrices is included in Addendum A of this study.

Table 3-3: Summary of technology management frameworks referenced per study



From this analysis, the most striking characteristic of the technology management frameworks discussed in the various studies is the lack of a unified framework. As presented in Table 3-3[2], only one framework was discussed by more than one study, the Strategic Alignment Model (SAM)[41], [43]. This is not too surprising, as a number of papers have noted the need for more consensus in the field of technology management [5], [31], [38], [40], [43], [49]–[52]. In addition to the lack of a universal or unified framework to facilitate technology management, various studies also call for methods to practically implement the principles of technology management in a real-world situation [3], [7], [31], [37]–[40], [49]–[51], [53]. These two findings may indicate that due to the lack of a unified framework and established practical methods to implement the various existing frameworks, technology management practitioners tend to derive their own framework, thus best suited for their specific application.

Instead of only establishing the common features and characteristics of the various frameworks, it is valuable to rather determine the approaches that were followed for the various frameworks. The common approaches between the various studies and frameworks then form the scientific core of a specialised custom-made framework for the specific application for which it is intended.

As can be seen in Figure 3-7, the most common theoretical approach that most studies based their frameworks and conclusion on are the *Resource Based Approach* [31], [33], [37]–[40], [52], [54]–[56] and *Dynamic Capabilities Theory* [3], [5], [7], [39], [40], [51], [56]–[59]. The *Dynamic Capabilities Theory* was developed by Gregory [5] and is also based on the management of resources. Another common approach is the Knowledge Based Approach [33], [55], [59], which is also an adaption of the Resource Based Approach, and concerns itself rather with the management of knowledge in an organisation instead of other resources [55]. These three approaches share the view that an organisation should exploit its internal resources, capabilities and/or knowledge

[2] The frameworks in the table are numbered according to the matrices in Addendum A.1.

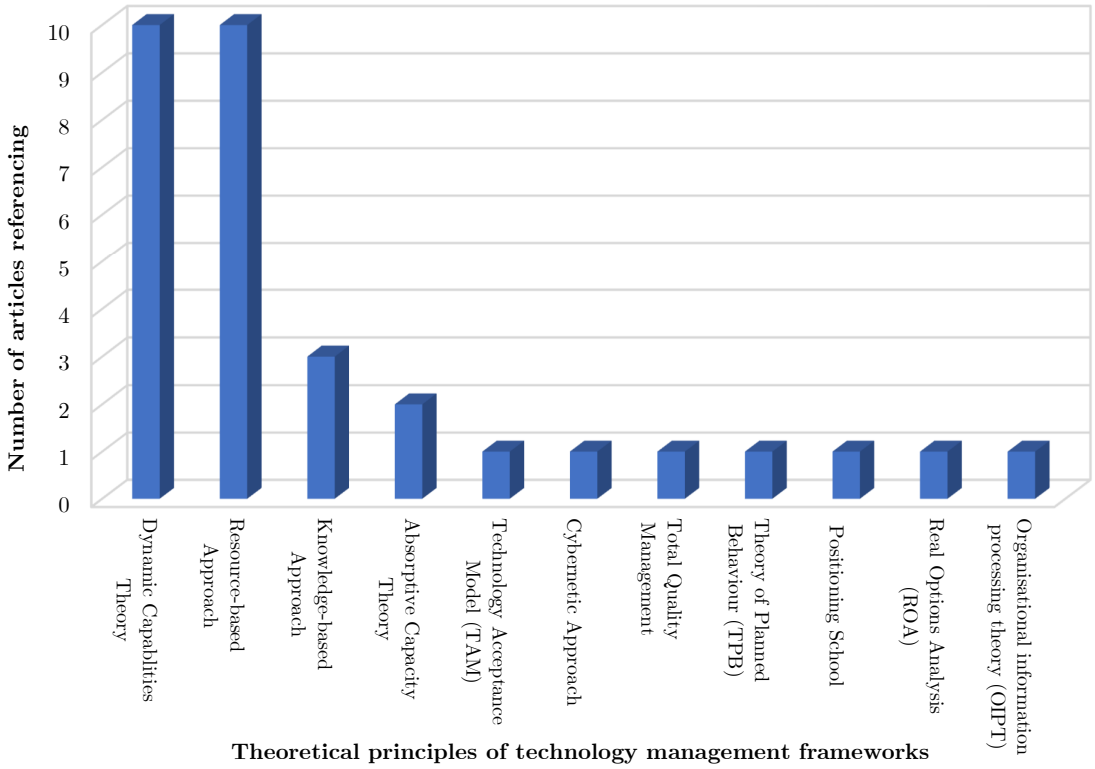


Figure 3-7: Summary of the common theoretical approaches for technology management frameworks for the studies included in the review

respectively to secure or maintain a competitive advantage. The prevalence of this view of managing internal capabilities is especially pronounced in the list of the 20 most relevant studies of the past three years. Twelve out of the twenty studies included are, at the very least, partially based on one of these three views.

A summary of the common features of technology management frameworks is shown in Figure 3-8. This summary indicates that the majority of the frameworks covered in the various studies are conceptual and tend to be qualitative in nature, but most have some kind of graphical output or model. These graphical outputs are probably related to the fact that more than half of the frameworks applied offer some type of decision support. The graphical models seem to assist the decision support process by making the findings of the frameworks more palatable to different role-players. Due to the number of conceptual frameworks, the frameworks are often not empirically validated. The validated frameworks only have their core principles validated and not the entire

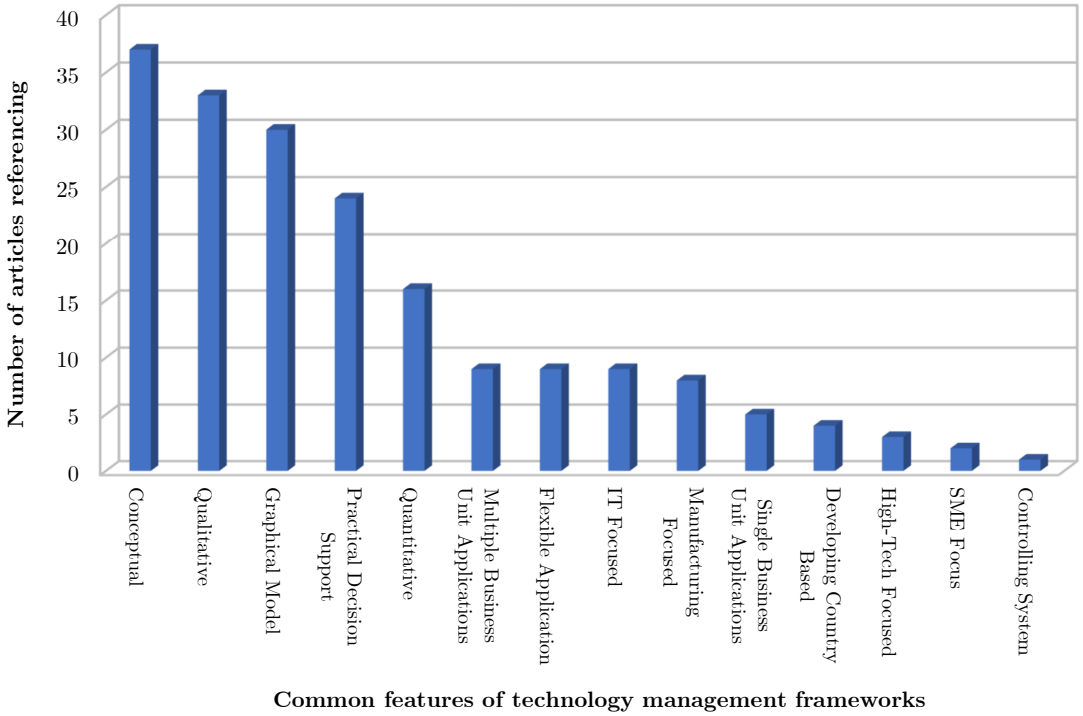


Figure 3-8: Summary of the common features of technology management frameworks for the studies included in the study

framework as a whole, nor how the framework fares when implemented in real-life applications.

Most of the frameworks were either developed through or applied in case studies. Again, this seems to indicate that frameworks are often specialised for their applications. Large scale surveys were also often applied, but more often than not these surveys were used to prove underlying principles rather than the final frameworks themselves. Structured interviews and workshops are also popular ways to interact with subjects in the studies. From the limited number of workshops, it does seem that interviews are the preferred choice, probably due to time constraints that limit the practical arrangement of workshops. Workshops, especially recurring workshops, are time-consuming; thus, interviews seem to be a more manageable alternative to engage with subjects.

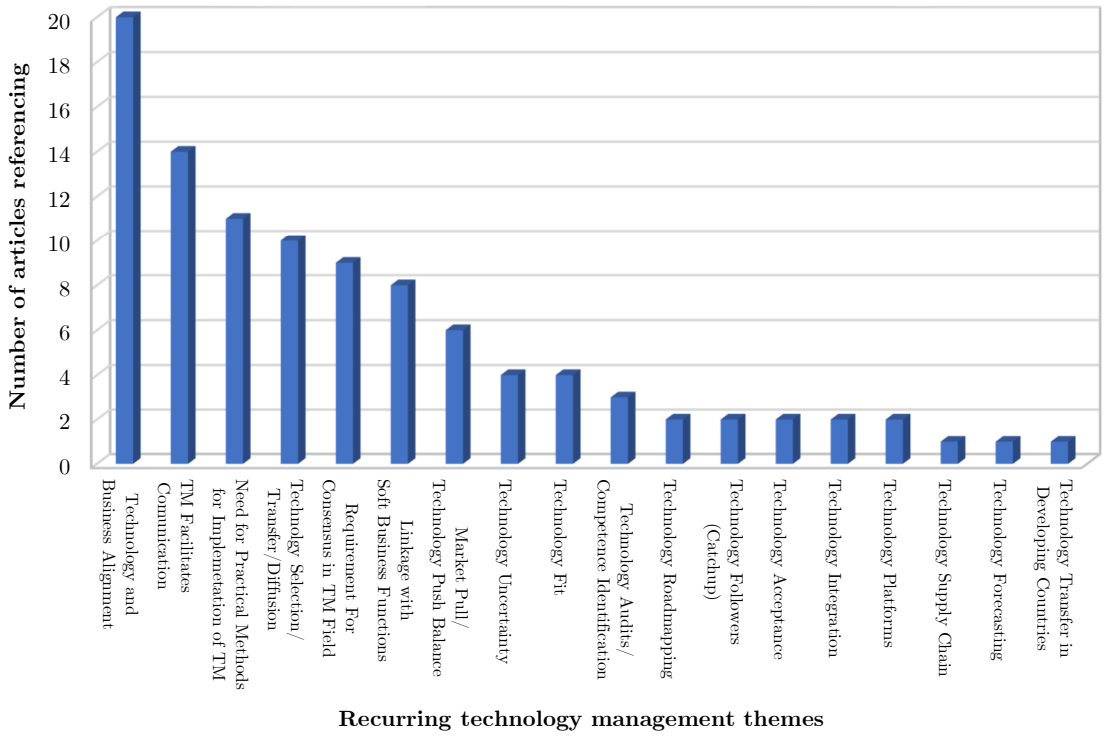


Figure 3-9: Summary of common recurring technology management themes of the articles included in the review

Two core objectives of technology management are clearly visible by reviewing the recurring technology management themes in the literature, a summary of which is shown in Figure 3-9. The one is the importance of the alignment of technology and business strategy as one of the drivers of the successful leveraging of an organisation's competitive advantage [3], [5], [31], [42], [44]. The second objective is directly related to the former; technology management facilitates communication within organisations [3], [5], [31], [44]. In particular, technology management attempts to bridge the communication gap between the business and technical elements in an organisation. Technology management frameworks facilitate both these objectives, by first, illustrating the linkages between business and technology objectives. Second, due to its predominantly graphical nature, technology management frameworks become efficient communication tools to share information and objectives at different levels and departments of organisations [3], [44], [60].

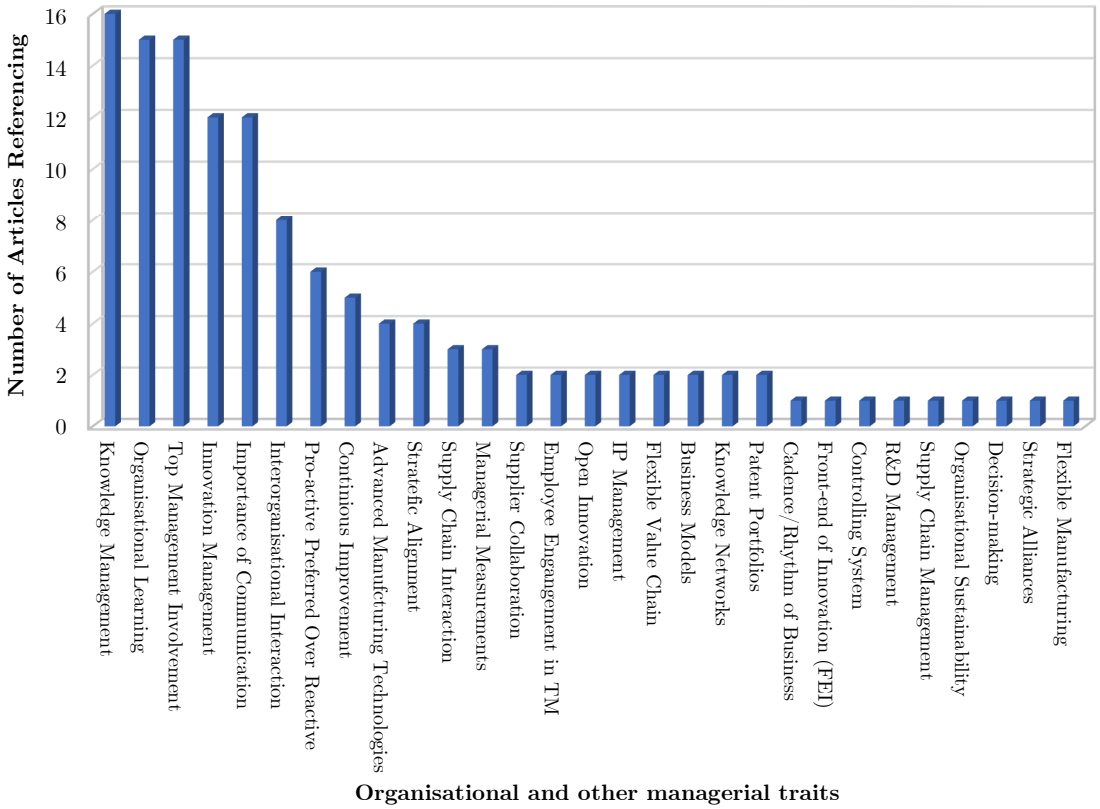


Figure 3-10: Summary of organisation and other managerial traits referred to in conjunction with technology management in the articles included in the review.

Other than recurring technology management themes, other management themes and organisational traits were often referred to in the literature in conjunction with technology management. A summary of these traits is given in Figure 3-10 and highlights the overlaps between technology management and other management forms. In particular knowledge management and innovation management share many similarities with technology management [3]. All three different types of management are concerned with the utilisation of resources available within an organisation in order to obtain and sustain competitive advantages. The three different management forms are often used interchangeably in the literature and are being implemented simultaneously at an increased rate [3], [33]. The three different management forms also share many analogous principles that seem applicable and transferable between the different forms of management.

Many of the papers touch on specific principles regarding how to manage the technological potential of organisations. Technology management can be divided into separate activities with different names in the different studies[3] and many of these activities are covered by the various papers included in this literature review. These activities most notably are various forms of technology selection, transfer, and utilisation. Technology selection includes activities that identify new technology that must be acquired, developed or utilised in some way. Activities related to technology transfer includes ensuring that new technology can fit with already established technology within an organisation and how to ensure that the new technology is effectively incorporated into the organisation, with all the associated resources, namely knowledge, skills, etc. The manner in which these technologies can then be utilised is also discussed in diverse ways. Methods to manage technology in different types of organisations covered include technology platforms and technology supply chains. For effective planning of technological resources, concepts such as technology forecasting and road mapping are explored in different studies.

With so many different dimensions, the field of technology management is one of complex interdependencies between many different role-players and elements in any given organisation [3], [5], [42]. To adequately manage the complexities of technology management a balance must be struck between the two main drivers in any technological organisation. The one driver is market pull – which is the pressures and opportunities presented by different markets. The other driver is technology push – which is the potential of what can be created by the technological capabilities within an organisation. A balance must be struck between what respective markets need and what an organisation can potentially create. The optimum balance between the two drivers will lead to the most efficient leveraging of an organisation's competitive advantage [3], [31], [60].

Finding this optimum balance is, however, no easy task and it is often difficult to combine all the different aspects related to technology into a manageable package. The

first step to manage an organisation's technology is to determine its current technological capacity. This is often done through a process of technology auditing, wherein an organisation determines the technological capabilities it possesses and how these capabilities are utilised to create products that can be supplied to relevant markets. Based on the results of these technology audits, an organisation can determine the best strategies to follow to further expand and utilise their technological capabilities to their best advantage [3], [5], [40].

To assist organisations in managing the diverse applications and implications of technology management various tools have been developed and covered in the literature. Similar to technology management frameworks it seems as if specialised tools are developed to achieve specific goals [42]. As can be seen in Table 3-4[3] almost none of the tools covered are used in more than one study. Indeed, the only tool covered in more than one paper is the S-Curve tool and the two papers covering the tool are in fact two papers in the same series.

Again, there seems to be no unified set of tools to use for technology management, thus it is worthwhile to rather determine which features are most often associated with tools applied in the literature. The common features of technology management tools, as identified from the literature review, is presented in Figure 3-11.

[3] The frameworks in the table are numbered according to the matrices in Addendum A.2

Table 3-4: Summary of technology management tools referenced per study

Tool Number	Article Index																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
None		x						x	x			x		x		x		x				x	x	x	x
1	x																								
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Tool Number	Article Index																								
	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
None	x		x	x		x	x	x		x				x	x	x	x	x	x		x	x	x		
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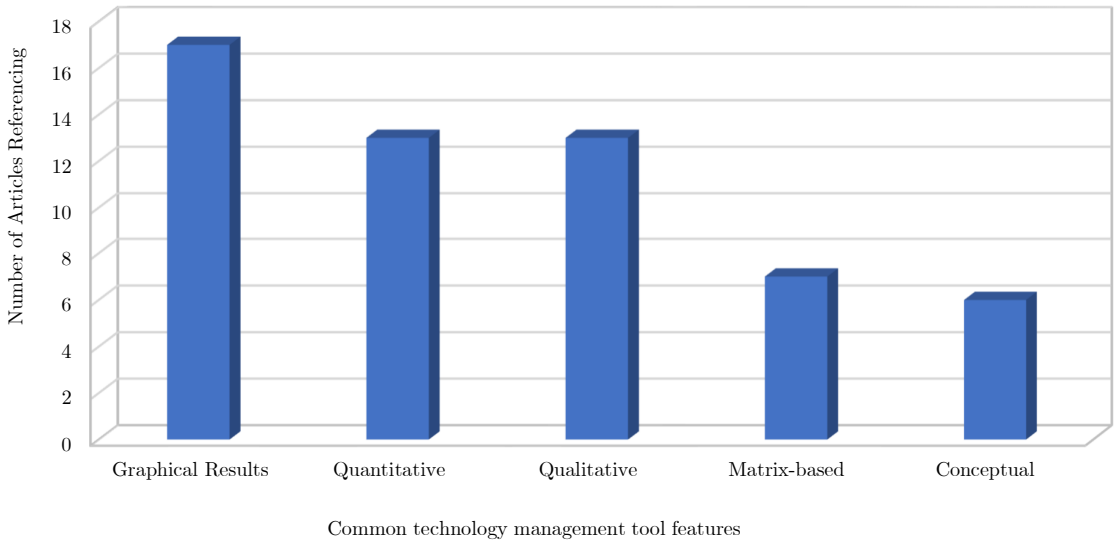


Figure 3-11: Common technology management tools identified from the articles included in the review.

The summary shows that the most common feature of tools included in the study is graphical results, thus making the outcomes of these tools easily relatable to various role-players in technology management [42]. Also noticeable is that quantitative and qualitative aspects are equally prevalent in the studies included in this review. Indeed, some of the tools even combine quantitative and qualitative attributes into the same tool.

Regardless of the fact that none of the tools were used more than once in any of the studies, there was one family of tools that did reappear often throughout the literature review. The matrix-based family of tools seem to be a popular set of tools and according to Phaal, Farrukh and Probert [42] these tools are easily relatable, flexible and adaptable. These tools can be used as qualitative, quantitative or both, depending on the application. As there are so many different tools covered by the literature, the matrix family of tools seem especially appealing due to the fact that they can easily be adapted to the specific situation of a particular organisation [42].

As with the tools, the literature review has revealed that there is no single framework or method to implement technology management, especially for real-world situations.

That said, analysis of the frameworks, methods and tools shows that there are certain principles that form the foundation of the field of technology management and its applications.

In particular, the resource-based approach and its derivatives (the *Dynamic Capabilities Theory* and the knowledge-based approach) have become the dominant underlying theory of technology management. In this approach a balance needs to be struck between the different drivers of technology management, this balance can only be achieved if there is sufficient alignment between the business and technology functions of an organisation. This balance requires efficient communication between the various stakeholders. Technology management – through its various frameworks, tools and approaches - creates the context and provides the shared language between these two important functions. Technology management is then the link between business strategy and technological potential in an organisation. This link should be leveraged to ensure that an organisation establishes or maintains a competitive advantage over its rivals.

3.3 Conclusions from Structured Literature Review

The structured literature review has established a broad understanding of the field of technology management and specifically technology management frameworks. In particular, trends in the development of technology management frameworks are evident. This section will attempt to show how the outcomes and principles from the literature review can be applied to real-world situations, in addition to how the current study can add to the already established literature.

From the sample of articles included in the literature review, there is a need to study the manner in which technology is managed within SMEs and developing countries. The *Alphawave* group of companies are an ideal case study to evaluate how technology is managed within an SME consisting of distinct entities, each with their own unique competencies. Further, as *Alphawave* is firmly rooted in the developing economy of

South Africa, it is also an opportunity to evaluate how technology is managed within a successful company in the developing world.

Based on the sample of studies included in this literature review, it seems as if the resource-based approach is the leading approach when considering technology management frameworks. Especially when regarding the most recent articles included in the study, the resource-based approach and the related *Dynamic Capabilities Theory* has become the de facto standard for technology management frameworks. Both these theoretical approaches view the success of organisations as the effective leveraging of their technological capabilities to obtain the maximum competitive advantage in their strategically chosen markets.

The *Dynamic Capabilities Theory* expands on the concept of managing capabilities but includes that the management of these capabilities should be dynamic in nature. Thus, an organisation should be able to re-organise, re-align and expand its capabilities in a dynamic manner to effectively address rapidly changing external environments. This theory's premise is that effective management of technological capabilities can, in fact, be a core competence in itself [3].

This *Dynamic Capabilities Theory* seems to fit well with the diverse nature of the respective companies within the *Alphawave* group. The *Alphawave* group has a broad spectrum of technological capabilities imbedded in the various companies that service a diverse range of clients in varying markets. The history of the *Alphawave* group also contains examples of how technological capabilities were reused in new markets to leverage new strategic opportunities.

Although the *Dynamic Capabilities Theory* is well established in the literature, there is still no single, all-encompassing framework applicable to all contexts. This is, however, not unique to the *Dynamic Capabilities Theory* and, as shown in the previous section, most of the articles included in this literature review created its own framework for its specific context. It then seems as if the best way to define a technology

management framework for an organisation, such as the *Alphawave* group, would be to develop a specialised framework based on the *Dynamic Capabilities Theory*.

Technology management frameworks should support decision-making and enable efficient communication between the different levels of an organisation. Based on the summary of common framework features, as shown in Figure 3-8, this specialised framework should assist with practical decision support, especially when relating how to incorporate technological expertise into long term corporate strategy. At the same time, the framework should include a graphical model. A graphical model makes it easier to communicate the diverse concepts incorporated in technology management frameworks to a diverse set of stakeholders in the organisation.

The question then arises, how is such a framework developed? Especially since there is no clear unified and accepted method to address it. Certain authors have attempted to create universally applicable processes to implement technology management. In particular the "fast-start" approach for implementing technology road mapping (T-Plan) developed by Phaal, Farrukh and Probert seems to give a proven and efficient process to implement technology management in an organisation [42].

One of the basic types of tools incorporated in various studies, which form part of this literature review, is matrix-based tools. Specifically, some of these tools form the cornerstone of the T-Plan approach. This particular tool is used to link the different technology aspects with business goals in a system that is easily completed and easily communicable.

For the purpose of this study, the *Dynamic Capabilities Theory* seems to be the best for application with the *Alphawave* group of companies. Using matrix-based tools, the manner in which the different technological aspects interact with each other and are leveraged to reach strategic goals will be analysed. Not only will this be a valuable exercise for the *Alphawave* group to evaluate the efficiency with which they leverage their technological capabilities, but it is also an interesting case study into how a

successful SME in South Africa aligns its technological capabilities with its business strategy to maximise its competitive advantage.

3.4 Selective Literature Review of Relevant Key Technology Management Concepts

The structured review of 50 articles gives a good overview of the key concepts present in technology management and the accompanying frameworks. This overview is important to understand the fundamentals of the field but is not enough to fully explore the various concepts that make up the diverse field of technology management.

In an attempt to gain a better understanding of the specific key concepts that make up the field of technology management, and the development and implementation of technology management frameworks, a selection of these concepts will be explored further to gain a deeper understanding of how to apply it to real-world situations. This will ensure that a richer understanding of the most specific key concepts is gained for application in the rest of the study.

3.4.1 Technology Audits

Technology audits, similar to financial audits, are used to determine the current state of an organisation based on a particular field of interest. Technology audits are useful tools to determine the available capabilities within an organisation [61]. For the purpose of this research, the capabilities available within the different companies of *Alphawave* and the group as a whole will be determined.

Various different models of technology audit processes have been developed and successfully implemented in a wide variety of industries. These models are examined, adapted and combined into an applicable audit system that can be used to determine what capabilities are available in *Alphawave* and how they spread over the different companies of *Alphawave*. The results of the technology audit give an indication of how different capabilities are linked in the different companies and the *Alphawave* group as a whole. [42]

						PRODUCTS				
						P1	P2	P3	P4	P5
					M1	X		X		
				MARKETS	M2	X	X		X	
					M3		X	X		X
TECHNOLOGIES					M4		X	X		X
T1	T2	T3	T4	PROCESSES						
X				PR1		X	X			
	X	X		PR2		X		X	X	
		X	X	PR3		X			X	X
	X		X	PR4		X	X			

Figure 3-12: Visual example of a technology balance sheet [35]

3.4.2 Technology Balance Sheets

To form and visualise this link between the capabilities of the different companies, some formal process is required. Prahalad and Hamel describes a system that identifies core competencies within an organisation. These core competencies should then be exploited to leverage the best possible advantage in the marketplace [10]. In particular, the matrix class of tools have proven to be versatile, easy to implement and an efficient way to summarise and convey the information at a glance [42]. From a more South African perspective, De Wet describes a similar system called the technology balance sheet (TBS), with a visual example shown in Figure 3-12 [35].

In preliminary discussions with role-players in *Alphawave,* the TBS showed promise as the basis for discussing and mapping the different technologies, processes, markets and products encapsulated by the different entities. The visual method the TBS employs to link the technology base to the prospective markets through a system of processes and products was effective in describing the basic principles of technology management. Also, it was an effective example of the potential benefits that might be obtained by implementing a technology management process into the company. This was essential to obtain the necessary buy-in from the *Alphawave* role-players to partake in the study at hand.

By using and adapting these established systems, the current links between capabilities and products in the various companies can be mapped out visually. Furthermore, it will provide valuable insight into how existing capabilities can be linked to possible

future products or systems. As a TBS will be completed for each entity in the *Alphawave* group, the technology available and application thereof can easily be compared between the different entities.

3.4.3 Dynamic Capabilities Theory

From the structured literature review, three predominant approaches of technology management were identified. As indicated in Figure 3-7, the *Dynamic Capabilities Theory* is not only the second most referenced approach, but also the approach most often cited in more recent studies [3], [5], [7], [39], [40], [51], [56]–[59]. From the growing popularity of this approach, especially in recent years, it seems to be the current foremost technology management approach and is an ideal approach to base a technology framework on.

The *Dynamic Capabilities Theory* is, in fact, derived from the most cited approach as identified during the literature review, namely the *Resource Based Approach*. Both of these approaches advocate that an organisation should exploit its internal capabilities or resources to best exploit or maintain its competitive advantage. The *Dynamic Capabilities Theory*, in particular, expands on the concept of managing capabilities and elevates the capability to dynamically re-organise, re-align and expand capabilities to a core competence of an organisation. [3]

As proposed by Gregory, the key processes of technology management can be identified as *Identification, Selection, Acquisition, Exploitation* and *Protection*. These processes can occur at any time and often occurs concurrently. By effectively managing these processes an organisation can ensure that it remains abreast of technological advances, both internally and externally, while also ensuring that it remains competitive as a business. [5]

The *Identification* process entails all the activities within an organisation that identifies what technological advances might have an influence, positive or negative, on the business. This includes, but is not limited to, internal communication and/or collaborations as well as regular engagement with external networks, alliances or any

other method to remain updated on current technological developments outside of the organisation itself. Although the main subject of the *Identification* process is technology, it should be noted that this process can also involve the identification of new market opportunities or challenges. [3], [5]

The *Selection* process drives decision-making regarding which technologies should be supported by the organisation. It involves the strategic determination of the potential of a technology as well as how investment in this technology would affect the strategic business objectives. It is a critical process, as over- or under commitment of resources to a particular technology or technologies could adversely affect both the technological and business prospects in the future not just to the particular technology, but also other technological or business prospects. It is thus essential to accurately assess the importance of technology as well its impact on the overall business strategy. [3], [5]

The *Acquisition* process entails decisions regarding how selected technologies should be incorporated into the organisation. Technologies can be acquired through different manners; by developing the technology in-house through research and development or through organisational learning. Technology might also be acquired through collaboration or partnerships with external role-players. Finally, the organisation can also acquire the new technology outright by purchasing the technology or the business that holds the technology. The *Acquisition process*, however, is not merely concerned with how to obtain the technology, but also how the new technology is effectively embedded within the organisation. [3], [5]

The *Exploitation* process involves the manner in which technology within the organisation is converted into profitable products and/or services, or in some other manner is able to extract value from its technology, for example through the sale of technology, joint ventures or some operational or functional improvements within the organisation. Although this process might seem like it only involves hard technical skills to produce and manufacture products, it actually also involves other managerial and operational developments, such as improvement of internal processes, additional

marketing, etc. Further, this process also relates to how the different technologies of an organisation can be fused together to create radically innovative products. At the same time, however, organisations should ensure that processes are in place to preserve its technological advantages and thus prevent technologies to become obsolete or wane. *Exploitation* is thus much more than simply developing new products, it also entails ensuring that the maximum profit can be extracted from technologies by ensuring effective operational processes, market development and technology maintenance. [3], [5]

The *Protection* process concerns how the knowledge and expertise embedded in the technology can be preserved. This includes, but is not limited to, ensuring critical staff retention, patenting of intellectual property, concealing sensitive information within products, and ensuring compatibility with other manufacturers' products to ensure larger market penetration. The core function of *Protection* is thus to ensure, through a combination of managerial, operational and development functions, that the technologies of an organisation remains firmly entrenched within the organisation. [3], [5]

From the above discussion of the various processes identified as part of the *Dynamic Capabilities Theory,* it is clear that the effective management of technology is not only dependent on hard technical skills, but also on various supporting organisational activities. These activities will vary from organisation to organisation, depending on their relative size, complexity, and so forth. These activities should assist the technical activities in the organisation to effectively leverage its technology in the most efficient manner. [3]

As with technology management frameworks in general, there is still no single catch-all framework to implement the *Dynamic Capabilities Theory*, especially in practice. Two examples of how this theory can be implemented at an abstract level are shown in Figure 3-13 and Figure 3-14. These frameworks are taken from the two most cited

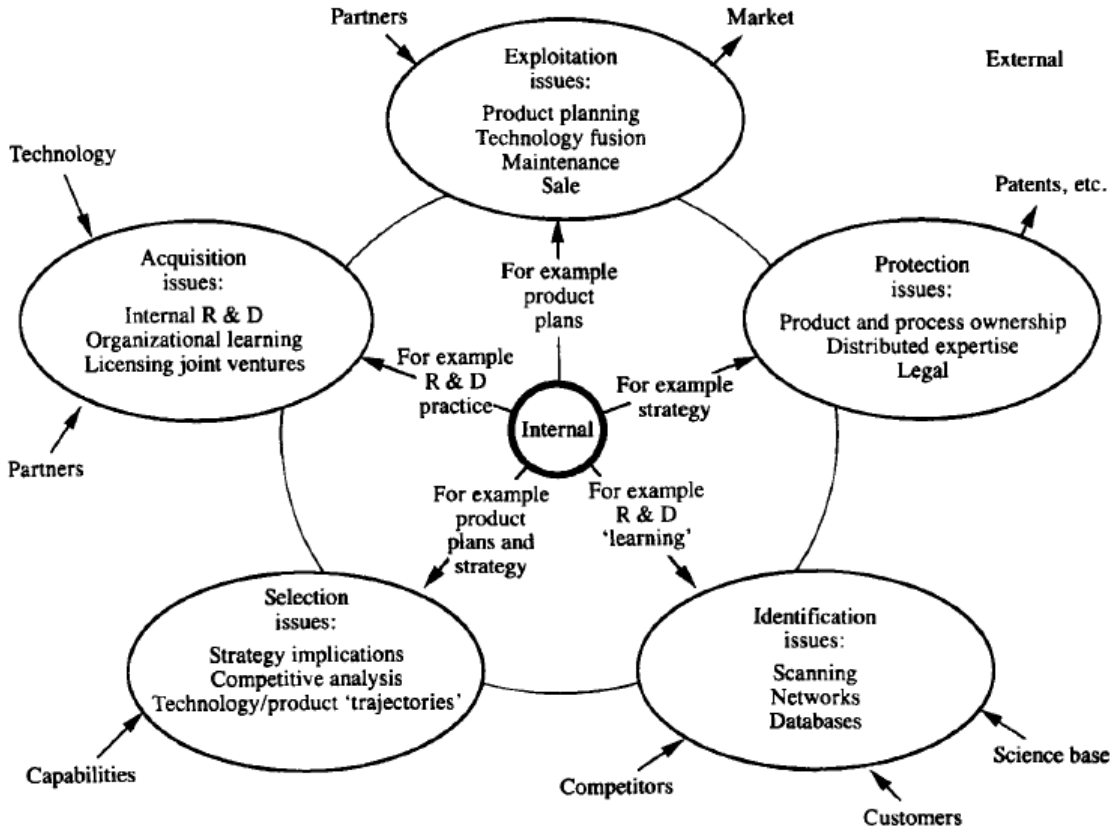


Figure 3-13: Gregory's technology management process framework [5]

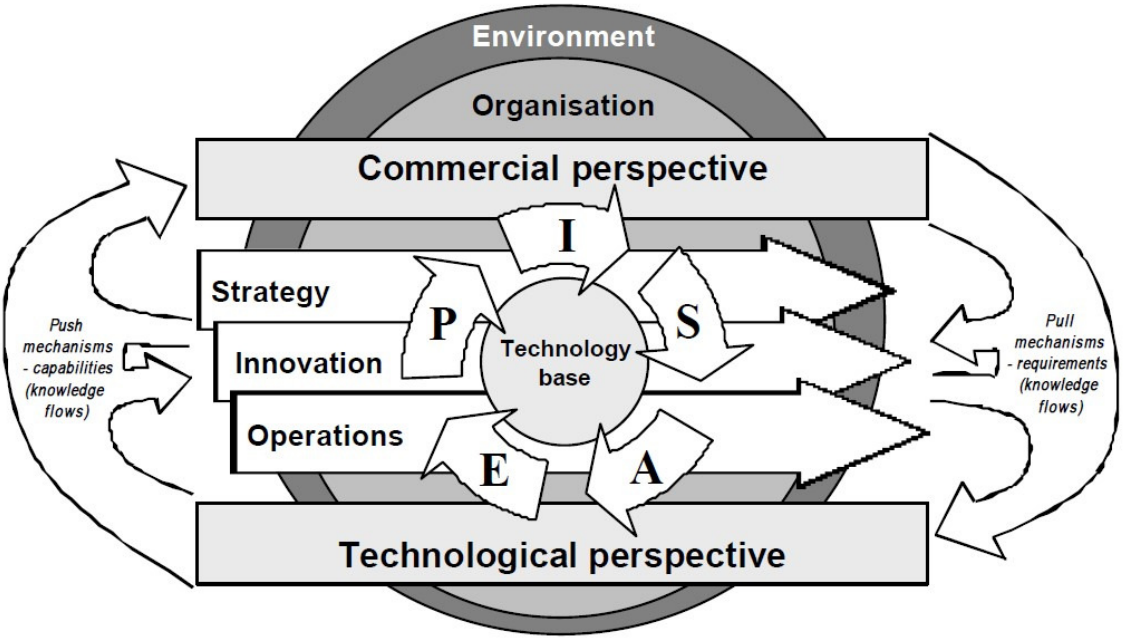


Figure 3-14: Technology management framework by Phaal et al. [6]

articles involving *Dynamic Capabilities Theory* as identified as part of the structured literature review of Section 3.2. [3], [5]

While it is clear that there are many differences between these two frameworks, there are a couple of clear similarities between them. Both frameworks clearly show that a balance should be struck between internal and external pressures and opportunities of an organisation. This balance should be maintained by utilising the different processes and supporting activities in an efficient manner and at the appropriate times. [3], [5]

In addition, both frameworks have a distinctly circular nature. This highlights the fact that management of technology is not a linear or once-off exercise, but rather a continuous process with many different functions and activities taking place concurrently. This is true not just for individual products, but for the entire technology portfolio of the organisation. The complete technology portfolio should be maintained and updated constantly to ensure that it remains at a competitive advantage. [3], [5]

The *Dynamic Capabilities Theory* emphasises the importance of aligning technological capabilities between themselves, as well as with business goals. This should ensure that an organisation can remain at the leading edge of technological innovation and effectively use its technology to reach its business goals. This especially true if the organisation can develop its own capability to constantly and dynamically re-organise, re-align and expand capabilities to a core competence of an organisation. Thus, ensuring that effective structures are in place to maintain its competitive advantage over its rivals.

3.5 Conclusion of Literature Review and Findings

This literature review has explored how technology management is implemented according to established literature. Based on a combination of often-cited articles as well as a number of more recent studies a broad overview of technology management frameworks has been established. This analysis shows that there is a need for practical methods and examples of implementing technology management in real-world

situations. That said, most studies tend to develop their own specialised technology management framework based on their own specific context.

A trend in the literature is the emergence of the *Dynamic Capabilities Theory* (based on the resource-based approach), especially in recent years. Not only is the *Dynamic Capabilities Theory* a popular theory to apply to technology management, but it is also a seemingly good fit for the *Alphawave* group of companies.

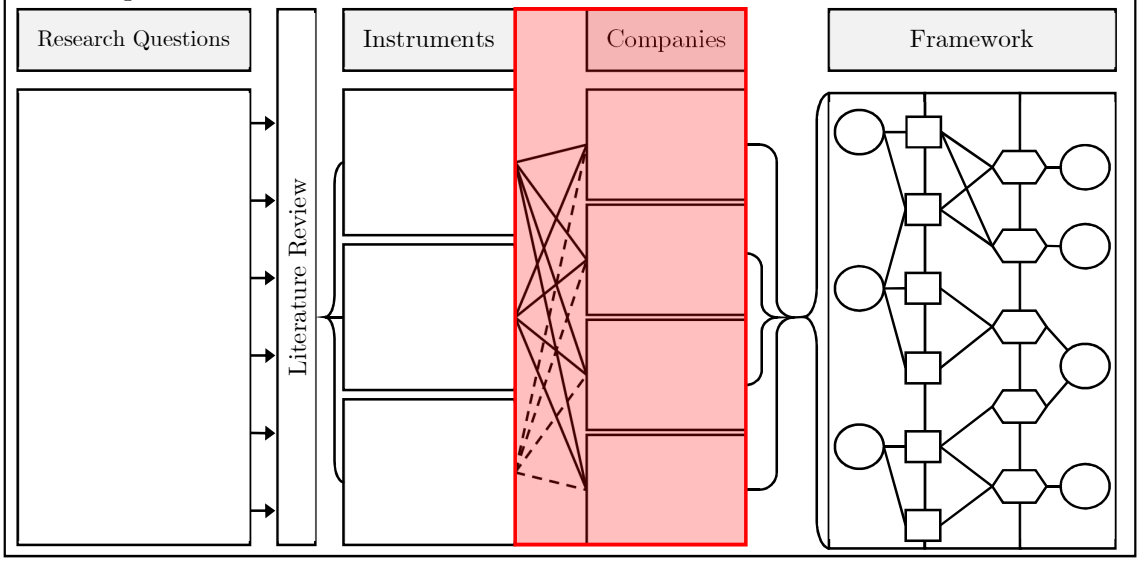
The exploration of how technology is managed within the *Alphawave* group will not only benefit the *Alphawave* group itself but other companies in developing economies as well. Technology management has not been studied in such depth in developing economises as in developed economies. More studies are required to confirm whether technology management is universally applicable to different economies or more narrowly adapted to its historic roots in the manufacturing companies in developed economies.

CHAPTER 4

RESULTS AND ANALYSIS OF TECHNOLOGY AUDITS

This chapter summarises the data captured and analysed for this research. The data and analysis thereof are in the below form:

- Based on interviews with representatives from different companies, the general state of technology, technology management and innovation in each company is audited.
- These results are combined to determine the state of technology and technology management in the group and how technology can be and is shared between entities.
- The general state of technology and technology management is then evaluated, especially with regard to its limitations and potential expansion.
- The elements discussed in this chapter form part of the overall research process as below:



4.1 Introduction

One of the main outcomes of this study is to investigate how technology management can be practically implemented in a real-world situation. To meet this outcome a technology audit is designed, as described in Section 2.3, and implemented at the

Alphawave group of companies to assess the state of technology management within the group.

This chapter will detail the results of each individual technology audit for each of the *Alphawave* companies included in this study, namely, *EMSS Antennas*, *ETSE Electronics*, *Honeybee* and *EMSS Consulting*. This chapter then further analyses the results of these individual audits in relation to the group. Finally, the chapter investigates how the further implementation of technology management structures can strengthen the different companies and the group as a whole.

Each of the sections detailing the results of the individual technology audits will largely be reproductions of *Technology Management Analysis* reports as detailed in Section 2.3 and included in full in Addendum B of this study.

4.2 Technology Audit of *EMSS Antennas*

This section summarises the status of technology management within *EMSS Antennas* post-2006[4]. The information contained within this section is based on an interview conducted by the author and both the incoming and outgoing managing directors of *EMSS Antennas* (Participant A and B, respectively, as denoted in Table 2-1). The outgoing managing director managed *EMSS Antennas* until the end of the year (thus 2016) before this interview. The incoming managing director headed EMSS Antennas from the start of the year of the interview (thus 2017). All facts contained in this section were directly obtained from the participants during the interview.

4.2.1 Business Environment of *EMSS Antennas*

At the time of the interview, *EMSS Antennas* has an uncertain future. The company is a specialised antenna development company within an academic field. Their clients and partners are academic institutions and government departments, who often do not understand the intricacies of businesses and the pressures of the bottom-line.

[4] Before 2006, *EMSS Antennas* was effectively in a "subsistence farming" mode.

EMSS Antennas is a world-class player in the radio astronomy industry, but it is an industry with very little room for growth. Due to the nature of the industry, where slow and expensive iterative product development is the norm, *EMSS Antennas* is a slow-moving company with an almost obsessive level of attention to detail. This level of attention is the only way to be successful within the radio astronomy industry, but also means that *EMSS Antennas* operates too slow to really be competitive in other industries and markets.

While EMSS Antennas is actively looking for new environments to do business in, it is also in the process of redefining its business processes. The entire manner in which the company does business needs to evolve to be successful in other, completely different markets.

As part of the overall drive by *EMSS Antennas* to build its business opportunities in other environments and markets, the entire management structure has been restructured. The incoming managing director had successfully managed the largest project in the company for years. He is now to apply the skill set he developed for running a large and complex project on running the company.

Since the task of running the company has been taken away from the outgoing managing director and other directors, they are in the position where they can explore other environments and markets for *EMSS Antennas* to do business in. The directors are specifically encouraged to investigate new business prospects to pursue, especially through their professional networks.

4.2.2 Product Innovation Process of *EMSS Antennas*

EMSS Antennas have in the past proven to be very skilled at generating new and exciting ideas. However, they have had only limited success in translating ideas into successful products. Only one of their three main product lines was identified internally. The other innovations came either from clients or partners within the larger *Alphawave* group.

The main project and product of *EMSS Antennas* is the radio astronomy (L- and UHF band) cryogenic receivers for the *MeerKat* project (a pilot project of the larger *SKA* project). *EMSS Antennas* was approached by *SKA-SA* and was awarded the contract as they were the only company approached with the appropriate skills, while also willing to commit to develop and produce the receivers to the required specifications.

A second and already mature product that *EMSS Antennas* played a major part in was the *fieldSense* personal RF safety monitor. This product was the result of a joint venture of *EMSS Antennas* and *EMSS Consulting*. *EMSS Consulting* had identified the need for a personal RF safety monitor and approached *EMSS Antennas* to help develop and produce the first version of the product. *EMSS Antennas* also helped to develop the second version of the product. Although no longer part of the *fieldSense* production, *EMSS Antennas* still receive royalties from sales of *fieldSense* units. If any further development, specifically sensor development, is required on future versions of the *fieldSense*, it is likely that the capabilities of the original *EMSS Antennas* team will have to be employed again.

A new product that *EMSS Antennas* has been developing over the last number of years is *X-Range*, a golf ball radar tracking system. The product development started as a side project to utilise resources that were freed up as *MeerKat* development tapered off. The system has evolved through various different versions over the years but started as an exercise to see what *EMSS* could do if they focus on an application outside of continuous-wave applications. Radar products per se had the potential to still be developed into various different markets and products. With the assistance of *So-Zo Labs* (the Virtual and Augmented Reality development lab of the *Alphawave* group) the three-dimensional modelling of the golf balls' tracked path helped to promote the system to potential early investors.

The development history of these products clearly shows the limited success of *EMSS Antennas* in delivering their innovative ideas to new markets. They, however, seem

adept at constantly developing and producing very high-quality products, as well as solving difficult technical problems within the development cycle of the products.

4.2.3 Core Competencies of *EMSS Antennas*

The core competencies of *EMSS Antennas* can be well summarised by two statements made by the respective directors. The incoming managing director stated that the success of *EMSS Antennas* was made possible by *"a handful of exceptionally skilled people, combined with a team who are committed to enable the exceptionally skilled people's ideas and work to become reality."* The outgoing managing director, on his part, summarised *EMSS Antennas*' commitment to quality as: *"If you pay us enough, we will create the greatest thing in the world."*

The company culture within *EMSS Antennas* then seems to play a crucial role in the success of the company. This culture was established while the company was small in size and was maintained while the company expanded. This culture drives the staff to motivate themselves internally to continually deliver the best work possible. This leads to a culture of teamwork, dedication and pride in each staff member's work. This culture, although not easily measurable, should be seen as one of the core competencies within *EMSS Antennas*. Although not a technical competency, it is a competency that enables other, technical, competencies to be successfully exploited.

The core competencies and capabilities identified by the directors are listed below, along with an evaluation of each competency's relative standing:

- Radio Astronomy:
  The capabilities of EMSS Antennas in Radio Astronomy is considered world-class.
- Reputation and credibility of products:
  The reputation and credibility of the products of EMSS Antennas are considered world-class.
- Production:
  The production capabilities of EMSS antennas are considered to be amongst the most technically advanced in South Africa, although for specialised use only and in a limited capacity.

- Specialised Test Procedures:
  The specialised test procedures of EMSS antennas are considered to be amongst the most technically advanced in the world, although for specialised use only.
- RF Electronics:
  The RF electronics capabilities of EMSS antennas are considered to be more technically advanced than most others in South Africa.
- Radar:
  The radar capabilities of EMSS antennas are considered to be more technically advanced than most others in the world.
- Signal and data processing:
  The signal and data processing capabilities of EMSS antennas are considered to be more technically advanced than most others in the world.
- Software development:
  The software development of capabilities of EMSS antennas are considered to be technically comparable with most others worldwide.

It should be noted that most of the above capabilities are not widely spread and most reside in only a few individuals in the company.

In addition to the core competencies and capabilities identified by the directors of *EMSS Antennas*, another capability was identified during the course of the interview. According to the directors, none of the individual components in the receivers of the *MeerKat* are massive improvements of previously available components. Rather, each component was improved on incrementally to specifically benefit the overall system. Although the individual parts weren't ground-breaking, the final system was. This seems to indicate that *EMSS Antennas* has significant system design capabilities, especially to ensure that separate parts are optimised for the specific goal of the system as a whole.

4.2.4 Technology Analysis of *EMSS Antennas*

The technology balance sheet shown in Figure 4-1 details how the different capabilities of *EMSS Antennas* are currently utilised to create products for its existing markets. Black crosses indicate the current situation. Red crosses indicate new expansions currently being implemented. Black circles indicate old applications.

Legend:	
o	Old
x	Current - In Place
x	Current - In Progress
w	Wishlist

TECHNOLOGIES										MARKETS	PRODUCTS									
EMI/EMC/RFI Skills	Antenna Design	Test Procedures	ISO 9001 Standards	RF Electronics	Radar	In-time signal processing	Data processing	Cryogenic Cooling	Software Design		Meerkat Receivers	SKA Receivers	X-Range	fieldSense	Product Zeta	Control Module for UAV	Explosive Rope	Somebody else's product	Somebody else's problem	Own Future Products
										Radio Astronomy	x	x								
										Interplanetary Comms and Radar					w					
										Electronics in Sport			x							
										EMF Safety				x						
										Somebody else's market						x	x	w		
										Somebody else's solution									w	
										Own Future Markets										w
										PROCESSES										
x	x	x		x	w	w	w			Product Development	o	x	x	o	w					w
x	x	x		x	x	x	x	x	x	System Development	o	x	x		w				w	w
x		x	x						x	Production Capability	x	w		o	w	x	x	w	w	w
		x								Implementation (Set-to-work)	x	w			w					w

Figure 4-1: Technology balance sheet of *EMSS Antennas*

Yellow shaded chains indicate avenues being explored by *EMSS Antennas* to insert new revenue streams by developing products and systems for other companies/partners. The green shaded chain indicates the ideal future revenue stream, where *EMSS Antennas* uses its own technology to develop and produce its own products for its own markets.

Various potential future ventures are included. Three ventures (two being implemented and one potential future venture) are included for companies to make use of *EMSS Antennas'* production capacity. The products of these companies, much like the products of *EMSS Antennas*, are very specialised and intricate.

Another potential future venture is based on previous successes by *EMSS Antennas* in system development. As *EMSS Antennas* do not have much experience in entering new markets, *EMSS Antennas* could assist companies and/or partners who have already identified products and suitable markets but do not have the capabilities to develop an entire system or production capabilities and/facilities to produce the products. *EMSS Antennas* can then utilise their system development and production capabilities to create high quality products and systems, without much of the risk of entering unknown markets. They can then solve problems identified by another entity, which that entity can then take to market.

Lastly, a potential future venture (labelled *Product Zeta*) is included for the Interplanetary Comms and Radar market. This venture, if successful, will be similar to the current *MeerKat* and upcoming *SKA* projects, only in a different market.

If leveraged correctly the corporate culture and exceptional technical skills vested in the capabilities of *EMSS Antennas*, could enable them to build the same reputation it has in radio astronomy in another market. This would come at a steep learning curve that could be alleviated if they can find a willing partner to allow them the resources to realign their capabilities for new markets.

4.2.5 Conclusion of *EMSS Antennas* Technology Audit

EMSS Antennas are in a difficult situation. Limited resources to serve current contracts, while at the same time trying to insert new revenue streams are putting the company under significant pressure. That said, the corporate culture and exceptional capabilities of the company have ensured that *EMSS Antennas* is a well-respected technical company around the world.

EMSS Antennas are at a critical point in their existence. The restructuring that has taken place is a strong move to get the company back on track. They are actively trying to find new ways to exploit their considerable capabilities in new and unknown industries and markets.

For the company to survive it will have to effectively leverage its strengths; system development, corporate culture, exceptionally skilled experts and well-deserved reputation into new innovative processes and markets.

4.3 Technology Audit of *ETSE Electronics*

The information contained within this section is based on an interview conducted between the author and the founder and current managing director of *ETSE Electronics* (Participant C, as denoted in Table 2-1). All facts contained in this section were directly obtained from the participants during the interview.

4.3.1 Business Environment of *ETSE Electronics*

Although founded more than 20 years ago, *ETSE* only became part of the *Alphawave* group in 2014. *ETSE* was founded with no specific corporate goals or strategies in mind. Projects would be taken on as opportunities presented themselves.

Over the years *ETSE* has completed close to two hundred different projects. These projects ranged in scale from small single device projects for individual clients to large multi-faceted projects for various different organisations and companies over a wide range of industries.

Upon joining the *Alphawave* group, the focus of *ETSE* shifted to product development rather than project-based operations. After evaluating all the current and past projects, two product lines were chosen to be pursued further, as well as one additional project that would remain active.

The two identified product lines are *Farmtrack* and *Farmranger*. Both are established products with existing clients, which could be expanded on. The last remaining project is the design and production of the CPUT *CubeSat* project.

Although *ETSE* has worked in a wide range of industries and with an even wider range of technologies, the current products are both aimed at the agricultural sector and based largely on *ETSE*'s electronic design capabilities.

4.3.2 Product Innovation Process of *ETSE Electronics*

The majority of *ETSE* innovation has taken place at component and system level and *ETSE* does not have a lot of experience at innovating at a product or corporate level. As such, *ETSE* is capable of finding innovative technical solutions for problems that are presented to them by potential clients. They do not seem, however, that adept at searching for new problems that can be solved with its own established technological capabilities. *ETSE* has not in the past had corporate strategies to target specific markets or industries, but rather entered markets and industries as required for the technical solutions of the specifications of their clients.

Although there was no formal innovation structure, a culture seems to exist that encourages the exploration of new technologies before they are required for a specific project. Part of this encouragement is the concept of "*Personal Jobs*", which allowed employees to spend time on learning how new technology works and how it can be used to solve practical problems. Bluetooth capabilities, for example, were explored in this manner. This increases the chance that when a project requires new technology to be incorporated, the capability has already been developed and the knowledge to implement it is readily available.

Knowledge sharing between employees is facilitated by numerous different factors. The relatively small number of employees and shared work areas are more conducive to knowledge sharing than at larger organisations. Weekly meetings with the entire team also promote the sharing of knowledge within the company. As an example, these meetings create a forum for employees to describe the technical hurdles they face, with the opportunity for solutions to be suggested by the other team members.

Irrespective of the innovation at project level, the exploration of new markets or clients was not a priority. Finding innovative problems to solve was never part of *ETSE*'s corporate strategy. New markets and/or clients came mainly through referrals out of the engineering network and former clients of ETSE.

4.3.3 Core Competencies of *ETSE Electronics*

Although *ETSE* has an abundance of technological capabilities, at their core the most important of these are RF and Microwave design, as well as electronics design (such as embedded, FPGA, PCB's, GPS, GSM, etc.). The focus of ETSE has mostly been on hardware design, with very little emphasis on software design other than embedded software.

The product lines *ETSE* will continue to pursue will mainly rely on their electronic design capabilities. Both *Farmtrack* and *Farmranger* use electronic systems to interpret measured inputs from various sensors and transfers it to a backend system for further

processing. Both of these products' systems are already well established, but with scope available for further improvements.

Other than the capabilities employed by ETSE in their chosen product lines, they have also developed significant capabilities in the RF and microwave design field. *ETSE* has previously been involved with various projects of various scales, ranging from two-way radio systems to satellite ground systems. They have, in the past, designed various components (LNA's, filters, mixers, etc.) as well as modules (receivers, transmitters, etc.) over a frequency range of 50 MHz to 24 GHz. Except for the CPUT *CubeSat* project, *ETSE*'s RF and microwave design capabilities are not be utilised in any of the active product lines.

Other than the hard-technical capabilities of electronic and RF/Microwave design, *ETSE* has developed the ability to derive technical specifications from often vague user specifications. They seem to be adept at expressing ideas in terms of electronic systems. This capability enables them to effectively translate ideas from a potential non-technical client into a workable electronic system that can meet the client's needs. This skill will, understandably, be underutilised as both the existing product lines have already passed the development phase. This capability, though, still has potential to aid the development of future products.

Two of *ETSE*'s largest shortcomings has partly been addressed with the merger with *Alphawave*. *ETSE* has limited capabilities with regard to application software design and development. By enlisting the capabilities of the *EMSS Consulting* software development team, *ETSE*'s product lines have been strengthened with user applications and interfaces. These improvements seem to have had a positive effect on sales of both products.

Another shortcoming for *ETSE* in the past was an informal financial system, with the financial management vested in the managing director. The *Alphawave* financial team has assumed responsibility of the day-to-day finances of *ETSE* and, again with the

Legend	
o	Old
x	In place
N	New Technology

TECHNOLOGY										MARKETS	PRODUCTS			
RF and Microwave Systems	RF and Microwave Components	Digital Electronics	Analog Electronics	PCB Layout	Technical Specification	Embedded Software	Front End Software	Back End Software	Datamining		CPUT CubeSat	Farmranger	Farmtrack	Past Projects
										Satellite Communication	x			o
										Farm Management		x	x	
										Military Communication				o
										Radar Communcation				o
										Satellite Ground Stations	x			o
										Medical Devices				o
										Other Electronic Applications				o
										PROCESSES				
x	x	x	x		x		x	x	N	System Design	x	x	x	o
x	x	x	x	x	x	x		x		Circuit Design	x	x	x	o
x	x	x	x	x						Manufacturing	x	x	x	o
x	x	x	x	x		x				Testing	x	x	x	o
x	x				x		x	x		User Interface Design		x	x	o
					x		x			Customer Installation, Training and Support	x	x	x	
							x	x	N	Customer Relation Management		N	N	

Figure 4-2: Technology Balance Sheet of *ETSE Electronics*

assistance of the *EMSS Consulting* software team, the recordkeeping and capturing of client information has been automated to a large extent.

4.3.4 Technology Analysis of *ETSE Electronics*

The Technology balance sheet shown in Figure 4-2 details how the different capabilities of *ETSE Electronics* are currently utilised to create products for their existing markets. Black crosses indicate the current situation. Black circles indicate old capabilities not pursued at the moment. Black 'N'-symbols indicate new technology that should be developed/acquired and implemented in the respective products.

Red shaded chains indicate technology capabilities from other *Alphawave* companies being used by *ETSE*. The green shaded chain indicates areas where future expansion is available and, in some cases, required.

From the balance sheet, it is clear that the products developed for the Farm Management market have been improved by utilising software capabilities available in *Alphawave*. These capabilities assisted in creating user interfaces that made the products more user-friendly and thus more marketable.

Further, the balance sheet shows that there are many other markets where *ETSE* had in the past successfully completed projects. The technological capabilities and processes that utilised in the past are still available within *ETSE*. It could therefore be possible to develop new products to enter these markets by combining the underutilised capabilities of *ETSE* with technological capabilities or prospects of other *Alphawave* companies to create marketable products.

Datamining is viewed as a new technological capability that can be applied to the current farm management systems to enhance its marketability. At the moment, a large amount of data is received and notifications are sent to customers. If the data can be analysed and reworked, more comprehensive and proactive feedback can be provided directly to the customer, for example sending a message indicating that urgent attention is required at a specific flock or orchard. This should enhance the customer experience and assist with customer retention and marketing.

As a whole, the balance sheet shows a company with a broad span of capabilities. And while these capabilities are currently exploited in limited markets and products, there is potential for these capabilities to be exploited as new products for both established and new markets.

4.3.5 Conclusion of *ETSE Electronics* Technology Audit

The inclusion of *ETSE Electronics* into the *Alphawave* group shows potential to be mutually beneficially for the development of technological capabilities in both parties. *ETSE* has specialised capabilities in hardware design and production over a wide scope of applications, which could aid the development of more physical products within the group as a whole. *ETSE,* in turn, is aided by the software design knowledge base within *Alphawave*, such as for the development of user application software.

Alphawave has proven themselves capable of translating technical knowledge into marketable products. This capability could potentially assist both *ETSE* and the *Alphawave* group as a whole to identify new products that can be taken to market.

There is a concern that old technical capabilities will become outdated and/or redundant if opportunities are not created for them to be exploited or expanded on in the near future. Opportunities could be explored to leverage the technical capabilities of *ETSE* along with capabilities of other companies in the group to develop new, innovative products.

4.4 Technology Audit of *Honeybee*

The information contained within this section is based on an interview conducted between the author and the CEO of Honeybee (Participant D, as denoted in Table 2-1). All facts contained in this section were directly obtained from the participants during the interview. Since the interview has taken place, *Honeybee* has been rebranded as *Skynamo*.

4.4.1 Business Environment of *Honeybee*

Honeybee evolved out of the software development team of *EMSS Consulting*. This team had been actively searching for ways to leverage its technical capabilities into new products. After realising that there was a significant market for systems that facilitate the management of sales representatives, the *Honeybee* application was developed to service this need. The application assists sales representatives as well as sales managers to track and document interactions with clients, process orders and various other sales-related tasks, all by using a single mobile application.

The sales of the new product grew steadily and the application has grown into a fully-fledged software package. Additional services were added to support the sales and users of the *Honeybee* mobile application, including training and technical support.

Honeybee is entrenched in the local market and their sales figures are showing continual growth. They sell to a wide range of companies, but mostly to manufacturers, importers, resellers, etc. Based on their success in the local market, *Honeybee* has developed strategies for entering foreign markets.

The global cloud CRM market is large, but underdeveloped. Although it seems possible to enter foreign markets, new sales tactics and skills will be required to successfully enter these new markets. *Honeybee* has begun developing two new go-to-market strategies to use in the UK, namely through partnerships and digital routes via enterprise resource planning (ERP) ecosystems.

Honeybee has a simple goal; they want to be a $1 billion company by 2035. Whether this goal is attainable or not, it is a key driver in *Honeybee*'s decision-making process.

4.4.2 Product Innovation Process of *Honeybee*

The founding of *Honeybee* was due to innovative technology transfer. The development team of *EMSS Consulting* had identified that the competencies developed for in-house software can be re-used outside of the traditional fields and markets of the then *EMSS* group. When the market potential for sales representative management systems was identified, the *Honeybee* application was developed to meet this need.

The culture of innovation that had been developed within the *EMSS Consulting* development team was inherited by *Honeybee*. The core of the *Honeybee* team was the result of a transfer of already developed capabilities of *EMSS Consulting* to *Honeybee*. As new capabilities were required it was either developed in-house or acquired. Based on market needs or technical requirements the capabilities of *Honeybee* have expanded from software development to as diverse fields such as sales, training, technical support, etc.

The innovation process employed by Honeybee has evolved over time. Initially, with only the relatively small team at the founding *Honeybee*, the innovation process was not managed in a formal manner. Ideas were discussed collectively, with the final decision resting with the (then) managing director. The entire development team was thus directly involved in the innovation process. This informal system was successfully utilised until *Honeybee* reached an organisational complexity that necessitated a more structured approach.

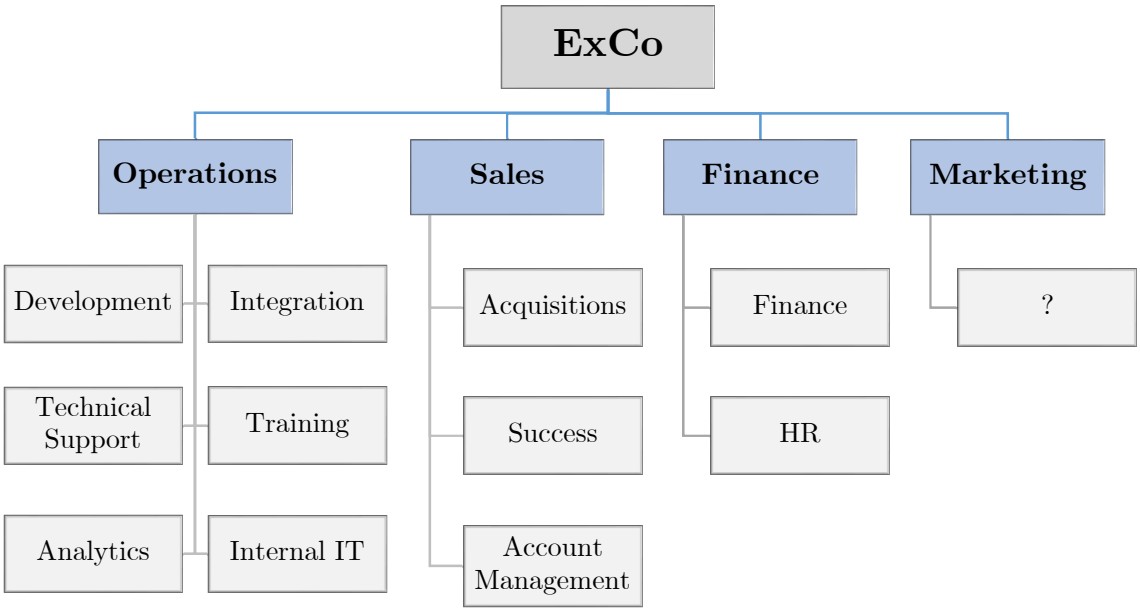


Figure 4-3: ExCo management structure implemented at *Honeybee*

An Executive Committee (ExCo) was established to manage innovation within *Honeybee*. The ExCo meets regularly to discuss possible opportunities and weighs the opportunity costs against potential rewards. The ExCo then decides to reach a consensus on whether to pursue a particular new opportunity. If a consensus cannot be reached the decision falls to the CEO. At the time of this interview, the ExCo is made up of an assortment of eight team leaders from each of the different departments. Each member of the ExCo is expected to be an aggregator and disseminator of information within their respective teams. The three-tiered structure of the ExCo is shown in Figure 4-3, also showing expansion plans to add a fourth marketing tier.

This multidisciplinary innovation decision-making structure is unique within the *Alphawave* group. Most of the other companies in the group do not innovate over such a wide range of domains and focus mainly on hard technical capabilities for innovation. Each member of the ExCo is responsible to determine what opportunities are available out of their respective teams. They are also then responsible to implement and relay decisions made in the ExCo meetings to their teams. The minutes of all ExCo meetings are made available to all staff members to support effective communication to all levels in the company.

This structure lends itself very well to be used with the culture of collective innovation inherited from *EMSS Consulting*. There is an expectation from every employee that all the other employees are constantly trying to improve *Honeybee*. Ideas from all levels and teams are considered at least at some part of the structure. Good ideas are celebrated throughout the *Honeybee* community and rewarded based on the scale of the idea.

This structure and management style has fostered the culture of collective innovation inherited from *EMSS Consulting*. This culture, in turn, has ensured that *Honeybee* innovates on a daily basis and is regularly re-evaluating and realigning its capabilities and resources to actively and continually expand on its competitive advantage.

4.4.3 Core Competencies of *Honeybee*

As evident from the multi-disciplinary nature of the ExCo, the core competencies of *Honeybee* are a mix of hard technical skills and softer capabilities. The two primary core competencies are software development and sales. There are also two secondary support competencies, which are vital to ensure effective customer engagement with the product. These secondary competencies are training and technical support. Both of the secondary competencies have been developed from minor skills to strong capabilities. According to the interviewee, these competencies are at a maturity level with the potential to be implemented independently as separate ventures, if required.

When comparing *Honeybee* to its competitors, it seems a much stronger software development organisation than their competitors. Especially in terms of work environment, processes, quality of developers hired, etc. This organisational strength was mostly inherited from *EMSS Consulting*. As mentioned by the CEO, *"It took EMSS ten years of doing it wrong to figure out how to do it right. And now we are just benefitting from it"*. The overall development environment in *Honeybee* ensures maximum utilisation of the capabilities and resources of its developers, while also attracting high quality developers.

Honeybee has a strong sales competency. Sales have been growing at a significant pace since *Honeybee* was launched. Although the results of the sales competency are strong, the sales process is weak. Most of the sales capabilities are vested in one specific salesperson. Out of a sales team of nine people, more than 50% of the sales come from one individual. This is a known risk for the entire sales system, but it also prevents *Honeybee* from scaling their sales capacity. A significant amount of resources are spent in an attempt to replicate the sales person's results through better sales systems and processes. If these results can be reproduced by other salespeople within *Honeybee* it will ensure both the continued growth in sales and also potential expansion, including possible foreign markets.

A strong technical support competency was required from early on, as is expected when developing software for use by non-technical clients. The capability was developed from the ground up. Initially manned by members from the development team assisting with customer queries the service has developed over time into an in-house designed and managed call centre. The call centre functions effectively and is trusted by the company and clients alike, with potential for scaling as required.

Training for *Honeybee* clients was also required from early on. Initially, training was presented by the sales team to new clients. When an opportunity presented itself to employ someone solely responsible for training a former high school science teacher was hired. The quality of training improved significantly, with noticeable results. Clients understood the product better and were able to utilise it more efficiently, while also allowing the sales team to focus on its own tasks. The training capability was further improved by hiring an experienced training manager. The entire training process and system was formalised and structured in such a way that hundreds of clients pass through *Honeybee*'s different training centres.

These four competencies position *Honeybee* well for good growth prospects. There are, however, serious deficiencies in marketing. There are only limited marketing capabilities available within *Honeybee* (and the *Alphawave* group as a whole) at the

time of the interview. Strong marketing could see *Honeybee* leapfrog their competitors, not just in the local market, but especially in their new ventures into global markets. *Honeybee* judged that the process to develop marketing capabilities would not be possible in their planned timeframes, so marketing capabilities were acquired by hiring a marketing manager. After only two months, the marketing competency is far from being a vested and scalable capability, but significant progress seems to have been made.

Honeybee has proven themselves as a company that not only has strong capabilities, but also a company that continuously innovates to grow these capabilities. This innovation and growth ensure that they remain at the forefront of the cloud CRM market locally and, expectantly, in the global market in the foreseeable future.

4.4.4 Technology Analysis of *Honeybee*

The technology balance sheet shown in Figure 4-4 details how the different capabilities of *Honeybee* are currently utilised to create its single product for the CRM market. Crosses indicate that a capability is either in place, but weak (lowercase x), or in place, and strong (uppercase **X**). Circles indicate outsourced technology. Blank cells do not necessarily indicate that the capability is absent, but rather that is underdeveloped.

The technology balance sheet of *Honeybee* shows a wide range of technologies, but only the one product, *Honeybee*. Although *Honeybee* is only delivered to one market, their technology base is ever-changing with new technologies regularly being added to *Honeybee* through their structured innovation processes. The technology section of the balance sheet will continue to expand, as new capabilities are required to keep *Honeybee* current in a dynamic market.

In contrast to the technology balance sheet drawn up for other companies in the *Alphawave* group, the process segment of the balance sheet has been adapted to rather reflect phases in the innovation process. This adaptation is better suited to *Honeybee*'s situation, as it better reflects how new technology is incorporated into the *Honeybee*

Legend	
O	Outsourced
x	In place (weak)
X	In place (strong)
	Underdeveloped

TECHNOLOGY															PRODUCT	
Backend Development	Web Frontend Development	Mobile Frontend Development	Functional QA	Automated QA	Product Managment and Design	Technical Support	Training	Sales Acquisitions	Sales Success	Account Management	Marketing	Finance	HR	Integration	Analytics	MARKET / PROCESS PHASES	Honeybee
						X	X	x		x				x	x	Recruitment	x
x	x	x	x	O	x	x	x	x	x		x	x	x	X	x	Ideation	x
x	x	x	x	O	x	x	X	x	x		x	x	x	X	x	Prototyping	x
X	x	x	X	O		x	x	X	x	x	x			x		Small Scale Impemenation	x
X	x	X	x	O		X	X			x		x		X		Large Scale Implementation	x

Figure 4-4: Technology Balance Sheet of *Honeybee*

family of products. The recruitment phase is included to evaluate how well *Honeybee* is able to source skilled personnel, as according to this interview) this can be seen as a general weakness of the *Alphawave* group. The balance sheet clearly shows that *Honeybee* has been more successful at recruiting in certain technologies than others.

Other than most of the other companies in the *Alphawave* group, *Honeybee* has a growing number of softer technological capabilities, e.g. sales, marketing, training, etc. They have not only established nominal capabilities but in some cases have been able to expand these softer capabilities into fully-fledged and scalable capabilities.

Honeybee's dynamic and innovative technology base could potentially benefit the overall *Alphawave* group's technology base. *Honeybee* already shares their software capabilities and experience with other entities within the group, but several of their other capabilities could also prove invaluable if transferable between the various companies. Especially their established sales and growing marketing capabilities could in the future be valuable capabilities to transfer to the other companies.

Honeybee has a varied and dynamic range of capabilities, which is a combination of hard technical skills and softer skills. This wide base of technology is supported by an innovative structure, which enables the efficient expansion of available capabilities.

The softer skills, in particular, are mostly unique to *Honeybee* in the group and if exploited correctly, can be invaluable to the *Alphawave* group as a whole.

4.4.5 Conclusion of *Honeybee* Technology Audit

Honeybee inherited a culture of innovation from *EMSS*. The foundation of *Honeybee* is a product of this culture that prompted the core group of developers from *EMSS Consulting* to explore new possibilities.

This culture was, however, not just inherited, but actively fostered and constantly realigned with structures appropriate for the size of the company. Technologies not directly related to the traditional capabilities within the *Alphawave* group were developed due to effective management of the innovation process. All employees from each level of the company are continually attempting to, and actively motivated to, improve and expand the capabilities of *Honeybee*.

Honeybee has assembled a team of exceptionally capable people and manage them in such a way that they remain leaders in their field. They have been able to harness the capabilities developed by *EMSS* and leverage them to exploit new opportunities in markets outside the traditional markets of the *Alphawave* group.

Honeybee is at the innovation vanguard of the *Alphawave* group. Not only is *Honeybee* successful in its own right, but the principles upon which *Honeybee* was conceived and developed can be used as blueprints for future endeavours of the *Alphawave* group or for other companies in the *Alphawave* group to expand their capabilities into new and markets.

Honeybee is firmly established in the local market and to continue its growth rate it would need to engage on a global scale. Its culture of innovation and excellence will hopefully gain them a foothold in these new and expanded markets.

4.5 Technology Audit of *EMSS Consulting*

The information contained within this section is based on an interview conducted between the author and the managing director of EMSS Consulting (Participant D, as denoted in Table 2-1). All facts contained in this section were directly obtained from the participants during the interview. Since the interview has taken place, *EMSS Consulting* has been rebranded and divided into three separate entities, namely, *Alphawave Mobile Network Services*, *Alphawave Mobile Network Products* and *Alphawave Ventures*.

4.5.1 Business Environment of *EMSS Consulting*

EMSS Consulting was founded as a technology transfer in 2005. By then *EMSS* was already a successful company. It was delivering both the world-class antenna modelling tool, *FEKO*, and electromagnetic consulting and research services to various clients, including one of the biggest mobile operators in South Africa.

EMSS Consulting was founded to service the then newly signed operational services contract with the above-mentioned operator, by employing the capabilities already developed within *EMSS*. *EMSS Consulting* remained part of the *EMSS* group, which at the time, consisted of *EMSS-SA* (who continued with the development and sales of *FEKO*), *EMSS Antennas* (responsible for the design and production of the *MeerKat* feeders) and *EMSS Consulting*, although *EMSS-SA* was later sold to an international company, Altair, in 2014. Since its founding *EMSS Consulting* has developed into an independent and successful company in its own right.

The business operations of *EMSS Consulting* can be divided into three distinct teams, each delivering their own products or services for their respective markets. These teams are the operational services team, the *Ixus* team and the *fieldSense* team. All three of these teams are currently being rebranded as separate entities, but this change will not affect the basic operational structure of the respective teams, nor the *EMSS Consulting* management structure.

The operational services team (since then rebranded as *Alphawave Mobile Network Services*) provides operational electromagnetic health and safety services to various clients in the mobile network industry. These clients include mobile network operators, infrastructure management companies and regulators both in South Africa and the rest of Africa. In addition to the operational services provided, *EMSS Consulting* also plays a consulting role to these clients as well as various other entities, city councils, members of the general public, etc. This consulting role is not a major avenue of revenue, but rather a by-product of their position as a specialist company with local and international expertise in the area of electromagnetic health and safety.

The *Ixus* team (since rebranded as *Alphawave Ventures*) is the software development team of *EMSS Consulting* and develops software solutions for various entities within the *Alphawave* group. The longest standing product of the *Ixus* team is the *Ixus* software package, a compliance management tool incorporating a database system and a 3D simulation and modelling tool. *Ixus* is sold to various clients across the world, mostly in Australia and Canada, and is also the primary tool used by the operational services team to deliver their services to their clients. In addition to *Ixus*, the team also develops software for two *ETSE* products (*Farmranger* and *Farmtrack*), as well as *MySidekick* (a software application for the retail industry).

The *fieldSense* team (since rebranded as *Alphawave Mobile Network Products*) is responsible for the development, manufacturing, marketing and sales of the *fieldSense* personal RF monitor. Originally developed in conjunction with *EMSS Antennas*, the *fieldSense* is a (relatively) inexpensive monitor intended to be used primarily by RF contractors while working on various different sites, often close to RF transmitters. The *fieldSense* warns the user when the RF exposure reaches levels close to the relevant guidelines. The *fieldSense* (now already in its second version) is a very successful product, especially in the US market. The current objective of *fieldSense* is to break into the European market.

EMSS Consulting has proven themselves adept at quickly dominating markets where they are able to find a foothold. They have very little competition with their operational services in the local market. The *Ixus* software package is the de facto industry standard in Australia and has good market penetration in Canada. The sales of *fieldSense* in the USA has been growing steadily. This success is closely related to *EMSS Consulting*'s inherent culture of ensuring that the best possible product is delivered to the client; a product that services the specific functional needs of the client, not just perceived needs.

Although *EMSS Consulting*'s main revenue generator, the operational services, has little pressure from competitors in their niche market, they are subject to normal business pressures. With a large range of clients, with different contractual needs and differing priorities, constant effort is required to ensure that all payments are up to date and that each client is serviced adequately. Worldwide the mobile network industry is under financial pressure, whether from increased competition, government regulations, etc. The mobile operators in South Africa are under constant pressure to lower their costs and transfers this pressure to their suppliers, including *EMSS Consulting*.

Even with these pressures, *EMSS Consulting* is well-positioned in various markets. They deliver their services and products in the same market segment, but to vastly different clients in different geographical markets. Even if one of their operations or products are threatened, it is unlikely that all of their different endeavours will be affected simultaneously.

EMSS Consulting's continued success over such a long term has made it the cornerstone of the *Alphawave* group and the company is currently the largest revenue generator in the group. Without the stability of this regular revenue stream, the *Alphawave* group would not have been able to diversify and expand its ventures into new products and markets.

4.5.2 Product Innovation Process of *EMSS Consulting*

Innovation in *EMSS Consulting* is not limited to innovation only within the company itself. A number of the products of the *Alphawave* group either has their roots in *EMSS Consulting* or *EMSS Consulting* has played a big part in ensuring that the product ideas become a reality.

With a steady revenue stream, *EMSS Consulting* has made numerous attempts to develop new and innovative ideas and products. Although not all of them have been successful, some of the most successful products in the group was developed from within *EMSS Consulting*. *fieldSense*, *Ixus* and the newly established *Honeybee* were all developed from within the *EMSS Consulting* structures.

EMSS Consulting is at the forefront of developing new ideas and products for the *Alphawave* group. The *Ventures* team, in particular, are actively involved in developing the software for many of the latest products being developed in the group as a whole. New ideas are obtained either from within *EMSS Consulting*, the greater *Alphawave* group, or even external partners. For example, the expertise within the *Ventures* team was crucial to develop software for both the *ETSE Farmtrack* and *Farmranger* products.

The products and services delivered by *EMSS Consulting* (*Ixus*, *FieldSense* and operational services) are all mature products. Developments made to these products are generally incremental in nature, typically based on suggestions from active users, i.e. clients and operational services personnel. Potential improvements are weighed monthly against requirements from external clients, other members of the *Alphawave* group and internal requirements. These improvements include changes, such as improving compatibility with national databases in Australia, incorporating surveyor management into established systems, updating measurement parameters to reflect changing spectrum allocations, etc. One of these improvements, the *Site Inspector* mobile application that eliminates paperwork on site, was the reason for the development of the capabilities that would eventually be used to create *Honeybee*.

Within *EMSS Consulting*, the directors are tasked with actively searching for new opportunities. New avenues are constantly being pursued, but as *EMSS Consulting* is operating in a niche market, these opportunities are limited. With the exception of promoting *fieldSense*, especially in Europe, *EMSS Consulting* does very little marketing of their products and services. Instead, *EMSS Consulting* keeps themselves relevant by being actively involved with national and international entities, such as ITU and IEC working committees. These activities have the dual purpose of ensuring that *EMSS Consulting* stays up to date with the latest international advances and builds its network of potential clients. A number of *EMSS Consulting*'s clients have either been identified from these networks or approached *EMSS Consulting* from these networks. *EMSS Consulting* is thus pro-active in keeping up to date with international advances, but reactive, albeit swiftly, when pursuing new clients.

Since both *Ixus* and the operational services are mature and scalable product lines, they can easily be implemented for new clients with minimal customisation required. The structure of each client for the operational services, for example, are fundamentally similar and can be, and indeed has been, easily reproduced for new clients. This means that new clients can easily be serviced by merely employing new personnel in already well-defined roles.

More radical forms of expansion, for example, expansion into new markets, are done in a more circumspect manner. Investment into these new ventures is limited from the outset and only increases incrementally if the potential success of the venture can be proven with small scale success. If successful, the venture is either incorporated into a new structure within the operational services or redeveloped into an entirely new entity, of which *Honeybee* is a recent example.

4.5.3 Core Competencies of *EMSS Consulting*

Historically, the original *EMSS* group's main competency has been electromagnetics. In order to support this competency *EMSS* actively developed an entirely new competency in the field of software development. *EMSS Consulting* inherited both of

these competencies and especially applied them to the field of electromagnetic health and safety. With the valuable experience and knowledge of various markets, both local and globally, *EMSS Consulting* has been able to exploit their competencies efficiently in various different markets.

Naturally, the respective teams of *EMSS Consulting* have their own distinct competencies. This notwithstanding, there is one competency that is shared by all three of the different teams, their emphasis on customer service. Each of the different teams have been able to gain control of their respective markets by ensuring that they offer the best possible service or product to their clients.

Both the products and services of *EMSS Consulting* has been aligned to ensure that their respective clients' needs are addressed in the simplest and most efficient way possible. This not only ensures that they deliver the best possible product at competitive prices, but that they also remain a well-known player in the niche markets wherein they operate.

There have been very little radical changes in competencies at *EMSS Consulting* over the years. Rather, all of these competencies have been grown incrementally and steadily throughout the years. The combination of their knowledge, both technical and market-related, and their software development skills have ensured that their products and services are difficult to compete with, even on the global market. As they actively develop their own tools, they are able to fine-tune their services and, in turn, develop products to specifically meet their customers' specific needs. In particular, it is these competencies of software development and the effective development of client-orientated products that are often shared with other entities within the *Alphawave* group.

EMSS Consulting has been a successful business for many years and they have actively led the way in establishing the *Alphawave* group. Their core competencies, especially of customer service and software development, has been the basis for the expansion of

TECHNOLOGIES								PRODUCTS						
Assembly	Software Development	System / Procedure Design	Data Processing	Logistics	EM Regulatory Knowledge	Practical EM Principles	MARKETS/CLIENTS	Operational Services	Consulting / Advisory Services	Software Services	FieldSense	IXUS (Including Meas. Module)	Training	Interference
							Mobile Operators	x	x		x	x	x	x
							Infrastructure Companies/Contractors	x	x		x	x	x	
							Regulators		x			x	x	
							Software Buyers / Outsourced Development			x				
							Internal (Technology redeployed within Consulting)			x	x	x	x	
							PROCESSES							
	x	x	x				Software Development			x	x	x		
		x	x	x	x	x	(RF) Measurements	x	x		x		x	x
		x	x	x	x	x	Compliance Assessments	x	x			x	x	
	x	x			x	x	R&D				x	x		
x		x		x			Production				x			
		x	x			x	Quality Assurance	x			x			x

Figure 4-5: Technology Balance Sheet of *EMSS Consulting*

the *Alphawave* group out of its initial electromagnetics base into innovative opportunities in entirely new markets.

4.5.4 Technology Analysis of *EMSS Consulting*

The technology balance sheet of Figure 4-5 shows how the different capabilities of *EMSS Consulting* are currently utilised to create products for its existing markets. Crosses indicate that a capability is in place.

The strength of *EMSS Consulting* is not merely contained in its available technologies, but also in its well-established processes. Although not unique to only *EMSS Consulting* in the *Alphawave* group, *EMSS Consulting* is especially adept at reorganising its structures and operations to effectively exploit presented opportunities. The structure of the operational services, in particular, can easily be replicated to accommodate new clients. Automation has been implemented where practical, to ensure that complex and repetitive tasks can be performed by even non-technical personnel. If any task becomes too labour intensive, the company will try to update or automate its processes to keep it as lean and efficient as possible.

Other than its capabilities in the field of electromagnetics, most of the other capabilities were developed out of necessity. Logistics and data processing capabilities had to be developed fast in order to visit and assess thousands of cellular base stations around South Africa. The entire operations structure was developed and built around these capabilities. Again, unique to *Consulting*, a large number of their staff are working in geographically different locations on a daily basis.

Similarly, their software development capabilities were developed to support their operational activities. This, in turn, led to new products, which were commercialised and sold to external customers. The *Site Inspector* tool, which eliminated paperwork on-site, was developed to improve the efficiency of gathering and documenting information on site, while at the same time ensuring that the information can be sent back electronically to the various offices much faster and more securely than before. This greatly improved the operational team's efficiency, but also eventually led to the development of *Honeybee*.

Throughout the history of *EMSS Consulting*, technological capabilities have been shared between the different teams and also the different entities, first within the *EMSS* group and now within the *Alphawave* group. *EMSS Consulting*'s established and entrenched capabilities are ideal to be shared with the different entities within the group. The success of *Honeybee*, the software user interfaces of the *ETSE* products, to name but a few, are some of the several examples showing how effectively *EMSS Consulting* can contribute to the expansion of capabilities within the rest of group.

No matter which of the technological capabilities of *EMSS Consulting* is considered, it is an established capability. Not just established, but incrementally growing. The company has successfully implemented and fostered a culture and system where the different teams and capabilities are constantly working together to improve themselves and each other. This, along with the strong processes in place, ensure that their capabilities are effectively used to leverage competitive advantages in various markets.

4.5.5 Conclusion of *EMSS Consulting* Technology Audit

EMSS Consulting has been one of the success stories of, first the *EMSS* group, and now the *Alphawave* group. After the sale of *EMSS-SA*, *EMSS Consulting* became the flagship company of the group that would eventually become the *Alphawave* group. By consolidating their market share wherever they are able to gain a foothold, they have been able to grow into a secure business. Although their growth is not the fastest in the group, theirs is the most stable. This reliable revenue stream funds the *Alphawave* group's search to find innovative new markets outside of their traditional fields of electromagnetics.

Each of the different teams of *EMSS Consulting* have different capabilities and are generally active in vastly different fields. They are, however, able to work together to identify and create solutions that customers, both locally and globally, are willing to pay for. The success of *EMSS Consulting* lies in that they have been able to combine and recombine their different capabilities in different ways to ensure that they constantly meet the specific needs of their respective clients.

This continual interworking between the different teams in the company ensures that these teams work together to continually grow the business of *EMSS Consulting*. This ability of *EMSS Consulting* to effectively translate operational services into commercial products is a cornerstone of the *Alphawave* group and, as such, means that *EMSS Consulting* is well poised to continue to deliver ever better service and deliver ever better products.

4.6 Results of Technology Audit of the *Alphawave* Group

The technology audits of the different companies within the *Alphawave* group reveal a diverse and technological advanced group of companies. Not only are the different

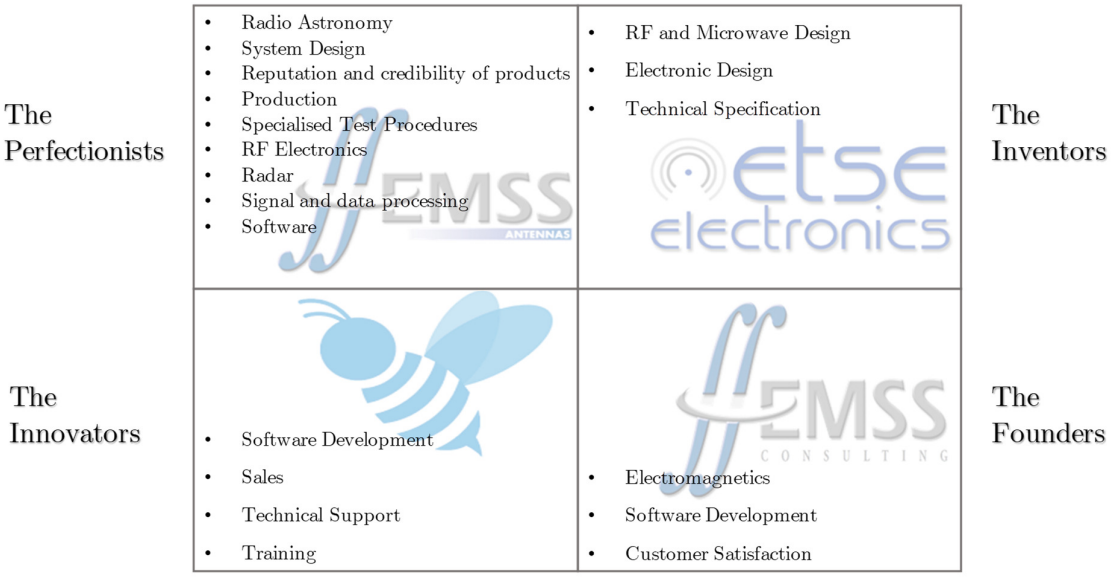


Figure 4-6: Core competencies of the companies of the *Alphawave* group

companies active in different markets and experts in different technological areas, but they are also at different stages of their organisational life cycles.

The different core competencies for each of the companies are summarised in Figure 4-6. Also illustrated in this figure is the unique character that each company has developed in conjunction with its selection of competencies and capabilities.

EMSS Antennas can be described as the perfectionists of the group as the company spends large amounts of resources to make incremental improvements to its systems and components. This level of perfectionism is warranted for the radio astronomy field in which they are active. Although the company has a technical superiority in this specific field, its focus on perfectionism has also made it a slow company, especially to change direction or embark on new ventures.

ETSE Electronics is the first major acquisition of the *Alphawave* group, specifically acquired to increase the overall electronic capabilities within the group as a whole. *ETSE* can be described as the inventors of the group. They are exceptionally skilled at translating real-world problems into electronic solutions. Although its solutions are often innovative as well as designed and produced at a high standard, the company

has historically struggled to take their products to market, as well as scaling their operations as required.

Honeybee is a mobile application start-up venture and as such can be described as the innovators of the group. It is constantly trying to innovate both incrementally and at times radically to ensure that it keeps and exploits its advantage over its competition. This level of innovation does come at a price and there have been numerous false starts over the years. The development of *Honeybee* remains expensive, especially as all development is devoted to one product.

EMSS Consulting remains the company at the core of the group. With many ventures and products, at least partly, originating from this company it can be described as the founders of the group. Innovative ideas are often not kept within the company, but rather spun-off into new ventures or companies within the group. Further, as the most mature company in the group, the structures, processes and products are well established and scalable, there are not a lot of changes that are required internally.

To illustrate the relative maturity of the various products in the *Alphawave* group's stable, a series of illustrative S-curve graphs are shown in Figure 4-7 to Figure 4-10. These S-curves are not empirically created and is not based on any actual data and serve only as an indication of the level of maturity of the various products based on discussions with the relevant representatives of the various companies. These S-curves attempt to describe the remaining potential in these current technological products.

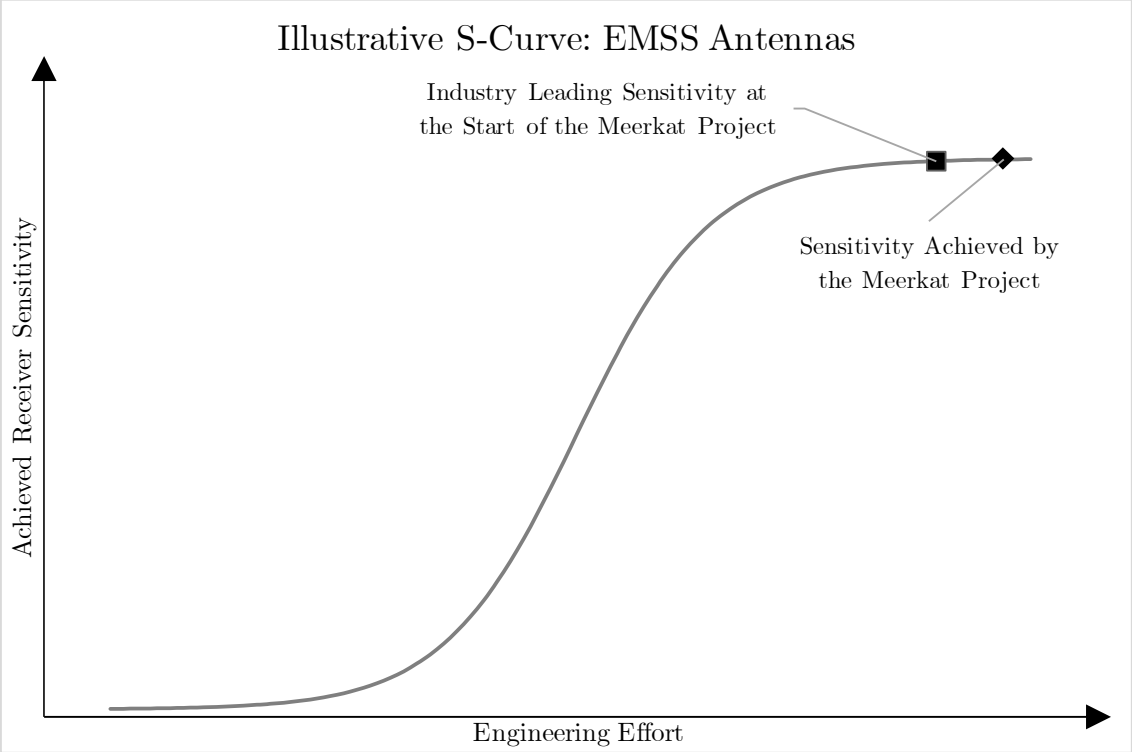


Figure 4-7: Illustrative S-Curve showing the contribution of *EMSS Antennas* to receiver sensitivity in the radio astronomy industry.

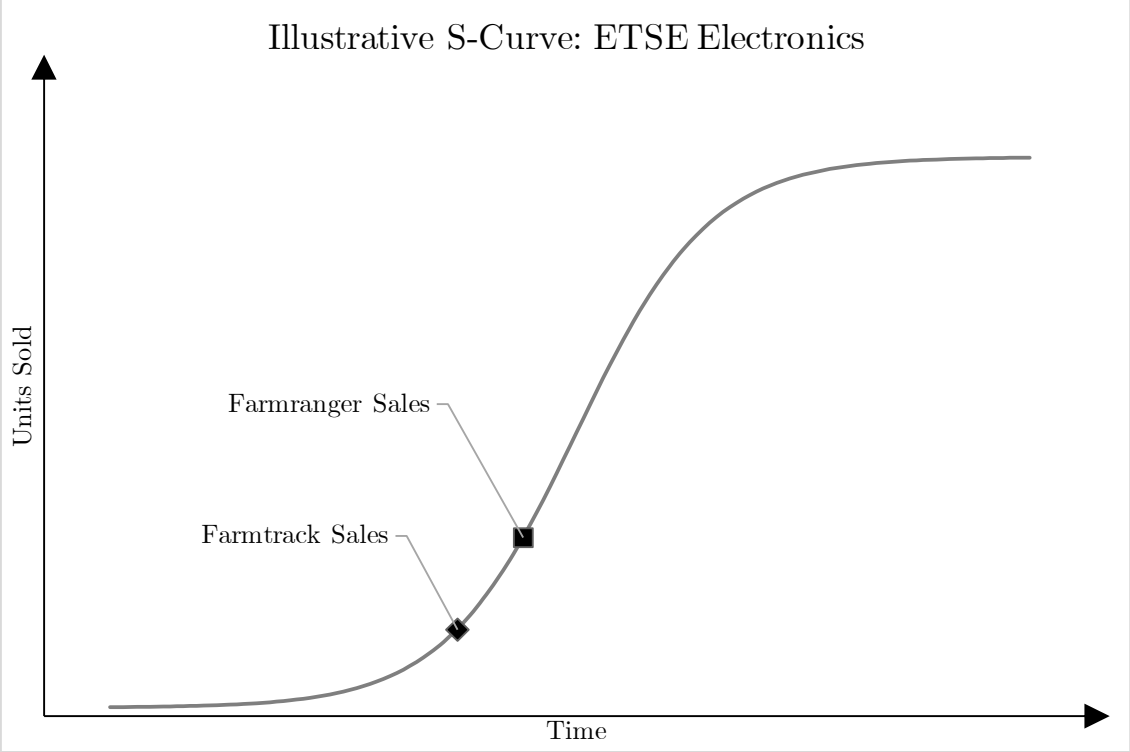


Figure 4-8: Illustrative S-Curve of *ETSE Electronics*' product sales

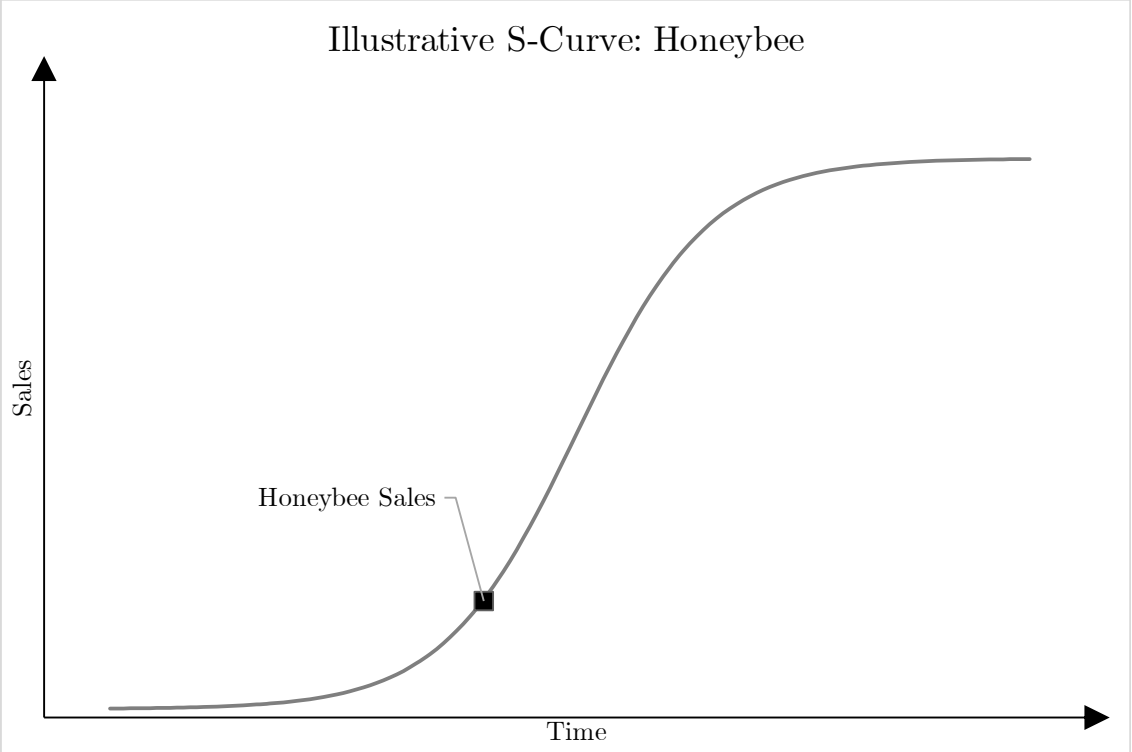


Figure 4-9: Illustrative S-Curve of *Honeybee* product sales

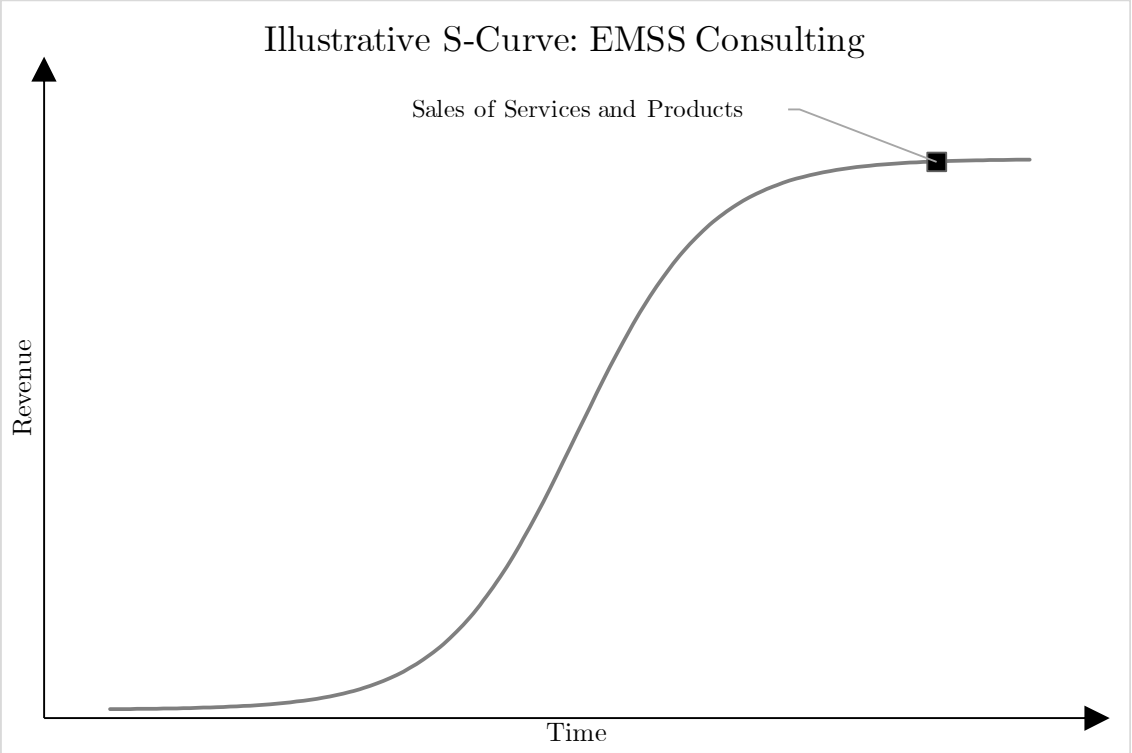


Figure 4-10: Illustrative S-Curve of revenue generated by products and services of *EMSS Consulting*

The two axes chosen for the S-curve of *EMSS Antennas* are *Achieved Receiver Sensitivity* and *Engineering Effort.* This results in the S-curve shown in Figure 4-7, where a disproportionately large amount of engineering effort was required to make a small improvement in the industry-leading level of sensitivity. This level of specialisation required to achieve these results as well as the limited number of potential clients willing to spend such a large amount resources shows why *EMSS Antennas*, although experts in their field, will have difficulty to adapt its receiver to other markets or clients.

The products of both *ETSE Electronics* and *Honeybee* are on the same trajectory, as shown in Figure 4-8 and Figure 4-9 respectively. All these products have passed its initial development stage and have seen an increase in sales. *Honeybee*, in particular, has seen a large increase in sales, due to the size of their chosen market as well as the large number of potential customers. These customers are not limited to local customers, but international as well. Any technological advances in these products can be expected to be incremental for the time being as most resources will probably be allocated to ensuring that each product and its supporting structures are able to scale appropriately.

EMSS Consulting is still, financially, the most successful company in the group. Based on the success of *EMSS Consulting* new ventures, such as *Honeybee*, can be explored. That said, the revenue generated by the products and services of *EMSS Consulting* has reached a plateau, as illustrated in Figure 4-10. This is primarily due to the fact that there are very few other customers who could benefit and afford the services of *EMSS Consulting* on a large scale. The service contract of *EMSS Consulting* is still the main revenue generator of the company. Although the group has benefitted from the innovative history of *EMSS Consulting,* some innovation will be required if any significant growth can be expected in the future.

The technology audit has revealed a group of companies with a diverse portfolio of technologies. Also, the various companies have proven that they are able to effectively

both develop and acquire new technology internally and externally of the group. Furthermore, the different market offerings of the companies in the group are at different life cycles. This ensures that enough capital is generated by the established products to support the newer products until they become profitable in their own right.

The group as a whole seems healthy from a technology and business perspective. It is not immediately clear whether the same is true for the individual companies in the group. In the next section, further collaboration between the different companies will be discussed to ensure that each individual company can successfully achieve, maintain and leverage its competitive advantage. Not just for the individual companies, but for the group as a whole.

4.7 Analysis and Conclusions of the Technology Audit

As mentioned in the previous section, the technology audit revealed a strong technology base within the different companies and *Alphawave* group as a whole. Throughout the history of the *EMSS* and subsequent *Alphawave* groups, the development and transfer of technology has played an integral part in the creation and development of the various companies that make up the group. That said, technology was never formally managed as a structured and regular process, but rather as an ad-hoc reactive requirement as needed whenever an opportunity presented itself.

Similarly, innovation and technical excellence have continually played a central role in the group and its companies. Again, however, there are very few formal structures to manage innovation, but innovative thinking is ingrained in the culture of the group. Based on a shared character of innovative thinking and technical excellence, as well as the ability to leverage existing technological competencies into new opportunities and companies, the various companies have each developed their own unique technology portfolio.

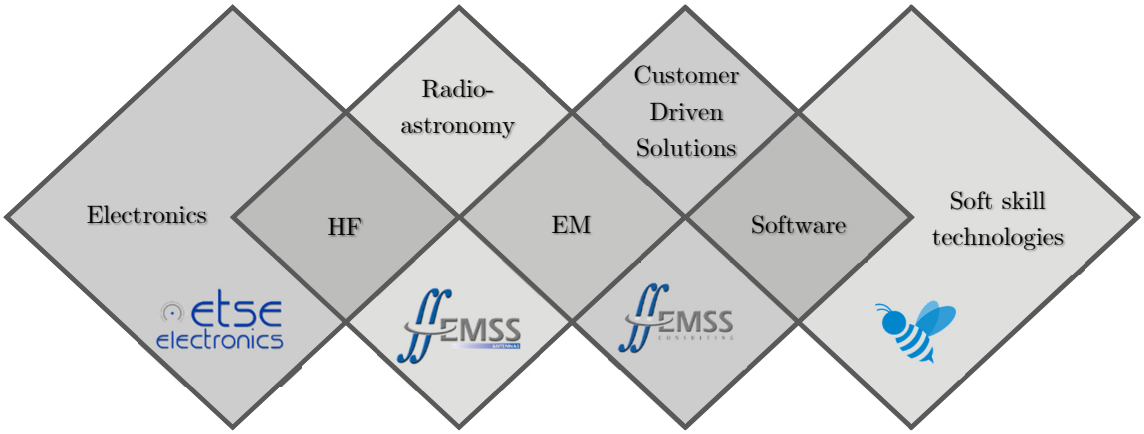


Figure 4-10: Sharing of competencies and capabilities between the different companies of the *Alphawave* group.

A summary of the main competencies of the *Alphawave* group are shown in Figure 4-10, including competencies unique to each company as well as shared between different companies. Some of these shared competencies are actively managed together in the group as a whole, for example, the strong software competency. The shared electromagnetic (EM) competency between *EMSS Antennas* and *EMSS Consulting* has in the past been leveraged into a successful product-line; the *fieldSense*. Other shared competencies have not yet been actively pursued, such as the share High-Frequency (HF) competency between *EMSS Antennas* and *ETSE Electronics*.

Beyond the shared competencies, there is also the potential to share even more of the competencies between the different companies. As an example, the strong sales competency of *Honeybee* would be an invaluable addition to especially *ETSE Electronics*, although all the other companies would be able to benefit. Although sales is not generally considered a technological capability, there is evidence from the literature that so-called soft capabilities, such as sales, finance, marketing and human resources, can (and possibly should) be managed in the same manner as hard technological capabilities [3], [5], [31], [38], [56], [62]–[64]. *Honeybee* has had some success in scaling its sales capabilities, and if transferable, this sales competency could be a great asset to the other companies and assist them to more effectively take products to market.

A more proactive approach to technology management also has the potential to lead to greater opportunities based on the already established technologies. By implementing technology strategic planning with clear long-term technological goals, the group can plan and control the development of innovative products and new markets. Most of the group's products were based on a technology push, rather than a market pull. When a market pull effected the development of a new product, it was generally based on already established technologies within the group. By implementing longer-term strategic technology management, future market opportunities can be identified and the development of new technologies to meet these specific opportunities can be planned for.

As part of a strategic technological management process, expanding the innovation structures could also be beneficial to the group. At the moment it seems as if most of the innovation is vested at director level, especially with regard to identifying potential opportunities and threats in current and new markets. A more structured and collaborative approach could assist the companies and the group to more effectively expand its technological capabilities and market share.

This approach is not unfamiliar to the group, *Honeybee* has been able to implement some of these structures on a smaller scale. The clear long-term goal of *Honeybee* – to be a billion-dollar company by 2035 – is a definitive driver of how the company manages its technology and structures. It provides a framework for decision-making and innovative thinking beyond the here-and-now. Also, the ExCo structure of *Honeybee* ensures that the relevant persons with access to the correct and relevant information is part of the decision-making process to guide the company's corporate strategy to best leverage its technological potential.

As proven by the technology audit of the different companies in the *Alphawave* group, the group has a strong and diverse technology portfolio. Although it has been able to leverage its strong technological capabilities, innovative culture and technical expertise into successful products, by formalising its technology and innovation structures into

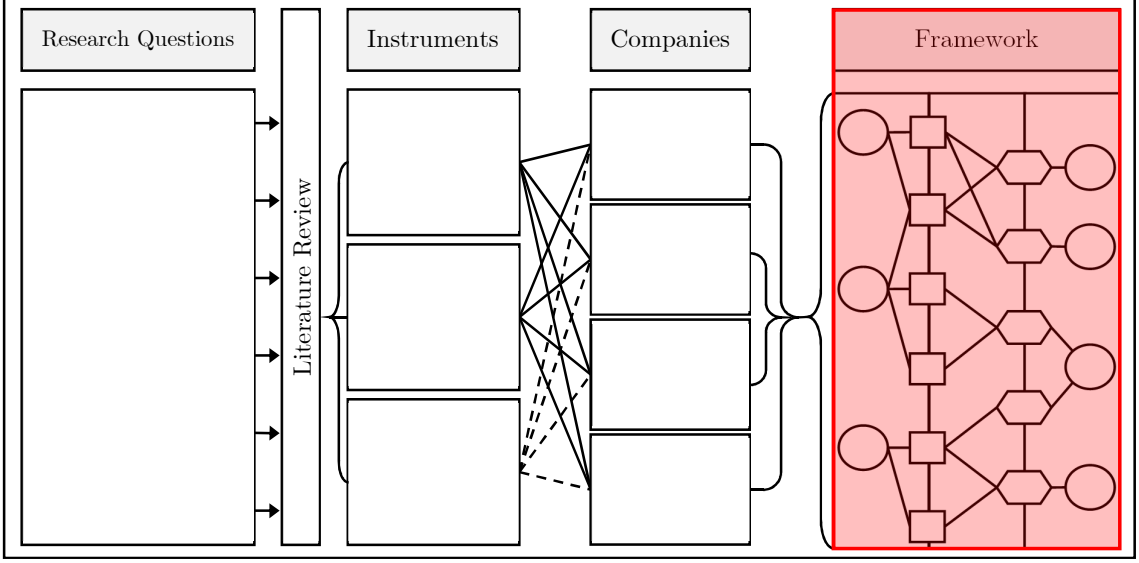
long-term technology strategies with specific and clear goals, the group will be able to effectively expand its technological capabilities further into innovative products. This will ensure that the *Alphawave* group can continue to maintain and further exploit its competitive advantages in its established as well as brand new markets.

CHAPTER 5

CONCEPTUAL TECHNOLOGY MANAGEMENT FRAMEWORK

This chapter will detail the development of a conceptual technology management framework and will attempt to effectively present:

- An attempt to address some of the areas of technology management where *Alphawave* was found lacking from the audit results of the previous chapter.
- An attempt to incorporate technology management principles as identified from the literature review.
- Definitions of different framework elements and framework for the general case
- An application of the different framework elements and framework to the *Alphawave* case.
- A test of the validity of the framework for the *Alphawave* case.
- The framework is the final output of the research process as shown below:



5.1 Goals of the Conceptual Framework

As found during the technology audit of the *Alphawave* group, the group has been successful in the past due to its fruitful leveraging of its technological competencies

and capabilities. That said, the manner in which technology is managed within the group is mostly reactive in nature and does not include a group-wide long-term technology strategy.

To support the *Alphawave* group to manage its technology in an ever more efficient way, a conceptual technology management framework is developed in this section. The framework will build on the already strong technology portfolio vested in the *Alphawave* group and its various companies. The primary goal of the technology management framework will be to function in such a manner that the *Alphawave* group can regularly and with minimal effort establish its current technological state and direct its capabilities into new potential ventures. Thus, creating a combined strategy linking the group's business and technological goals. [3], [5], [31], [42], [44]

As discovered during Chapter 3, the literature review of this study, an all-encompassing framework to implement technology management has not been found or developed. The lack of this all-encompassing framework seems to have prompted the development of various frameworks each suited to apply to a particular case and or situation. [5], [31], [38], [40], [43], [49]–[52].

Also, as noted as part of the literature review, the most common approach to base these frameworks on is the *Dynamic Capabilities Theory*. This theory is especially prevalent in the more recently published literature included in the literature review. As the prevalent theory, the conceptual framework described in this section will be based on the principles of the *Dynamic Capabilities Theory* [3], [5], [7], [39], [40], [51], [56]–[59].

The conceptual framework is developed around the principle that technological capabilities should be managed in order to exploit an organisation's competitive advantage. The framework also accounts for the dynamic nature of these capabilities and how these capabilities interact with each other. The framework is of a graphical nature to ease and promote the communication of long-term technology strategies between various role-players in the group. It is intended that this graphical framework

will make the overall technology strategy of the group relatable to role-players found in various different companies, levels and functions within the *Alphawave* group as a whole. [3], [44], [60]

5.1.1 Application of Dynamic Capabilities Theory

A constant feature of technology is how swiftly it changes. This seems to be one of the main reasons for the popularity of the *Dynamic Capabilities Theory* in the field of technology management. *Dynamic Capabilities Theory* states that the technology capabilities of organisations should be ever-changing to remain relevant in fast-moving technology markets.

It is not only the individual capabilities of an organisation that are dynamic, the manner in which these capabilities interact with each other is also dynamic. An organisation should also constantly realign, reorganise and expand its technology capabilities to ensure that they gain maximum leverage from their capabilities in their chosen market. In fact, the manner in which these capabilities are managed can be seen as a core competency in its own right [3].

This framework will then attempt to first, show the various capabilities vested in the different companies of the *Alphawave* group, as well how these capabilities interact with other capabilities throughout the group as a whole. This description of the current state of technology within the group should form the foundation for decision-making on future endeavours for both the individual companies, as well as the group as a whole.

From the current state of technology, possible new ventures can be identified to be investigated for possible future undertaking. Further, the framework should assist in establishing what additional capabilities will be required for these new ventures to be successful and whether these capabilities are available within the group or if it can be developed or should be acquired by one or more of the individual companies in the group [3], [5].

Although primarily focused on technological capabilities, other capabilities can also be included in the framework. Especially softer functions, such as sales, marketing, etc. can be incorporated in the dynamic interaction of the various technological components [3].

These softer functions are often critical to ensure that the products generated by the harder technical capabilities are successfully taken to market. By treating the traditionally non-technical soft functions in the same way as technical capabilities, they can be more effectively managed as part of the greater technology portfolio, thus also ensuring that they are aligned with the requirements of the overall business and technology strategy as a whole [3], [5].

The dynamic nature of technology and business, and the management thereof, will be incorporated into the framework. This will position the framework as an essential tool to ensure that all current and potential future capabilities are optimally aligned to adequately leverage the competitive advantage of the *Alphawave* group in established and promising new markets [3], [5].

Ultimately, the proposed framework should ensure that regardless of what other capabilities and competencies are vested in the *Alphawave* group, the dynamic management of these technologies remains a core competence [3], [5].

5.1.2 Graphical Model

An important function of technology management is to facilitate communication. This communication does not only relate to communication between different technology role-players but also between different functional departments of an organisation as well as between the different levels of an organisation [3], [5], [31], [44].

As noted as part of the literature review of Chapter 3, graphical models are common features of both technology management frameworks and tools. These models make the complex and dynamic relationships between different technological capabilities more relatable to diverse sets of role-players and stakeholders [3], [44], [60].

By developing the proposed framework with a graphical output, the framework should be an ideal tool to first, summarise the current state of technology within the different companies of the *Alphawave* group. Second, to facilitate strategic considerations of new ventures. And third, to easily relate both technology and corporate strategy to the diverse role-players at different levels of the *Alphawave* companies and group.

As the graphical model is designed to be relatable with the different role-players, it is also hoped that the model itself will promote communication between the role-players from different backgrounds. The graphic nature should create shared foundation between technical and non-technical personnel to find a mutual understanding of the technological and business standing of the group. This should ensure that all parties are able to give constructive input to the development and advancement of corporate and technology strategy in the group [42].

The graphical model of the framework will also be given additional depth by using different colours for different aspects, elements and timespans. For example, the current state should be coloured separately from the planned states. This will ensure that the current 'as-is' state of the technology portfolio can easily be differentiated from the planned 'to-be' state. This differentiation should highlight what developments and/or acquisitions are required to move the group from the 'as-is' to the 'to-be' state.

By employing a graphical model of the framework, the framework can function as both an at-a-glance summary of the *Alphawave* group's technology portfolio as well as a tool for in-depth strategic planning. The model can be used to communicate the overall technology strategy of specific companies or the group as a whole to all role-players at various levels and functions within the group.

5.1.3 Proactive Long-term Strategic Tool

As noted in Chapter 4, the *Alphawave* group could benefit from a more proactive way of managing its technology portfolio. By setting future targets for expanding its technologies and markets the group can actively develop or acquire the relevant

capabilities or competencies to optimally secure their foothold and dominance in these chosen markets. Similarly, by taking a long-range view of their current technology situation potential technological threats might be identified and circumvented in a timely fashion [2], [31], [37], [39], [43], [59].

To adequately manage any situation, it is essential to first establish what the current state of the particular situation is. For this reason, the framework should be updated regularly to be an accurate representation of what the current state of the specific organisation is. The framework is then intended to be adaptable enough to be reconfigured with minimal effort to reflect the dynamic nature of the manner in which the different elements interact with each other [3], [5], [40].

The intention is that whenever a discussion of how the technology portfolio can be applied or expanded in new innovative ways, the current 'as-is' state will always first be updated. The framework is developed in such a way that updating the current state should be an easy exercise if the correct information and relevant role-players are available to accurately describe the current 'as-is' state.

Based on this current 'as-is' state of technology within the group, strategies can be developed to expand the technology portfolio of the group as well as the exploitation thereof. If, for example, a new market is targeted for expansion, the required capabilities can be identified and aligned from various companies within the group to create the most suitable product to use to enter the target market.

A similar process can be followed if an added feature is required for an existing product. By identifying relevant capabilities already available in the group, the feature can be added to the product by either sharing, developing or acquiring additional capabilities into the production of the product.

The framework can then be used for strategic decision-making by either approaching from a technology, market or, more likely, a combination of the two perspectives. By approaching from a technology perspective, the capabilities of the group are evaluated and new possible markets are identified based on the available capabilities.

Approaching from a market perspective is effectively from the opposite direction. New potential markets are first identified. Based on the requirements of the market, the capabilities required for successfully launching a product into the market are determined. These capabilities are then either developed within the group or acquired externally.

This dual-directionality of the framework ensures that the group can efficiently balance both technology push and market pull forces to achieve the optimal leveraging of the group's capabilities for maximum gains in its chosen markets. The framework simultaneously shows the current 'as-is' state and maps out how the technology portfolio should be expanded to reach the planned 'to-be' state.

5.2 Conceptual Framework

This section will define the different elements of the proposed framework and the framework itself. These definitions should, however, not be seen as absolute and is intended to be adapted as required. A generic graphical model of the framework is shown in Figure 5-1. The various elements will be defined and discussed at the hand of this example.

As part of the discussions of the various elements comprising the framework, the *Alphawave* case will be used as an example of how these elements would be populated in a real-world situation. The real-world implementation and application of the *Alphawave* case will be discussed in further detail in the subsequent section, Section 5.3.

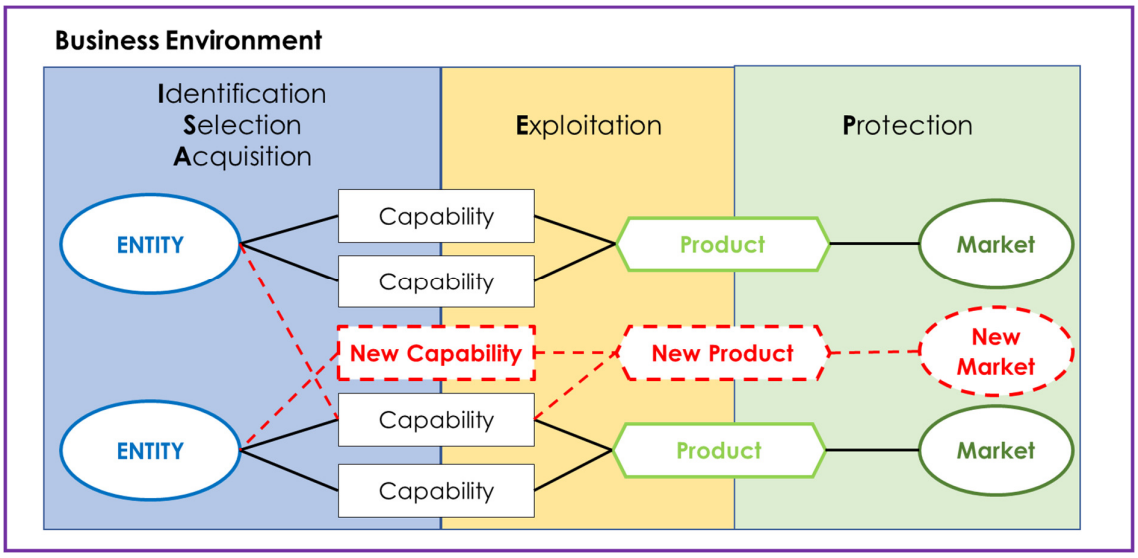


Figure 5-1: Generic graphical model of the conceptual technology management framework

5.2.1 Entities

The entities elements of the framework are the smaller independent units of the organisation as a whole. For the case of a single business unit firm, the entities can be defined as the different departments of the firm. In the case of a multiple business unit firm, such as the *Alphawave* group, the entities can be defined as the separate independent companies that make up the group as a whole.

The entities are located on the left-hand side of the framework and house the capabilities of the organisation. The entities can then be viewed as the physical embodiment of the functional resources of the organisation.

The entities defined for the case of the *Alphawave* group are the individual companies of the group, i.e.:

- *EMSS Antennas*
- *ETSE Electronics*
- *Honeybee*
- *EMSS Consulting*

5.2.2 Capabilities

The capabilities in the framework are the technological capabilities entrenched within each of the elements. These capabilities can either be unique or shared between the different elements. Each capability should, however, only be included once in the framework.

Lines are drawn showing how each capability is linked to one or more of the entities. Capabilities shared between entities will have lines linking them to each of the respective entities.

Similarly, the capabilities are linked with lines with the products wherein they are utilised. Again, if a capability is utilised by more than one product, more than one line will be used to link the capability with all the relevant activities. In the case of unused capabilities, they will have no lines connecting them to any activities.

For the specific case of the *Alphawave* group, the capabilities will be defined based on the technologies identified in the various Technology Balance Sheets as detailed in Chapter 4. Some of the capabilities are expanded, lumped together or removed completely in order to simplify the model. The list of capabilities for each of the respective companies of the *Alphawave* group are as follows:

- *EMSS Antennas*
    - Antenna Design
    - Test Procedures
    - Production (Expansion of ISO 9001 Standards)
    - RF Electronics
    - Radar
    - In-time Signal Processing
    - Cryogenic Cooling
    - Data Processing
- *ETSE Electronics*

  - RF & Microwave Design (Combination of RF & Microwave Systems and RF & Microwave Components)
  - Electronic Design (Combination of Digital Electronics and Analog Electronics)
  - PCB Layouts
  - Technical Specification
  - Embedded Software
  - Datamining (Included as part of planned 'to-be' state)
- *Honeybee*
  - Quality Assurance (Combination of Functional QA and Automated QA)
  - Product Design (Renamed from *'Product Management and Design'*)
  - Technical Support
  - Training
  - Sales (Combination of Sales Acquisitions, Sales Success and Account Management)
  - Marketing
  - Integration
  - Analytics
  - Software Development (Combination of Backend Development, Web Frontend Development and Mobile Frontend Development)
- *EMSS Consulting*
  - Software Development (Shared with *Honeybee*)
  - Assembly
  - EM Regulatory Knowledge
  - System/Procedure Design
  - Logistics
  - Practical EM Principles
  - Data Management (Renamed to differentiate from *EMSS Antenna's* similar *'Data Processing'* capability)

5.2.3 Products

The product elements in this framework is a catch-all phrase intended to include any product or service offered to a client. These products are then the deliverables intended for the markets defined in the next section.

The products will be the result of one or more of the capabilities defined in the previous section. These products can be as a result of a multiple of the capabilities included in the framework. Lines will again be utilised to indicate which activities lead to which products as well as which products are intended for which of the defined markets.

The different products defined for the particular case of the *Alphawave* group will again be obtained from the results of the Technology Audit, as detailed in Chapter 4. Similar to the capabilities in the previous sections, some of the products have been renamed or removed to simplify the model for the *Alphawave* case. Potential products not yet in production will be included as part of the planned 'to-be' state of the framework. The products per *Alphawave* entity are listed below:

- *EMSS Antennas*
    - *MeerKat* Receivers
    - *SKA*- Receivers
    - *X-Range*
    - *Project Zeta* (Included as part of planned 'to-be' state)
    - UAV Control Module (Included as part of planned 'to-be' state)
    - *fieldSense* (Shared with *EMSS Consulting*)
- *ETSE Electronics*
    - *CPUT CubeSat*
    - *Farmranger*
    - *Farmtrack*
- *Honeybee*
    - *Honeybee*
- *EMSS Consulting*

- *fieldSense* (shared with *EMSS Antennas*)
- *IXUS*
- Training
- Consulting Services (Simplified from Consulting/Advisory Services)
- Software Services
- Operational Services
- Interference

5.2.4 Markets

The market elements in the framework are the targeted consumer groups for which the products created by the various elements in the framework are intended. The markets can be chosen to be specific or more general in nature depending on the requirement of the particular organisation.

Different products can be created for the same market or a single product can be created for multiple markets. As with the other dependencies listed in the other sections of this chapter, the linkage between the products and the markets are indicated by lines.

Potential new markets to be explored can also be included as part of the planned 'to-be' state of the framework. This should help visualise the expansions and realignments required of the other elements of the framework to successfully enter the new market.

The market elements for the *Alphawave* group are obtained from the results of the technology audits in Chapter 4, similar to the other elements already covered in this section. As for the capability elements, some of the markets might be combined for simplification of the framework. The market elements to be included for the *Alphawave* case are listed below:

- *EMSS Antennas*
  - Radio Astronomy
  - Interplanetary Communications and Radar (Planned 'to-be' market)

    - Sports Electronics
    - External Market (Rework of somebody else's market included as a Planned 'to-be' market)
- *ETSE Electronics*
    - Satellite communication
    - Farm management
- *Honeybee*
    - Customer relation management
- *EMSS Consulting*
    - Mobile operators
    - Mobile Infrastructure (Combination of Infrastructure companies/contractors)
    - Communications Regulators

5.2.5 Business environment and technology management processes

The *Dynamic Capabilities Theory* identifies five technology management processes that should be implemented within an organisation. These processes ensure that technology and, by extension, technological capabilities are managed efficiently to maximise gains from business operations, within the constraints of the organisation's business environment. These processes have been discussed at length in Section 3.4.3 and within the framework there are particular areas where the respective processes are most required [3], [5].

The Identification, Selection and Acquisition processes are of primary concern when evaluating which capabilities are available and required within the various entities. These three processes are applied at the linkage between the entity and capability elements within the framework. The Identification process identifies which capabilities are available within each entity and where potential is for the development or acquisition of new capabilities. The application of the Selection process selects the most favourable options. And finally, the Acquisition process drives the integration and/or

development of the new capabilities into the already existing operations of the organisation [3], [5].

The Exploitation process, in turn, is applied at the linkage between the various capabilities and their descending product elements. The Exploitation process converts the technological capabilities into marketable products. By careful control of this process, products should be created that exploit the available capabilities to maximum gain [3], [5].

Finally, the Protection process is applied at the linkage between the product elements and their respective markets. The Protection process requires constant assessment of market risks and potentials to ensure that the products taken to market remain competitive. This process is critical to guard against disruptive technology, while simultaneously scouting for potential ways to ensure that the products maintain and expand its market footprint. This is done by continually expanding the technology base through the effective execution of the five technology management processes [3], [5].

Although the different processes are associated mostly with the linkages described above, it does not mean that these processes should only be executed at these linkages. Indeed, these processes should be actively pursued throughout the technological, operational and business activities of the organisation. The linkages associated with the respective processes are where, in particular, these processes are most crucial for effective management of technology within the organisation.

5.2.6 Risks

Optional risk elements can be included as cautioning markers in the framework if deemed necessary. Risk elements are defined as any possible threat that can potentially impede the ability of an organisation to continue to deliver products to their chosen markets. These risks can influence any element in the chain leading to the eventual product.

Risks can be of a technical, organisational or market nature. Technical risks include the ageing of equipment and technological expertise, superior or disruptive technologies from competitors. Organisational risks include insufficient cash flow to develop and/or produce a product and inadequate support structures to successfully deliver the product to market. Market risks include the saturation of chosen markets as well as the shrinking of chosen markets.

Although included in the framework, the risks do not form part of the natural flow from entities to markets. Instead, the risks are markers to highlight possible impediments to further exploit the competitive advantage the organisation might have. Risks are marked as red triangles at the elements it could potentially have an impact on.

For the *Alphawave* example of the implementation of the framework, a number of risks have been included. Although not necessarily explicitly noted in the technology audit findings of Chapter 4, the risks included are inferred from the *Technology Management Reports* compiled for each of the companies.

The risks included in the *Alphawave* case are listed below:

- The *Two-way Radio* **capability** of *ETSE Electronics* is unused at the moment and is at risk of becoming obsolete.
- The *Sales* **capability** of *Honeybee* is only vested in a limited capacity. Indeed, 90% of the sales capacity is vested in a single salesperson. This creates a risk that the sales capability will be unable to upscale sufficiently to sustain the growth of *Honeybee*.
- The *Meerkat Receivers* **product** of *EMSS Antennas* is nearing completion and the production capacity vested in this product is at risk of being lost if the *SKA Receivers* project is delayed further.
- The *SKA Receivers* **product** has been significantly delayed already. This product was intended to replace the *Meerkat Receivers* as the revenue

generator of *Antennas.* If this product is not confirmed soon, the company is at risk of not being able to finance its operations.

- The *Radio Astronomy* **market** has only limited scope for expansion beyond the current *Meerkat-* and *SKA Receiver* projects. There is a risk that after the completion of these projects the market would be saturated, the only market in which *EMSS Antennas* are currently entrenched.
- The *Farm Management* **market** is becoming increasingly competitive. *ETSE Electronics* needs to ensure that it actively leverages its capability or run the risk of losing the market to new and/or larger competition.
- The *Mobile Operators* **market** of *EMSS Consulting* is nearing saturation, especially related to the delivering of operational services to local mobile operators. With increasing pressure on its clients to cut costs, there is a risk that the main revenue generator might shrink with few other clients available to pick up the slack.
- To limit the above risk, *EMSS Consulting* has already expanded its operational services to the *Mobile Infrastructure* **market**. Although active in the market, there has not been a great deal of success in landing large, full-scale contracts from the independent mobile infrastructure construction companies and contractors. The unreliability of retaining ongoing clients poses a risk to *Consulting,* if this is the only market option to expand its biggest earner into.

5.3 Alphawave Application of Conceptual Framework

Building on the generic graphical model of the framework shown in Figure 5-1, the model can be expanded to cater for the real-world *Alphawave* case. When populating the elements of the conceptual framework with data from the *Alphawave* case, as detailed in the preceding sections, an expanded graphical model of the framework is obtained. This graphical model of the *Alphawave* application of the conceptual framework is shown in Figure 5-2 and is discussed in further detail in the remainder of this section.

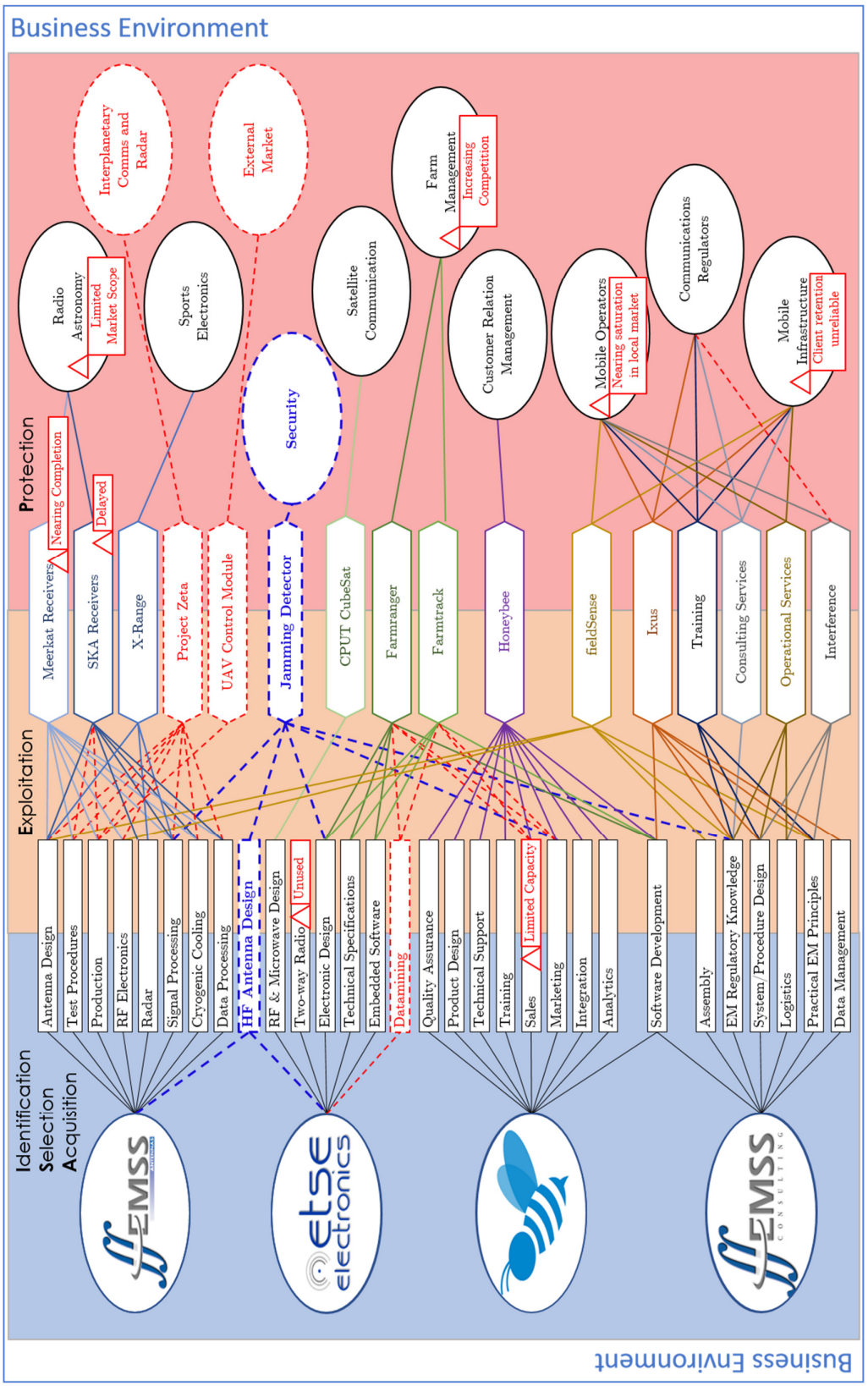


Figure 5-2: Graphical model of the conceptual technology management framework based on the Alphawave case.

As mentioned in earlier sections, both the current 'as-is'- and the planned 'to-be' states are shown simultaneously in the framework. The solid-lined elements are all elements that form part of the current 'as-is' state, based on the technology audits of the various companies of the *Alphawave* group. The different capabilities-product-market chains are coloured according to the chosen colour of the respective product per chain to make it visually easier to trace the various chains.

The elements of the 'to-be' state are indicated in red dashed lines. These elements or linkages between elements have not been established or entrenched yet and are either being planned or actively developed. The *SKA Receiver* product of *EMSS Antennas* is currently in its pilot phase and thus certain capabilities such as *Antenna Design, RF Electronics, etc.* are currently being utilised. If *EMSS Antennas* successfully implements the pilot phase and is awarded the full production contract for the *SKA Receiver* project this product will also incorporate the *Test Procedures* and *Production* capabilities developed by *EMSS Antennas* for the almost complete *Meerkat Receiver* contract. The links between these two capabilities and the *SKA Receiver* product are then indicated as the dashed red lines.

Similarly, for the *Project Zeta* capability-product-market chain, the same capabilities developed for the *Meerkat Receiver* and planned *SKA Receiver* products will be redeployed into the new *Interplanetary Comms and Radar* market. In much the same manner, the *UAV Control Module* capability-product-market chain will redeploy the production capability of *EMSS Antennas* by producing a product for an external client to distribute to its own external market. These 'to-be' state examples for *EMSS Antennas* show how the framework can assist and visualise the redeployment of available technological capabilities into new products and markets.

Three technological capabilities are indicated as part of the 'to-be' state of the framework for *ETSE Electronics*. The first capability is the *Datamining* capability, currently being developed by *ETSE* to further enhance its *Farmtrack* and *Farmranger* products. These enhancements are planned to enable the users of these products to

manage their orchards and flocks with even more precision. The other two capabilities are the *Sales* and *Marketing* capabilities, which could be transferred from *Honeybee* to assist *ETSE* in more effectively introducing and selling their products to potential clients in the *Farm Management* market. Both of these capabilities must, however, first be developed by *Honeybee* into fully saleable and transferable technology-like capabilities before this transfer can be undertaken.

Although a fairly new capability, the *Interference* product of *EMSS Consulting* could be expanded into the *Communication Regulator* market from the *Mobile Operator* market. This link between an established product and a potential new market illustrates how the 'to-be' state of the framework can be used to determine new potential markets for already established products.

The conceptual framework can further be used to balance the relevant market pull and technology push forces to assist the *Alphawave* group to continually expand and maintain its competitive advantage in a multitude of markets. For a market pull example, the *Alphawave* group might identify a potential gap in a new, unexplored market. They will then be able to evaluate their current available technological capabilities by hand of the framework. From these available capabilities, they can determine which product they can deliver for the chosen market and also which technology should either be developed or acquired to deliver the chosen product to market. Similarly, for a technology push example, *Alphawave* would be able to evaluate their available capabilities and determine which products they might be able to produce with these capabilities. They can then search for the optimal market for this product.

To illustrate the manner in which new products can be planned from already existing technologies, an additional chain is indicated in dashed blue lines as an example for the potential security market. Either by identifying the needs of the potential market or by identifying a potential product from their available capabilities they might decide to develop a remote jamming detector. This detector would be used to alert the

relevant parties that someone is using remote jamming equipment in close proximity to a vehicle or a parking lot full of vehicles. Such a jamming detector would require some development to become a fully operational product to take to market.

For the purpose of this example, capabilities from the various companies have been identified, which should potentially enable the company to create a successful remote jamming detector. First, the *Signal Processing* capability of *EMSS Antennas* could be utilised to develop the required components to identify a jamming signal. The actual electronic units could be designed using the *Electronic Design* capability of *ETSE Electronics.* As the market is an unknown quantity to the *Alphawave* group, the *Marketing* capability of *Honeybee* could assist greatly in announcing the new product to the market and identifying potential clients. With the knowledge, skills and contacts *EMSS Consulting* has developed in its *EM Regulatory Knowledge* capability, *Consulting* should be able to determine how to distinguish between lawful '*regular'* signals and the illegal *'jamming'* signals.

Finally, as most remotes work in the High-Frequency (HF) range, an HF antenna would have to be designed to be included in the product. With the combined knowledge of antenna design in other frequency ranges, *EMSS Antennas* and *ETSE Electronics* should be able to develop this new capability based on their established knowledge. This example of how to develop an entirely new product for an unfamiliar market shows how the framework would be able to address strategic questions that might arise from starting new ventures. The framework can help identify which capabilities are required, whether the capabilities are already vested in the group and if the capabilities can be developed from within the group or should rather be acquired from outside the group.

5.4 Preliminary Framework Validation

Although the framework developed is only conceptual in nature, a workshop was arranged to validate the potential worth of the framework within an organisation. The workshop was attended by all the participants of the various interviews, as detailed in

Table 2-1, as well as the *Alphawave* group chairman (designated as Participant F). The group thus included the highest level of management within the individual *Alphawave* companies included in the study, as well as at group level.

During the workshop, some background relating to the research and development into the conceptual framework was relayed to the attendees. Thereafter, the framework and its workings were detailed and explained, where after the attendees discussed and debated how such a framework could be implemented within the *Alphawave* group. After the discussion, each attendee was given a short questionnaire with which to indicate how well the framework would be able to drive different aspects of technology management within the group and the individual companies. It was anticipated that the attendees will consider the framework to have differing suitability when evaluating it in the context of the group as a whole than within the context of the company which they represent.

The questionnaire consisted of the following six statements, which each attendee could rate how much they agree with on a scale of 1 to 5, where 1 indicated *"Not at all"* and 5 indicated *"Extremely"*. The six statements are indicated below, also indicated after each statement, in parenthesis, are the information that was hoped to be learned from the answers:

- This framework reflects the current state of technology well.

  (This statement attempts to evaluate how each attendee considers the framework to be able to accurately and effectively map how technology is vested and shared in the various companies and the group as a whole.)
- This framework will be useful to identify new technological capabilities to be developed and/or acquired.

  (This statement aims to evaluate how each attendee considers the framework to be a useful decision-making tool to identify new technology to be either developed or acquired by the group or individual companies.)
- This framework will be effective to identify new opportunities to be exploited.

(This statement aims to evaluate how each attendee considers the framework to be a useful decision-making tool to identify new markets or products to be pursued by the group or individual companies.)

- This framework will advance innovation.

  (This statement aims to evaluate how each attendee considers the framework to be an effective means to guide the group or individual companies to continually search for innovative opportunities, whether internal or external.)

- This framework will contribute to effective communication with respect to technology's influence in business strategy.

  (This statement aims to evaluate how each attendee considers the framework to be an effective tool to relay how the technological capabilities are to be used to reach strategic business goals, especially ensuring effective communication in this regard across different levels of management and operations.)

- This framework will assist in making strategic decisions relating to technology and technology management.

  (This statement aims to evaluate how each attendee considers the framework to be a useful decision-making tool for management and operational role-players to align available technological resources for optimal business gains.)

For each statement the attendees were given the opportunity to rate how much they agree with the statement within the context of the individual company that they represent, as well as how much they agree with the statement in the group as a whole. The ratings given by the attendees to how much they agree with the statements at the level of their respective companies are shown in Table 5-1. Attendees with no particular company affiliation did not complete this section of the questionnaire. The ratings given by the attendees to how much they agree with the statements at group level are shown in Table 5-2. In each of the two tables, the company affiliation of each participant is indicated as part of the table.

Table 5-1: Validation Results at Company Level

Participant	A	B	C	D	E	Average
Company Represented	EMSS Antennas	EMSS Antennas	EMSS Consulting	ETSE Electronics	Honeybee	
Question 1	This framework reflects the current state of technology well.					
	4	5	5	5	3	4.4
Question 2	This framework will be useful to identify new technological capabilities to be developed and/or acquired.					
	4	4	5	4	2	3.8
Question 3	This framework will be effective to identify new opportunities to be exploited.					
	4	3	3	4	1	3.0
Question 4	This framework will advance innovation.					
	3	3	3	4	2	3.0
Question 5	This framework will contribute to effective communication with respect to technology's influence in business strategy.					
	3	4	3	4	2	3.2
Question 6	This framework will assist in making strategic decisions relating to technology and technology management.					
	3	4	3	4	1	3.0

Table 5-2: Validation Results at Group Level

Participant	A	B	C	D	E	F	Average
Company Represented	EMSS Antennas	EMSS Antennas	EMSS Consulting	ETSE Electronics	Honeybee	Alphawave Group	
Question 1	This framework reflects the current state of technology well.						
	4	4	5	5	4	4	4.3
Question 2	This framework will be useful to identify new technological capabilities to be developed and/or acquired.						
	4	4	5	4	2	4	3.8
Question 3	This framework will be effective to identify new opportunities to be exploited.						
	4	4	3	4	3	3	3.5
Question 4	This framework will advance innovation.						
	3	4	4	4	4	4	3.8
Question 5	This framework will contribute to effective communication with respect to technology's influence in business strategy.						
	4	4	3	4	4	5	4.0
Question 6	This framework will assist in making strategic decisions relating to technology and technology management.						
	4	4	4	4	4	4	4.0

To visually illustrate the results of the validation, each participant's answer to each statement is overlaid in a single web chart in Figure 5-3 for both at company and at group level. Comparing the different sets from ratings shows that, on average, the attendees consider the conceptual framework to be more valuable at a group level than at a company level. Not-withstanding, it is reassuring to note the generally positive results of the ratings at both levels.

Based solely on these ratings, it seems as if the framework is in particular useful in the following three aspects:

1. Mapping the current state of technology
2. The promotion of communication relating to technology management within the company
3. Assisting with making strategic decisions relating to technology and technology management.

These three aspects also correspond with three of the core characteristics of a technology management framework as explored in depth in the Core Outcomes of the Structured Literature review of Section 3.2.3. First, a framework should be able to graphically relay how technology is managed within an organisation. Second, it should assist with promoting communication within an organisation, especially between business and technological units. Finally, it should be an effective tool to assist with practical strategic decision-making. Although these ratings are by no means a comprehensive validation of the framework, it is still an encouraging indication of the potential usefulness of the framework in real-world situations. Other than the ratings, the level of discussion and debate regarding how to strengthen technology management within the group, based on the framework, was a strong indication of its use as a management tool.

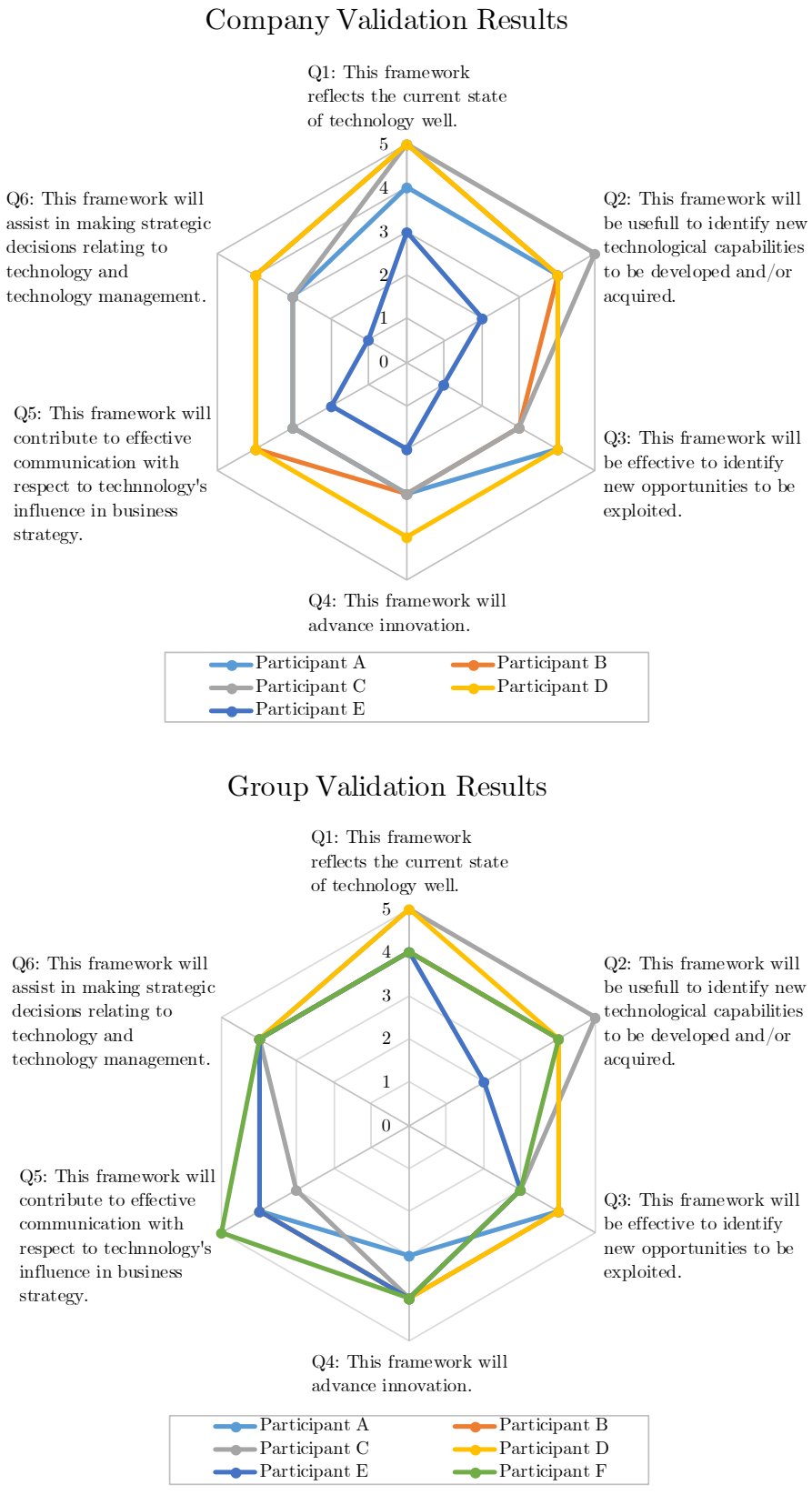


Figure 5-3: Web charts illustrating the results of the framework validation

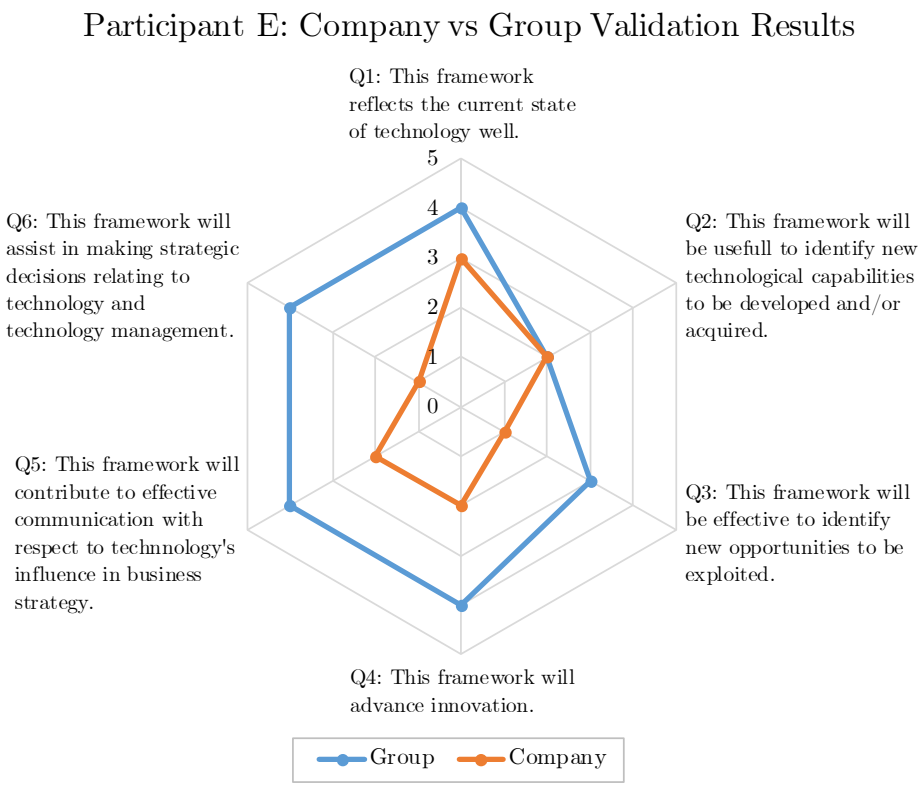


Figure 5-4: Web charts overlaying the validation results of Participant E for the company and group perspective

These generally positive results notwithstanding, one participant's ratings were markedly less favourable. These ratings were given by Participant E, the representative of Honeybee. When the participant evaluated the framework's suitability to Honeybee's situation, each statement was rated significantly below the average of all the participants. In an attempt to gain a better understanding of this participant's ratings, the participant's ratings for both at group and company level are overlaid on a single web chart in Figure 5-4 for easier comparison. Although this chart clearly shows that the participant rates the framework very lowly in the context of Honeybee it also shows generally positive ratings of the value of the framework in the context of the *Alphawave* group. Thus, it seems from this particular participant's viewpoint the

framework would be, in general, more valuable at group level than within the participant's specific company.

In particular, the aspects Participant E considered to be less useful at company level are aspects concerned with strategic decision-making, while the inverse is true for the same aspects at group level according to the same participant. These results are initially somewhat surprising, especially as Participant E rated the framework from the perspective of Honeybee, which seems to the most innovative company in the group. Upon further discussing the results with the participant, it became evident that the framework would be too slow to implement in a company that innovates as rapidly as Honeybee, but simultaneously valuable for a larger group as a whole.

At company level Participant E favourably rated the framework's ability to map the current state of technology within the company, and similarly rated this ability also well at group level. This corresponds well with the ratings of the other participants. Thus, it seems that the attendees consider the framework an effective way of mapping the current state of technology, both within the respective companies as well as the group as a whole.

Even with the low ratings from one of the attendees, the preliminary validation of the framework was generally promising. That said, there is significant scope to expand the validation to make it more comprehensive. Further validation could include similar workshops with role players in organisations, other than *Alphawave* and its companies. Further study could also expand on how to make the framework more applicable to individual companies rather than larger groups of companies. Finally, if possible, incorporating a means to weigh opportunity cost within the framework would be a valuable addition. The weighing of opportunity cost was a predominant operational consideration whenever realignment or expansion of a capability was considered. The careful operational consideration of realigning or expanding a capability is critical, as in a resource lean company unsupported changes to a capability can have a catastrophic effect on vital revenue streams.

5.5 Discussion

The conceptual framework is intended to partly be an at-a-glance map of an organisation. Showing where the organisation finds itself at that particular moment, and simultaneously what its strategic technological aims and goals are and how it intends to achieve it.

The framework, as applied to the case of the *Alphawave* group, shows an organisation that has a portfolio of varied, specialised and high-class technologies. Some of these technologies have been entrenched in the group since its founding, while others have been effectively and efficiently developed and/or acquired to create a world-class range of products.

Though the individual companies each have comparatively narrow markets wherein they do business, the group itself is exposed to a fairly wide range of markets. That said, the major weakness of the *Alphawave* group is also exposed, in that it tends to struggle to enter markets outside of its conventional technical and engineering markets. This trend does show signs of change, especially with the success of *Honeybee* entering a non-technical market. By emulating some of this success with products from the other companies, the *Alphawave* group might just be able to service a whole new spectrum of markets.

It should be noted that the framework is not intended as a tool to be used in isolation by individuals in the different companies. Rather, the framework is developed to promote communication between the different entities and role-players of the group. It is hoped that the framework will be updated during regular meetings of the relevant responsible role-players and used for strategic technology planning. Although the *Alphawave* application of this framework is based on technology audits performed, the specific application for the case of the *Alphawave* group could still be improved. By conducting a meeting or workshop with all the relevant representatives present, the information for each company can be updated specifically for the purpose of applying it to this framework.

This will hopefully ensure that all the different representatives and role-players will have a common foundation on which to plan technological goals that will be beneficial to both the individual companies and the group as a whole. Proactive strategic planning should assist *Alphawave* to determine which markets to approach and when, and ensure that its technology portfolio is expanded accordingly to effectively enter the new markets. Each company has its own specialised technologies and markets; thus, each company will have a unique perspective on future prospects that should be pursued by the group.

This framework should be robust enough to be applied at other levels of the *Alphawave* group as well. It should be well suited to be adapted at the level of a specific company, by substituting the various companies of the group with the different departments of the chosen company as the entities. The capabilities will remain mostly unchanged but might be separated and refined to add more definition to this level of application. The products will then be replaced with either department outputs or components. While the markets can be replaced by either different systems of products, depending on the situation of the specific company.

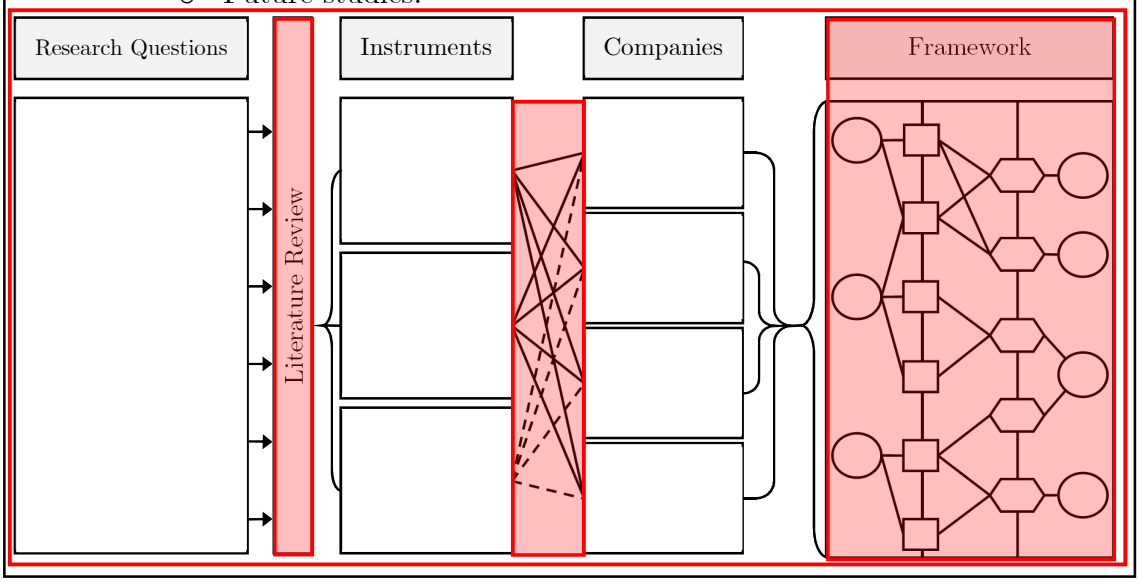
By creating a visual representation of how technology is vested and utilised in an organisation, beyond just the *Alphawave* group, while at the same time showing how it can further be developed and leveraged, the framework should assist an organisation to effectively manage its capabilities and how these capabilities interact with each other. As per the *Dynamic Capabilities Theory*, if executed correctly, this management of capabilities could be the defining capability of the organisation to continually grow its technology base and effectively leverage it to maintain and even expand its competitive advantage.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

This chapter will summarise the conclusions of this study, as well as recommendations for further activities, including:

- A summary of the results of the study.
- A review of the research process employed in this study and how it can be utilised in future studies.
- A discussion on how the different aspects of this study has contributed to practice, as well as their limitations and how they can be expanded upon.
- A self-assessment of the entire research study.
- Recommendations for:
  - The *Alphawave* group of companies,
  - Future studies.



6.1 Research Results

The goal of this study is to determine how technology management can be implemented in an existing holding company with a number of subsidiaries grouped together in a complex structure, as well as how technology management would benefit the company. The holding company in this particular case is the *Alphawave* group of companies,

which is made up of a diverse collection of technology-driven companies. The study's core research problems were identified in Chapter 1 as:

- Are there any established technology management frameworks that are applicable to *Alphawave*?
- What are the common characteristics of technology management frameworks that could be applied in the *Alphawave* context?
- Can it be determined whether technology management, in any form, is present in *Alphawave*?
- What is the technology base of *Alphawave*?
- How is this technology base utilised and how can it be expanded?
- Can a technology management framework be implemented in *Alphawave*?

A literature review was undertaken to determine the knowledge available in the field of technology management. Based on this literature review various key role-players in the *Alphawave* group were interviewed as part of a technology audit of the individual companies that make up the group, as well as the group itself. The results of this technology audit shed some light on some of the research problems.

It was found that there is no formal technology management process or structure in place within the *Alphawave* group, nor at most of the companies that form part of the group. Most of the technology management in the various companies take place at director level and is mostly reactive in nature, often drawing on implicit technology management processes. The main exception is *Honeybee*, which uses its *ExCo* structure to both manage the operations in the company, as well as the technological direction the company should take.

The *Alphawave* group was found to have a large and diverse technology portfolio. This portfolio of technological capabilities is detailed in Chapter 4 and has been developed and acquired over the 20 years that *Alphawave* (and previously *EMSS*) has existed. As most of the companies in the group were established from existing entities in the group,

there are some overlapping capabilities that are available in multiple companies. These capabilities are, however, applied in vastly different ways, scale and markets by the different companies.

Each of the companies have built on their shared competencies and developed their own auxiliary capabilities to develop better products to take to market. These capabilities are specialised and optimised to exploit their specific advantage in the relevant markets. Although these capabilities are actively exploited in the already entrenched markets by the various companies, there is scope to exploit these capabilities in new and innovative markets.

From the history of the *Alphawave* group, the trend is to reactively identify markets. Several of the successful products were developed only after they were requested by either potential clients or industry. By implementing a more pro-active approach to innovate and exploit capabilities, the group might be able to develop more new and innovative products for a large range of potentially lucrative markets. By actively and dynamically developing new capabilities to address future market needs, the group can ensure that they have the correct technology available to create new opportunities in different and innovative markets.

There were only limited capabilities identified as being lacking by the various role-players in the *Alphawave* group. One aspect identified as requiring definite development from more than one entity was a marketing capability. Also, as noticed in the technology audit, there were some difficulty in taking some of the products to market. This could indicate that a stronger sales capability might also be required. Although both of these capabilities are not traditionally seen as technological capabilities, both can add substantial benefit, not only to the group but to the individual companies as well. This is especially true if these capabilities can be developed into scalable and transferable competencies.

By implementing more structured and formal technology management systems into the *Alphawave* group's operations, it seems as if its existing technology capabilities can

be more effectively aligned with overall business goals. Especially with regard to pro-active strategic planning of what capabilities should be developed or acquired to ensure that the group and its individual companies continue to effectively leverage their competitive advantage in established and new potential markets.

6.2 Academic Contribution to Practice

This study contributes to the overall scientific community of technology management at two different levels. The study as a whole illustrates an effective approach for implementing technology management uniformly between different entities in the same organisation. Although the approach was developed to be implemented for the specific case of the *Alphawave* group, there seems to be no reason why this process could not be replicated for other cases. Furthermore, the individual aspects of the study expand the current scientific knowledge in three ways. The first is through a structured literature review of the available scientific literature. The second is by exploring how a technology audit can be conducted in practice at a diversified SME. Third, the study proposes a conceptual framework to visually map out how different entities, capabilities, products and markets are linked in a diversified organisation.

The inductive and qualitative research process employed in this study seems an effective approach to resolve specific research problems by identifying instruments, relevant to the specific case, from literature and implementing them uniformly in a selection of entities in an organisation. These instruments uncover the relationships between the various entities and how technology is shared within and between the entities to actively pursue markets. This web of relationships can then be mapped out on a technology management framework, which visually provides an overview of the state of technology within the organisation as a whole as well as the individual entities.

Although this process flow was described in Chapter 1 for the specific case of the *Alphawave* group, it can be reworked for application in other situations. A generalised version of the process flow is shown in **Fout! Verwysingsbron nie gevind nie.**. Naturally, each case would have its own objective and thus its own set of research

questions to be resolved. Also, an expansive literature review would not be required for each case. The literature review, in general, would only be required to identify the most relevant instruments to be implemented in the various entities.

The structured literature review of this study contributes to the current body of scientific knowledge by covering a wide range of aspects within the field of technology management. Although the literature review is not an all-encompassing review, it does shed light on how various trends in the field of technology management is developing. It was especially evident that there still is no uniform framework agreed upon to implement technology management in an organisation. Relatedly, a technology framework seems to be developed per organisation and/or case, based on the specific requirements and context of the organisation in question [3], [5], [31], [38], [39].

Although there is no single uniform framework available to implement technology management, there seems to be a definite trend in which the underlying approach is the most prevalent in the scientific literature. The resource-based school of thought was shown to be the most common approach for the application of technology management approach. In especially recent years the *Dynamic Capabilities Theory* has been a common approach to base technology management on. This theory's main consideration is that the different capabilities available within an organisation should be continually and dynamically re-aligned, re-positioned and re-ordered to effectively leverage the organisation's competitive advantage. How effectively an organisation can dynamically manage their capabilities is then considered to be a core competence in itself [3], [5], [7], [39], [40], [51], [56]–[59].

Another contribution of this study is the exploration of how technology management can practically be implemented in a real-world case. In particular, this study explored how a technology audit can be conducted within a group of companies with a complex hierarchical structure and specifically in the South African context. A series of semi-structured interviews were conducted as part of the audits to overcome the difficulty to get the relevant participants together in a single venue (e.g. for a series of

workshops). This limitation is anticipated to be similar for other companies, both in South Africa, as well as the rest of the world.

The final contribution is the development of a conceptual framework to map out how different capabilities of the different entities of an organisation are utilised and aligned to create different products for application in different markets. Although conceptual in nature, the framework was applied to the information obtained during the technology audits and a resulting graphical framework was created for the *Alphawave* group.

This framework has the ability to map the often complex interactions between the different capabilities in an organisation for both the "to-be" and "as-is" state. It serves as both an "at-a-glance" overview of the current state of the organisation and a strategic planning device. Using the framework, the organisation can determine which technological capabilities, products and markets to further pursue, as well as identify which capabilities could be shared between two or more entities to create innovative new products.

The framework was implemented at group level in this study, with the different companies in the group defined as the different entities. Although this framework is effective at group level, it can also be applied to various other levels. For example, it can easily be implemented at the level of one of the companies, with the entities redefined as different departments within the respective companies.

The study has then delivered contributions to the practice of technology management at different levels. The approach followed by the study establishes an inductive and qualitative research process to resolve research questions by identifying relevant instruments from literature and then applying them uniformly to different entities. Other than this inductive and qualitative process, individual aspects of the study also contributed to the scientific body of knowledge. A structured literature review has evaluated both established and recent studies to establish trends in the application of technology management frameworks. Based on this literature review, a technology

audit was conducted at the *Alphawave* group. Finally, and based upon the audit results, a conceptual technology management framework was developed to assist diversified companies to effectively map out and manage their current and future capabilities, products and markets.

6.3 Self-assessment

This study evaluated the most relevant scientific literature and based on this literature conducted a technology audit on the specific case of the *Alphawave* group. There are only limited examples of how technology management structures and processes have been implemented in real-world situations. Therefore, the methodology of the audit process was developed to obtain the maximum amount of information from the limited time available from the different interviewees. The effects of these limitations were restricted by the research process employed by the study and seem to be an effective process to undertake studies of this nature.

Also seen from the literature, unique and specific technology management frameworks are usually developed for specific cases and contexts. The results from the technology audit were then used to develop a framework to specifically assist the *Alphawave* group to combine their technological capabilities and business goals into strategic planning.

Although this study has covered theoretical, practical and conceptual elements of the implementation of technology management, there are limitations to the scope of the study. Each element included in the study was purposely bounded to ensure that its scope would fit within the timeframes of the study.

As mentioned in Chapter 3, the structured literature review is by no means a comprehensive review of all available literature. The intention of the review was to gain an overview of the most relevant topics for implementing technology management frameworks in real-world situations. As such, only one database of literature was queried to gather the list of studies to be included in the study, namely the *Elsevier*

SCOPUS database. The literature review can be greatly expanded by including results from other databases such as *Emerald Insight, ScienceDirect*, etc.

Expanding the literature review beyond the fifty articles included in this study is also possible. By utilising the different terms, themes and principles identified in this study a quantitative study of a larger body of existing literature can be conducted to obtain a more detailed view on the various subjects.

The technology audits could also be expanded in various ways. First, the interviews were conducted at only one level of each company. The audit process could be repeated for other levels (such as department level) to obtain a finer view of how technology is managed.

The audits could be expanded by incorporating regular and expanded workshop sessions into a technology management plan. Further, by including more representatives from the various companies a richer overview of how the different technological capabilities are shared between entities could be obtained. At each workshop, the effectiveness of the technology management plan can be evaluated and thus establishing a long-term assessment of the process within the group.

The conceptual framework's main weakness lies in the fact that it is untested. If it could be possible to regularly and periodically update and review the framework, while simultaneously using it for strategic planning, the validity of the framework can be tested. Not only will this test the value of the framework as a strategic decision-making tool, but also the ease with which the framework can be updated based on changing conditions in the various companies and markets.

Finally, as the scope of the study is limited to only one organisation, the study cannot definitively determine the validity of both the technology audit process and/or the conceptual framework outside of the *Alphawave* context. The scope of the study is intentionally limited to this one case study, but further investigation into the validity outside of this single context is warranted.

The research process of this study seems to have limited the effects of these limitations. Many of these limitations are related to the scale of various aspects of the study and the research process would undoubtedly be suitable to be reused again to further the study at a larger scale. Also, it seems reasonable that this process could be utilised in other studies of a similar nature.

Regardless of the limited scope of this study, it was still able to explore areas that had not been adequately documented in the scientific literature before. Particularly with regard to the practical implementation of technology management principles in real-world situations, this study has attempted to develop a process of how technology management can be implemented, by exploring a real-world case. Specifically, the study has focussed on the case of a group of companies assembled in a complex hierarchical structure.

6.4 Recommendations

This study concerns itself with both the case of implementing technology management at a particular organisation, as well as the state of technology management in general. Therefore, recommendations are made for both the *Alphawave* group of companies as well as for future studies in the field of technology management.

The recommendations for the *Alphawave* group will focus on how to implement and continually update and utilise the information captured in the conceptual framework. It is hoped that implementing this and perhaps other technology management principles and processes in the operations of the group, that the group will be able to maintain and expand its competitive advantage.

The recommendations for future studies will focus on how the principles, methods and models developed during this study can be further expanded, implemented and validated in other cases and contexts.

6.4.1 For the Alphawave Group

The technology audit of the four companies forming the core of the *Alphawave* group at the time of the study indicated that the group has a diverse and sophisticated

technology portfolio. That said, certain entities within the group have struggled at times to efficiently take their products to market.

If the softer, non-technical capabilities of, for example, sales and marketing of *Honeybee*, can be developed into scalable and transferable competencies, they can be re-applied in other companies. These 'softer' capabilities can then be used to ensure that the 'harder' technical capabilities are more effectively aligned with their respective markets with products that reach their intended consumers. This could apply to other capabilities as well and with the use of the developed conceptual framework more capabilities can be shared between the different companies.

From discussions with the various representatives, it seems as if the innovation process currently in place at *Alphawave* is mostly reactive in nature. In particular, it seems as if most new ideas are generated externally from the various companies, but with the different companies being able to quickly and efficiently realign themselves to take advantage of the opportunity. This method has been successful for the group in the past and proves that the group is quick to react to opportunities that cross their path.

From the principles of technology management, it seems as if even more opportunities might be made available if the group were to even more proactively develop and align its capabilities to create opportunities in existing or new markets. By proactively developing technologies to satisfy forecasted market needs, the group can more effectively balance the technology push and market pull pressures of its environment. By setting specific technological targets, they can develop and/or acquire the required capabilities to meet their business goals.

The *Alphawave* group has a history of innovation, however, it seems as if the innovation is increasingly vested at director level in the company. Formalising the innovation process at different levels of the different companies might be beneficial to identify potential future capabilities to develop, products to create and likely risks to the various companies' business markets. Implementing a system similar to the *ExCo* structure of *Honeybee* at each company could be one way to solicit technical knowledge

of possible threats and opportunities from the role-players who are most knowledgeable in their specific technical fields.

Regardless of all else, the *Alphawave* group of companies has proven time and again that they are a successful group of companies. They are clearly able to effectively take advantage of most opportunities that present themselves. It does, however, seem that an even more proactive strategy for developing technologies and exploiting new markets could see the group leveraging their competitive advantage even further in new innovative ways.

6.4.2 For Future Studies

Due to the limits imposed on the scope of this study, there are various elements of this study that can be expanded on in future studies. By applying the results of this study to a wider range of cases, the results can be revised and/or generalised for a larger body of work. The research process, especially, employed during this study seems a fitting method for further investigation into technology management in other, yet similar, cases.

As mentioned previously in this section, the size of the literature review can be increased in two ways. First, by including more articles than the fifty articles included in the analysis for this study even finer trends can be seen in the different keywords and principles already realised from the analysis performed in this study. In particular, a quantitative analysis of the entire body of available scientific knowledge would be valuable to determine the exact extent of the leading principles of technology management, as well as potential uncovering additional principles within the literature.

The search for relevant articles for inclusion into the literature review can be widened to include more sources of scientific literature, such as *Emerald Insight*, *ScienceDirect*, or any of the other available repositories. Also, more keyword searches can be performed to attempt to include an even wider range of relevant articles into the analysis. By including a larger number of studies from an increasingly wider range of

sources, more definition can be given to the results of the literature review and show even clearer trends evident in the field of technology management.

Other than just expanding on the results of the literature review and analysis, the actual methods and findings of this study can also be tested further in a larger number of cases. The methods developed to conduct the technology audit was specifically developed to obtain the required information from role-players in the *Alphawave* group. That said, it is not expected that these methods would only be applicable to this particular case. If similar audits can be conductive in other organisations, improvements can be made to the methods to better determine the current state of technology management in any company.

One of the reasons why the *Alphawave* group was identified as an ideal candidate for this study, was due to the fact that it is an SME within the developing economy of South Africa. Future studies can investigate the validity of these methods in both the South African and other contexts. Also, the efficiency of these methods can be tested at other types of organisations that might not yet have the complex hierarchical structure of the *Alphawave* group but plans to diversify its technology base.

Similarly, the conceptual framework should be tested in more cases to determine whether its principles and operations can be applied to other cases and contexts. Again, it was developed with the *Alphawave* group specifically in mind and it would be interesting to investigate whether the principles in the current form would be transferable to another organisation.

There seem to be limitations in the body of scientific knowledge of technology management for a number of areas touched upon in this study. The concept of technology management seems to be a valuable tool that can assist many SMEs to ensure their survival in an increasingly volatile, international environment. In particular, studies exploring how technology management principles can be implemented in real-world situations are very limited [7], [49], [50].

Although an increasing number of recent studies have investigated the role of technologies in developing countries, there seems to be even more scope to continue these investigations. There have been indications that technology management might play a crucial role in developing not just companies in developing economies, but entire countries. The principle of sharing technology through technology transfers could be applicable to more than just commercial partners, but can potentially be applied to developing technology development strategies of government as well [7], [47].

The South African context is also an important context to explore further. Very few studies have delved into how companies, especially SMEs, in South Africa can employ technology management to innovate and become more competitive in global markets. Perhaps a framework to assist, specifically, SMEs in the South African context to implement practical and actionable technology and innovation management systems, would be a useful addition to the South African industry.

The research process developed during this study shows promise as a repeatable method to consistently evaluate technology management in, especially, subsidiaries organised in complex hierarchies as part of a larger group. Replicating this process in other cases would simultaneously test the validity of the process and the constituent parts, while also providing a structured process to conduct the investigations. It is anticipated that the type of diversified organisation, as was investigated during this study, is not uncommon and that this process would benefit both other organisations and the field of technology management as a whole. Utilising this process to guide the implementation of technology management structures into other organisations should enhance the ability of the organisations to effectively leverage their technology. Also, it should expand the body of knowledge exploring the implications of the practical implementation of technology management.

Further study in the theoretical, practical and conceptual aspects of this study is not just possible, but in fact desirable. These studies would not just attempt the validity of the results of this study, but also attempt to test and refine the implementation of

the methods and tools in this study in an ever-wider range of companies in various different contexts and environments.

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ADDENDUM A –

ANALYSIS MATRICES OF STRUCTURED LITERATURE REVIEW

A.1 Analysis Matrices for Technology Management Framework Area of Investigation

Table A-1: Analysis matrix of references to different technology management frameworks in studies reviewed

Topic		Classification	30 Most Cited Studies																												20 Recent Most Relevant Studies																						
		Index / Element	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Frameworks	-	No specific framework																													x																				
	1	World Class Manufacturing Framework	x																																																
	2	Model to Articulate resource flows in Project Based Firms		x																																														
	3	A Revised Framework for Technology Acceptance by Individual Professionals			x																																													
	4	Strategic Alignment Model (SAM)				x														x																															
	5	Unified Framework (Update of SAM)				x																																												
	6	Framework for using patents in TM					x																																											
	7	Framework to identify and assess M&A based on patent information					x																																											
	8	Conceptual framework to illustrate impact of flexible manufacturing on capability and customer satisfaction						x																																										
	9	Integrated perspective for environmental operations management							x																																									
	10	Strategic Supplier Typology								x																																								
	11	Task/Technology Fit Research Framework									x																																							
	12	Prescriptive S-Curve Strategy										x																																						
	13	Extended framework of triggers and key											x																																					
	14	Advanced front-end innovation approach											x																																					
	15	Four-dimensional typology of business models												x																																				

Table A-1: Analysis matrix of references to different technology management frameworks in studies reviewed (continued)

Topic		Classification	30 Most Cited Studies																												20 Recent Most Relevant Studies																				
		Index / Element	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Frameworks	16	Balanced Business Scorecard	x																																															
	17	Sustainable development framework													x																																			
	18	Strategic Alignment Process														x																																	
	19	Extended Strategic Alignment Model															x																																	
	20	A Technology Management Process Framework																x																																
	21	Conceptual framework and intervention process that helps firms devise and implement an effective IT management architecture																	x																															
	22	Phaal et al.'s Technology management framework																			x																													
	23	T-Plan																				x																											
	24	Integrated Planning (IPL) Model																					x																										
	25	Product Technology Framework																						x																								
	26	Real Option Theory																							x																							
	27	Framework to relate business level strategy, manufacturing strategy and business unit performance																								x																						
	28	The Knowledge Spiral																									x																					
	29	Framework for measuring product development performance																										x																				
	30	Conceptual framework of external technology integration project performance																											x																				

Table A-1: Analysis matrix of references to different technology management frameworks in studies reviewed (continued)

Topic		Classification	30 Most Cited Studies																														20 Recent Most Relevant Studies																				
		Index / Element	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Frameworks	31	SECI Model																												x																					
	32	S-Curve Model of Architectural Innovation																											x																					
	33	Unnamed Framework																													x																				
	34	Cox proportional hazard model with time-varying covariates																														x																			
	35	Conceptual framework for CTS and paths of its alignment with CS																															x																		
	36	Patent Portfolio Value Analysis																																x																	
	37	Fuzzy Assessment Framework																																	x																
	38	A Real Options Methodology for R&D																																		x															
	39	Alignment Model																																			x														
	40	Framework of knowledge repositories																																				x													
	41	Problem-driven innovation to support technological development and																																					x												
	42	Conceptualisation of 'innovation spaces'																																						x											
	43	Conceptual Strategy Elements of Technology Platforms Model																																							x										
	44	TOGAF (The Open Group Architecture Framework)																																								x									
	45	Technology Strategy Framework																																									x								

Table A-1: Analysis matrix of references to different technology management frameworks in studies reviewed (continued)

Topic	Classification		30 Most Cited Studies																												20 Recent Most Relevant Studies																				
		Index / Element	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Frameworks	46	Schuh's Technology Management Framework																																																	
	47	Extended and reflective strategy-to-technology connection																x																																
	48	Framework on the relationship between TQM, TM and Sustainable Performance.																	x																															
	49	Framework for the Description of Technology Platform Strategies in Diversified Companies																		x																														
	50	Technology Selection Framework																																																x

Table A-2: Analysis matrix of references to technology management framework features in studies reviewed

Topic	Classification	30 Most Cited Studies																													
	Index / Element	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30
Framework Features	Conceptual		x	x		x	x	x	x	x		x	x		x					x		x	x	x	x	x	x	x		x	x
	Qualitative		x	x	x					x	x	x	x			x	x	x	x	x	x	x	x		x	x	x	x		x	x
	Quantitative				x	x			x	x	x			x	x	x					x			x							x
	Graphical Model		x	x	x		x		x		x	x		x			x		x	x		x	x		x	x	x	x		x	x
	Practical Decision Support				x	x					x	x		x		x	x		x	x	x	x	x			x		x		x	x
	Controlling System																														
	Manufacturing Focused	x					x		x								x				x	x			x						
	IT Focused				x									x		x		x	x							x			x	x	
	High-Tech Focused																										x				
	SME Focus								x																						
	Single Business Unit Applications	x							x		x														x						x
	Multiple Business Unit Applications		x															x													
	Flexible Application (e.g. Different Size, Contexts)										x					x				x	x										x
	Developing Country Based																														

Topic	Classification	20 Recent Most Relevant Studies																			
	Index / Element	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Framework Features	Conceptual	X	x	x		x	x	x	x	x	x	x	x		x	x	x	x	x	x	
	Qualitative	X		x		x			x	x	x	x	x		x		x	x	x		
	Quantitative		x			x	x	x												x	
	Graphical Model			x		x	x	x	x		x			x	x	x	x		x		
	Practical Decision Support		x		x	x	x	x	x		x									x	
	Controlling System															x					
	Manufacturing Focused																			x	
	IT Focused													x							
	High-Tech Focused	x						x													
	SME Focus		x																		
	Single Business Unit Applications																				
	Multiple Business Unit Applications			x					x	x			x		x			x	x		
	Flexible Application (e.g. Different Size, Contexts)						x	x	x						x						
	Developing Country Based			x											x			x		x	

Table A-3: Analysis matrix of references to technology management framework development in studies reviewed

Topic: Framework Development	Classification: 30 Most Cited Studies						20 Recent Most Relevant Studies					
Element \ Index	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6
Large Scale Survey			X			X	X	X				
Case Study		X		X	X				X		X	X
Workshopped												
Interviews		X							X			X
Focus Groups												

Topic: Framework Development	Classification: 30 Most Cited Studies												20 Recent Most Relevant Studies											
Element \ Index	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30
Large Scale Survey		X							X	X		X			X			X		X	X			
Case Study			X	X	X			X	X		X		X	X					X				X	X
Workshopped	X													X										
Interviews				X	X							X												X
Focus Groups																								

Topic: Framework Development	20 Recent Most Relevant Studies														
Element \ Index	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Large Scale Survey		X									X			
Case Study	X	X		X			X			X				
Workshopped								X					X	
Interviews		X								X				
Focus Groups		X												

Table A-4: Analysis matrix of references to technology management framework validation techniques in studies reviewed

Topic	Classification	30 Most Cited Studies																													20 Recent Most Relevant Studies																			
Framework Validation Techniques	Element / Index	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
	No validation techniques disclosed		X		X	X		X		X		X	X	X			X	X	X	X	X		X	X		X			X	X				X	X												X	X	X
	Cronbach's Alpha	X		X			X																					X																				X		X
	Card Sorting Pre-Tests			X																																														
	Pre-Test Survey			X			X																																											
	Factor Analysis	X		X			X		X																		X		X																			X		
	Hammon's One-factor Test			X																								X																						
	Q-Sort						X																																											
	Corrected Item - Total Correlation						X																																											
	Correlation Analysis	X							X																	X			X																					
	Analysis of Variance							X																																										
	Regression Analysis										X															X			X																					
	Delphi														X																																			
	Neural Networks															X																																		
	Two Tailed f-tests																		X																														

Table A-4: Analysis matrix of references to technology management framework validation techniques in studies reviewed (continued)

Topic	Classification	30 Most Cited Studies																														20 Recent Most Relevant Studies																						
Framework Validation Techniques	Element \ Index	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
	t-Tests																				X												X																			
	Logit																							X																												
	Inter-rater Agreement																									X																									
	Chi-square tests																											X				X																			
	Tucker-Lewis index [TLI]																															X																			
	Root Mean Square Error																															X																			
	Comparative Fit Index [CFI]																															X																			
	Stress Test																																X																		
	Construct Validity																																	X																		
	Reliability																																		X																	
	External Validity																																			X																
	Internal Validity																																				X															
	Consensus Measurement																																					X														
	Nominal Group Technique																																						X													

A.2 Analysis matrices for technology management framework area of investigation

Table A-5: Analysis matrix of references to different technology management tools in studies reviewed

Topic		Classification	30 Most Cited Studies																													20 Recent Most Relevant Studies																				
		Index / Element	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Tools	-	No Tool Covered	x							x				x		x				x													x	x																
	1	Measurement for Quality Measurement	x																																																
	2	Self-developed framework to determine the state of alignment within the firm				x																																												
	3	Patent Portfolio Method					x											x																																
	4	Inventor Portfolio					x																																											
	5	Market Share/Growth Matrix					x																																											
	6	Reliable instruments to measure manufacturing flexibility						x																																										
	7	Focus Group Technique							x																																									
	8	S-Curves										x																																						
	9	Classification of technology, R&D and innovation management											x																																					
	10	Standardised stages of corporate innovation process											x																																					
	11	Idea tunnel											x																																					
	12	New concept development model											x																																					
	13	Boeddrich's front end model proposal											x																																					
	14	Integrated front-end model of Sandmeier et al.											x																																					
	15	Cause and Effect Scheme													x																																			
	16	Structure for Corporate Information															x																																	

Table A-5: Analysis matrix of references to different technology management tools in studies reviewed (continued)

Topic		Classification	30 Most Cited Studies																														20 Recent Most Relevant Studies																				
		Element / Index	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Tools	17	The Information Pyramid		x													x																																				
	18	Corporate Map		x													x																																				
	19	Horizontal requirements indicator																	x																																		
	20	Technology management activities model																			x																																
	21	Portfolio Matrix																				x																															
	22	Organisation technology index																					x																														
	23	Technological Monitoring Tool																					x																														
	24	Matrix view of effective external technology integration																											x																								
	25	Technology Development Envelope (TDE)																																		x																		
	26	Hierarchical Decision Model (HDM)																																		x																		
	27	Fuzzy Likert Scales																																							x													
	28	The Market-Product Matrix																																								x												
	29	Taguchi's Robust Design Method																																								x												
	30	Technology Strategy Matrix																																									x											
	31	Cybernetic model of controlling technology management																																																			x	
	32	Fuzzy TOPSIS																																																			x	
	33	The Classification Model																																																			x

Table A-6: Analysis matrix of references to features, validation and application of technology management tools in studies reviewed

Topic	Classification	30 Most Cited Studies																												20 Recent Most Relevant Studies																				
	Element / Index	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Tool Features	Conceptual	x			x															x								x																				
	Quantitative	x			x	x	x				x					x				x	x							x						x	x												x
	Qualitative				x			x				x		x		x		x		x	x							x						x	x											x
	Graphical Results				x	x					x			x		x		x		x	x							x						x	x											x
	Matrix Based				x															x								x																			x
Tool Validation / Applications	Large Scale Survey Performed	x					x																																									
	Case Study Tested				x						x			x							x							x																			
	Expert Panel																																		x													
	Empirically Validated	x			x	x					x																																					
	Real-world Implemented					x		x						x		x		x		x	x							x						x	x											x

A.3 Analysis Matrices for Technology Management Principles Area of Investigation

Table A-7: Analysis matrix of theoretical approaches of technology management as identified in the studies reviewed

Topic	Classification	30 Most Cited Studies																													
	Element \ Index	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30
Theoretical Approaches	Positioning School																														
	Resource-based Approach/View		x																						x				x		
	Knowledge based Approach/View																												x		
	Dynamic Capabilities Theory																x			x											
	Real Options Analysis (ROA)																														
	Organisational information processing theory (OIPT)																											x			
	Absorptive Capacity Theory																														
	Cybernetic Approach																														
	Technology Acceptance Model (TAM)			x																											
	Theory of Planned Behaviour (TPB)			x																											
	Total Quality Management																														

Topic	Classification	20 Recent Most Relevant Studies																			
	Element \ Index	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Theoretical Approaches	Positioning School																				x
	Resource-based Approach/View						x	x	x	x					x	x					x
	Knowledge based Approach/View									x		x									
	Dynamic Capabilities Theory	x		x			x		x		x	x		x							x
	Real Options Analysis (ROA)							x													
	Organisational information processing theory (OIPT)																				
	Absorptive Capacity Theory														x					x	
	Cybernetic Approach															x					
	Technology Acceptance Model (TAM)																				
	Theory of Planned Behaviour (TPB)																				
	Total Quality Management																	x			

Table A-8: Analysis matrix of technology management themes mentioned in the studies reviewed

Topic	Classification	30 Most Cited Studies																													20 Recent Most Relevant Studies																			
Technology Management Themes	Element / Index	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
	Requirement for Consensus in TM Field				x												x			x																												
	Requirement of Methods for Practical Implementation of TM																			x														x															
	TM Facilitates Communication		x		x									x		x	x	x			x																												
	Technology and Business Alignment		x		x									x		x	x	x	x	x	x	x			x																							
	Technology Audits/Competence Identification																																															
	Market Pull/Technology Push Balance																			x	x				x						x																
	Technology Platforms																					x																										
	Technology Supply Chain																						x																								
	Technology Fit																					x	x					x																			
	Technology Uncertainty																					x	x					x																			
	Technology Integration																											x							x												
	Technology Roadmapping																																			x												
	Technology Selection/Transfer/Diffusion																	x				x	x					x									x										
	Technology Acceptance			x						x																																						
	Technology Forecasting																																															
	Linkage with Soft Business Functions (E.g. Sales, HR., Finance, Marketing etc)					x											x			x		x						x																			
	Technology Followers (Catchup)																																	x													x	
	Importance of Technology Transfer for Developing Countries																																															x

Table A-9: Analysis matrix of organisational traits associated with technology management in the studies reviewed

Topic	Classification	Index / Element	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Organisational Traits		Top/Central Management Involvement	x	x		x							x		x		x			x			x							x					x				x	x								
		Employee Engagement in Entire Process																												x						x												
		Organisational Learning				x											x	x			x		x	x			x			x								x	x	x								
		Continuous Improvement	x									x																			x																	
		Advanced Manufacturing Technologies								x							x						x			x																						
		Importance of Communication						x					x		x		x	x						x															x									
		Pro-active preferred over reactive				x																										x						x										
		Interorganisational Interaction																						x			x																					
		Supplier collaboration								x													x																									
		"If you can measure it, you can manage it"													x								x																									
		Cadence/Rhythm of Business																															x															
		Strategic Alliances																																													x		
		Organisational Sustainability																																														x

Table A-10: Analysis matrix of other management themes associated with technology management in the studies reviewed

Topic	Classification	30 Most Cited Studies																													20 Recent Most Relevant Studies										
	Element / Index	Overall Top 30 - 1	Overall Top 30 - 2	Overall Top 30 - 3	Overall Top 30 - 4	Overall Top 30 - 5	Overall Top 30 - 6	Overall Top 30 - 7	Overall Top 30 - 8	Overall Top 30 - 9	Overall Top 30 - 10	Overall Top 30 - 11	Overall Top 30 - 12	Overall Top 30 - 13	Overall Top 30 - 14	Overall Top 30 - 15	Overall Top 30 - 16	Overall Top 30 - 17	Overall Top 30 - 18	Overall Top 30 - 19	Overall Top 30 - 20	Overall Top 30 - 21	Overall Top 30 - 22	Overall Top 30 - 23	Overall Top 30 - 24	Overall Top 30 - 25	Overall Top 30 - 26	Overall Top 30 - 27	Overall Top 30 - 28	Overall Top 30 - 29	Overall Top 30 - 30	Recent Top 20 - 1	Recent Top 20 - 2	Recent Top 20 - 3	Recent Top 20 - 4	Recent Top 20 - 5	Recent Top 20 - 6	Recent Top 20 - 7	Recent Top 20 - 8	Recent Top 20 - 9	Recent Top 20 - 10	Recent Top 20 - 11	Recent Top 20 - 12	Recent Top 20 - 13	Recent Top 20 - 14	Recent Top 20 - 15	Recent Top 20 - 16	Recent Top 20 - 17	Recent Top 20 - 18	Recent Top 20 - 19	Recent Top 20 - 20
Organisational Traits	Strategic Alignment				x											x			x																	x								
	Knowledge Management/Transfer		x			x			x							x	x	x		x			x	x		x									x				x				x	
	Knowledge Networks																														x								x				x	
	Innovation Management		x								x	x				x	x			x			x							x									x	x				
	Front-End of Innovation (FEI)											x																																	
	Open Innovation												x																												x					
	Supply Chain Management																						x																					
	Supply Chain Interaction																																							x	x				
	Research and Development Management																																									x				
	IP Management					x																																								
	Patent Portfolios																																													
	Flexible Manufacturing					x																																								
	Flexible Value Chain																																													
	Business Models																																													
	Decision Making																																													
	Controlling System																																													

ADDENDUM B –

TECHNOLOGY MANAGEMENT ANALYSIS REPORTS

B.1 Technology Management Analysis Report of EMSS Antennas

TECHNOLOGY MANAGEMENT ANALYSIS

OF

EMSS ANTENNAS

(PART OF THE ALPHAWAVE TECHNOLOGY GROUP)

“A Glimmer of Greatness”

Author: Christo Visser

Edited by: LJ du Toit and Dawid Botha

Introduction

This report is intended as a summary of the status of technology management within EMSS Antennas post 2006[5]. The manner in which technological capabilities are identified, managed and exploited within EMSS Antennas and also how technology capabilities are shared between EMSS Antennas and other entities of the newly created Alphawave group.

The information contained within this report is based on an interview conducted by the author and L.J. du Toit and Dawid Botha. L.J. was the managing director of EMSS Antennas until the end of 2016. Dawid is the current managing director of EMSS Antennas.

EMSS Antennas Business Environment

The environment in which EMSS Antennas finds itself is borderline precarious. The company is a specialised antenna development company within an academic field. Their clients and partners are academic institutions and government departments, which often does not understand the intricacies of businesses and the pressures of the bottom-line.

EMSS Antennas is a world class player in the radio astronomy industry, but it is an industry with very little room for growth. Due to the nature of the industry, where slow and expensive iterative product development is the norm, EMSS Antennas is a slow-moving company with an almost obsessive level of attention to detail. This level of attention was the only way to be successful within the radio astronomy industry, but also means that EMSS Antennas is too slow to really be competitive in other industries and markets.

EMSS Antennas is actively looking for new environments to do business in. It would be an understatement to merely note that the company is merely looking for new markets. The entire manner in which the company does business needs to evolve to be successful in other, completely different markets.

As part of the overall drive by EMSS Antennas to build its business opportunities in other environments and markets, the entire management structure has been restructured. Dawid Botha, who had successfully managed the largest project in the company for years, has been appointed as managing director of the company. He will now apply the skillset he development for running a large and complex project on running the company.

Since the task of running of the company has been taken away from LJ du Toit and the other directors, they are in the position where they can explore other environments and markets for EMSS Antennas to do business in. Using LJ du Toit as an example, he now has more time to connect with his large professional network and attempt to find new opportunities for EMSS Antennas.

EMSS Antennas Product Innovation Process

EMSS Antennas are very skilled at generating new and exciting ideas. However, they have had only limited success in translating ideas into successful products. Only one of their three main product lines was identified internally. The other innovations came either from clients or partners within the larger Alphawave group.

[5] Before 2006, EMSS Antennas was effectively in a "subsistence farming" mode.

The main project and product of EMSS Antennas is the radio astronomy (L- and UHF band) cryogenic receivers for the MeerKAT project (a pilot project of the larger SKA project). EMSS Antennas was the only company approached by Prof. Justin Jonas of the SKA-SA who had the appropriate skills and were willing to commit to develop and produce the receivers to the required specifications.

A second and already mature product that EMSS Antennas played a major part in was the fieldSense personal RF safety monitor. This product was the result of a joint venture of EMSS Antennas and EMSS Consulting (now Alphawave Mobile Network Services). Consulting had identified the need for a personal RF safety monitor and approached EMSS Antennas to help develop and produce the first version of the product. EMSS Antennas also helped to develop the second version of the product, though no longer involved with the production of the fieldSense. Although no longer part of the fieldSense production, EMSS Antennas still receive royalties from sales of fieldSense units. If any further development, specifically sensor development, is required on new versions of the fieldSense, it will probably fall back to the original EMSS Antennas team.

A new product that EMSS Antennas has been developing over the last number years is X-Range, a golf ball radar tracking system. The product development started as side project to utilise resources that were freed up as MeerKAT development tapered off. The system has evolved through various different versions over the years, but started as an exercise to see what EMSS can do if they focus on an application outside of continuous wave applications. Radar products per se had the potential to still be developed into various different markets and products. With the assistance of So-Zo labs (another company in the Alphawave group) the three-dimensional modelling of the golf balls' tracked path helped to promote the system to potential early investors.

The development history of these products clearly shows the limited success of EMSS Antennas in delivering their innovative ideas to new markets. They are however very adept at constantly developing and producing very high-quality products, as well as solving difficult problems within the development cycle of the products.

Core Competencies of EMSS Antennas

The core competencies of EMSS Antennas can be well summarised by two statements made by the respective directors. Dawid Botha stated that the success of EMSS Antennas was made possible by *"a handful of exceptionally skilled people, combined with a team who are committed to enable the exceptionally skilled people's ideas and work to become reality."* LJ du Toit, on his part, summarised EMSS Antennas' commitment to quality as: *"If you pay us enough we will create the greatest thing in the world."*

The company culture within EMSS Antennas then seems to play a crucial role in the success of the company. This culture was established while the company was small in size and was maintained while the company expanded. This culture drives the staff to motivate themselves internally to continually deliver the best work possible. This leads to a culture of teamwork, dedication and pride in each staff member's work. This culture, although not easily measurable, should be seen as one of the core competencies within EMSS Antennas. It is not a technical competency, but still a competency that will enable other competencies to be exploited fully.

The core competencies and capabilities identified by the directors are listed below, along with an evaluation of each competency's relative standing:

- Radio Astronomy (best in the known universe)
- Reputation and credibility of products (world class)
- Production (up amongst the best in SA – but very specialised and for now limited capacity)
- Specialised Test Procedures (world class – but very specialised)
- RF Electronics (at the top end of SA capabilities)
- Radar (close to the top end of world capabilities))
- Signal and data processing (close to the top end of world capabilities)
- Software (in the middle of world capabilities)

It should be noted that most of the above capabilities are not widely spread and most reside in only a few individuals in the company.

In addition to the core competencies and capabilities identified by the directors of EMSS Antennas, another capability can be identified. To paraphrase LJ du Toit, none of the individual components in the receivers of the MeerKAT are massive improvements of previously available components. Rather each component was improved a little to specifically benefit the overall system. Although the individual parts weren't ground breaking, the final system was. This seems to indicate that EMSS Antennas has significant system design capabilities, especially to ensure that separate parts are optimised for the specific goal of the system as a whole.

Technology Analysis of EMSS Antennas

See below a Technology Balance Sheet of how the different capabilities of EMSS Antennas are currently utilised to create products for their existing markets. Black crosses indicate the current situation. Red crosses indicate new expansions currently being implemented. Black circles indicate old applications.

Yellow shaded chains indicate avenues being explored by EMSS Antennas to insert new revenue streams by developing products and systems for other companies/partners. The green shaded chain indicates the ideal future revenue stream, where EMSS Antennas uses its own technology to develop and produce its own products for its own markets.

Legend:	
o	Old
x	Current - In Place
x	Current - In Progress
w	Wishlist

TECHNOLOGIES										MARKETS	PRODUCTS									
EMI/EMC/RFI Skills	Antenna Design	Test Procedures	ISO 9001 Standards	RF Electronics	Radar	In-time signal processing	Data processing	Cryogenic Cooling	Software Design		MeerKat Receivers	SKA Receivers	X-Range	fieldSense	Product Zeta	Control Module for UAV	Explosive Rope	Somebody else's produc	Somebody else's proble	Own Future Products
										Radio Astronomy	x	x								
										Interplanetary Comms and Radar					w					
										Electronics in Sport			x							
										EMF Safety				x						
										Somebody else's market						x	x	w		
										Somebody else's solution									w	
										Own Future Markets										w
										PROCESSES										
x	x	x		x	w	w	w			Product Development	o	x	x	o	w					w
x	x	x		x	x	x	x	x	x	System Development	o	x	x		w				w	w
x		x	x						x	Production Capability	x	w		o	w	x	x	w	w	w
		x								Implementation (Set-to-work)	x	w			w					w

Various potential future ventures are included. Three ventures (two being implemented and one potential future venture) are included for companies to make use of EMSS Antennas production capacity. The products of these companies, much like the products of EMSS Antennas, are very specialised and intricate.

Another potential future venture is based on previous successes by EMSS Antennas with regard to system development. As EMSS Antennas do not have much experience in entering new markets, EMSS Antennas could assist companies and/or partners who have already identified products and suitable markets, but do not have the capabilities to develop an entire system or produce the products. EMSS Antennas can then use their system development and production capabilities to create high quality products and systems, without much of the risk of entering unknown markets. They can then solve problems identified by another entity, which that entity can then take to market.

Lastly, a potential future venture (labelled *Product Zeta*) is included for the Interplanetary Comms and Radar market. This venture will be similar to the current MeerKAT and upcoming SKA projects, only in a different market.

The corporate culture and exceptional skill vested in the company should enable EMSS Antennas to build the same reputation it has in radio astronomy in another market, if only given the opportunity and the existence of a willing and educated customer to do so.

Conclusion

EMSS Antennas finds themselves in a difficult situation. Limited resources to serve current contracts, while at the same time trying to insert new revenue streams are putting the company under significant pressure. This said, the corporate culture and exceptional capabilities of the company has ensured that EMSS Antennas is a well-respected technical company across the world.

EMSS Antennas realises that they are at a critical point in their existence. The restructuring which has taken place is a strong move to get the company back on track. They are actively trying to find new ways in which to exploit their considerable capabilities in new and unknown industries and markets.

By building on their strengths; system development, corporate culture, exceptionally skilled experts and well-deserved reputation, they can still exploit the glimmer of greatness that is clearly still embedded in the company's foundations.

B.2 Technology Management Analysis Report of ETSE Electronics

TECHNOLOGY MANAGEMENT ANALYSIS

OF

ETSE ELECTRONICS

(PART OF THE ALPHAWAVE TECHNOLOGY GROUP)

"Abundance of capabilities. Limited opportunities."

Author: Christo Visser

Edited by: Johann de Swardt

Introduction

This report is intended as a summary of the status of technology management within ETSE Electronics. This report will explore the manner in which technological capabilities are identified, managed and exploited within ETSE Electronics is and also how technology capabilities are shared between ETSE Electronics and other entities of the newly created Alphawave group.

The information contained within this report is based on an interview conducted by the author and Johann de Swardt. Johann is the founder and managing director of ETSE Electronics.

ETSE Business Environment

ETSE Electronics has been around for 20 years. The company was founded by Johann de Swardt and a final year student of his at the time. ETSE was founded with no specific corporate goals or strategies in mind. The idea was to take on projects as they came along and see where they lead to.

Over the years ETSE has completed close to two hundred different projects. These projects ranged in scale from small single device projects for individual clients to large multi-faceted projects for various different organisations and companies over a wide range of industries.

In 2014 the environment in which ETSE operated changed dramatically. The Alphawave group (via Alchemy-A at the time) purchased a 50% stake in ETSE, with the understanding that ETSE would shift focus to product development rather than project based operations. After evaluating all the current and past projects, two product lines were chosen to be pursued further, as well as one additional project which will remain active.

The two identified product lines are Farmtrack and Farmranger. Both of these were already established products with existing clients which could be expanded on. The last remaining project is the design and production of the CPUT CubeSat project which will continue under ETSE Space.

Although ETSE has worked in a wide range of industries and with an even wider range of technologies, the current products are both aimed at the agricultural sector and based largely on ETSE's electronic design capabilities.

Product Innovation Process

The majority of ETSE innovation has taken place at component and system level and ETSE does not have a lot of experience at innovating at a product or corporate level. As such ETSE is very good at coming up with innovative technical solutions for problems that are brought to them, but not at searching for new problems which can be solved with its own established technological capabilities. ETSE has not in the past had corporate strategies to target specific markets or industries, but rather entered markets and industries as clients contacted them for solutions for technical problems.

Although there was no formal innovation structure, there is a culture of exploring new technologies before they are required for a specific project. A big part of this culture is the concept of "Personal Jobs" which allowed employees to spend time on learning how new technology works and how it can be used to solve practical problems. Bluetooth capabilities, for example, were explored in this manner. When a project then needs the new technology, someone already has the knowledge to implement it and can share the knowledge with other employees of ETSE.

Sharing knowledge between employees is facilitated by numerous different factors. While the relative small number of employees and shared work areas make the sharing of ideas easier than at larger

organisations, weekly meetings with the entire team also ensured that everyone had an idea of what everyone was working on. Through these meetings employees could state which technical hurdles they are facing and solutions could be suggested by the other team members.

Regardless of all the internal innovation taking place, very little was done to explore new markets or clients. Finding innovative problems to solve was never part of ETSE's corporate strategy. New markets and/or clients came mainly through referrals out of their engineering network and former clients.

Core Competencies of ETSE Electronics

Although ETSE has an abundance of technological capabilities, at the core the most important of these are RF and Microwave design, as well as electronics design (such as embedded, FPGA, PCB's, GPS, GSM, etc.). Throughout ETSE's history the focus had been on hardware design, with very little emphasis on software design other than embedded software.

The product lines which ETSE will continue to pursue will mainly rely on their electronic design capabilities. Both the Farmtrack and Farmranger use electronic systems to interpret measured inputs from various sensors and transfers it to a backend system for further processing. Both of these product's systems are already well established, but can still be improved upon in the future.

The capabilities that has been developed in RF and microwave design field is vast. ETSE has in the past been involved with various projects of various scales, ranging from two-way radio systems to satellite ground systems. They had, in the past, designed various components (LNA's, filters, mixers, etc) as well as modules (receivers, transmitters, etc) over a frequency range of 50 MHz to 24 GHz. Except for the CPUT Cubesat project, ETSE's RF and microwave design capabilities are not be utilised in any of the active product lines.

Other than the hard-technical capabilities of electronic and RF/Microwave design, ETSE has developed the ability to derive technical specifications from vague user specifications. They are especially adept at expressing ideas in terms of electronic systems. This capability enables them to effectively translate ideas from a potential non-technical client into a workable electronic system that can meet the client's needs. This skill will, understandably, be underutilised as both the existing product lines has for the most part already been through this process already. However, this capability can prove to be invaluable for any future products or projects which might be developed.

Two of ETSE's largest shortcomings has partly been addressed with the merger with EMSS/Alphawave. ETSE had limited experience with application software design and development. The Alphawave software development team have throughout the years developed software capabilities that can be applied to numerous different platforms and architectures. Also, in the past ETSE used a very informal financial system, with almost all of the financial management being performed by the managing director. With the help of the software development team, the Alphawave financial team has assumed responsibility of the day-to-day finances of ETSE and also recordkeeping and capturing of client information.

Technology Analysis of ETSE Electronics

See below a Technology Balance Sheet of how the different capabilities of ETSE Electronics are currently utilised to create products for their existing markets. Black crosses indicate the current situation. Black circles indicate old capabilities and markets which, though available in ETSE, is not

Legend	
o	Old
x	In place
N	New Technology

TECHNOLOGY										MARKETS	PRODUCTS			
RF and Microwave Systems	RF and Microwave Components	Digital Electronics	Analog Electronics	PCB Layout	Technical Specification	Embedded Software	Front End Software	Back end Software	Datamining		CPUT CubeSat	FarmRanger	FarmTrack	Past Projects
										Sattelite Communication	x			o
										Farm Management		x	x	
										Military Communication				o
										Radar Communcation				o
										Sattelite Ground Stations	x			o
										Medical Devices				o
										Other Electronic Applications				o
										PROCESSES				
x	x	x	x		x		x	x	N	System Design	x	x	x	o
x	x	x	x	x	x	x		x		Circuit Design	x	x	x	o
x	x	x	x	x						Manufacturing	x	x	x	o
x	x	x	x	x		x				Testing	x	x	x	o
x	x				x		x	x		User Interface Design		x	x	o
					x		x			Customer Installation, Training and Support	x	x	x	
							x	x	N	Customer Relation Management		N	N	

being actively pursued at the moment. Black 'N'-symbols indicate new technology which should be developed/acquired and implemented in the respective products.

Red shaded chains indicate technology capabilities from other Alphawave companies being used by ETSE. The green shaded chain indicates areas where future expansion is available and, in some cases, required.

From the balance sheet, it is clear that the products developed to the Farm Management market has been improved by using capabilities from other companies within the Alphawave group. In this case, the capabilities are the software capabilities of Alphawave Ventures. These capabilities assisted in creating user interfaces which made the products more user-friendly and thus more marketable.

Further, the balance sheet shows that there are many other markets where ETSE had in the past successfully completed projects. The technological capabilities and processes which were utilised in the past are still available within ETSE, thus it should be possible to create new products to enter these markets. Previously used technology can then also be combined with technology available in other Alphawave companies to ensure that the product is as marketable as possible when it enters the market.

Both Farm Management products can also be significantly improved if datamining is applied to the current systems. At the moment, a large amount of data is received and notifications are sent to customers. If the data can be analysed and reworked, more comprehensive and proactive feedback can be provided directly to the customer, for example sending a message indicating that urgent attention is required a specific flock or orchard. This should enhance the customer experience and assist with customer retention and marketing.

As a whole, the balance sheet shows a company with an abundance of very strong capabilities. These capabilities are, for the moment at least, only exploited in limited markets and products. There is

enormous potential if these capabilities can be adequately exploited with new products for known markets.

Conclusion

The inclusion of ETSE Electronics into the Alphawave group has a lot of potential to grow the capabilities and products of both ETSE and the group as a whole. ETSE has very specialised capabilities in hardware design and production over a wide scope of applications, which is not available elsewhere in the group. ETSE can, on the other hand, benefit from the large software design knowledge base within Alphawave. Specifically, in application software.

Alphawave has also proven themselves as an effective organisation to translate technical knowledge into marketable products. This should help ETSE to identify new products which can be taken to market. Even any new ideas from within the Alphawave group which require hardware development, can now be resolved in-house at ETSE.

A growing concern should be that old technical capabilities will become outdated and/or redundant if opportunities are not created for them to be exploited or expanded on in the near future. As with the rest of the Alphawave group a comprehensive marketing strategy is required to link the strong technical capabilities of ETSE with new opportunities, not just new clients, but also unexploited markets.

ETSE is well poised at the moment. By building on their abundance of technical capabilities and the newly available capabilities from Alphawave, they are set to expand into new products and markets. They must learn how to exploit their abundance of capabilities into opportunities.

B.3 Technology Management Analysis Report of Honeybee

TECHNOLOGY MANAGEMENT ANALYSIS

OF

HONEYBEE

(PART OF THE ALPHAWAVE TECHNOLOGY GROUP)

"A Billion Dollar Company by 2035"

Author: Christo Visser

Edited by: Sam Clarke

Introduction

This report is intended as a summary of the status of technology management within HoneyBee. This report will explore the manner in which technological capabilities are identified, managed and exploited within HoneyBee and also how technology capabilities are shared between HoneyBee and other entities of the newly created Alphawave group.

The information contained within this report is based on an interview conducted by the author and Sam Clarke. Sam is the CEO of HoneyBee.

Honeybee Business Environment

Honeybee is a fairly young company within the Alphawave group, having been founded as Field Office in 2012. The initial intention with the new company was to sell the competencies developed by the development team of EMSS Consulting to external companies. In particular, the competencies developed for the implementation of the Site Inspector application. The Site Inspector is an application used by field workers to capture information about cellular base stations on an android device and sync it automatically back to a central database.

After realising that there was a significant market for systems that facilitate the management of sales reps, the Honeybee application was developed to service this need. The application assists sales reps, as well as sales managers to track and document interactions with clients, process orders and various other sales related tasks all by using a single mobile application.

The sales of the new product grew steadily and the application has grown into a fully-fledged software package. More and more services were added to support the sales and users of the Honeybee app, including training and technical support. With the success and growth of Honeybee, the idea of Field Office selling their expertise to various different external clients was shelved. Field Office was rebranded as Honeybee CRM and all resources are committed to developing the Honeybee brand.

Honeybee is very well entrenched in the local market. Their sales figures are showing continual growth and they are very competitive in the local market. They sell to a wide range of companies, but mostly to manufacturers, importers, resellers, etc. Based on their success in the local market, Honeybee had developed strategies for entering foreign markets.

As their former sales manager has moved to the UK, they tasked him with starting a Honeybee office in London. This fortunate event has enabled Honeybee to expand the footprint from South Africa to Europe. The global cloud CRM market is massive, but very underdeveloped. The time then is right for global expansion, but new sales tactics will be required to successfully enter the new markets. Honeybee has already started to develop two new go-to-market strategies to use in the UK, namely through partnerships and through digital routes, specifically through ERP ecosystems.

Honeybee has a simple goal, they want to be a $1 billion company by 2035. They have established a solid foothold in the local market, but that won't be enough to reach their goal. The expansion to Europe, and the inevitable lessons they will need to learn, is a crucial step to reach their ultimate goal.

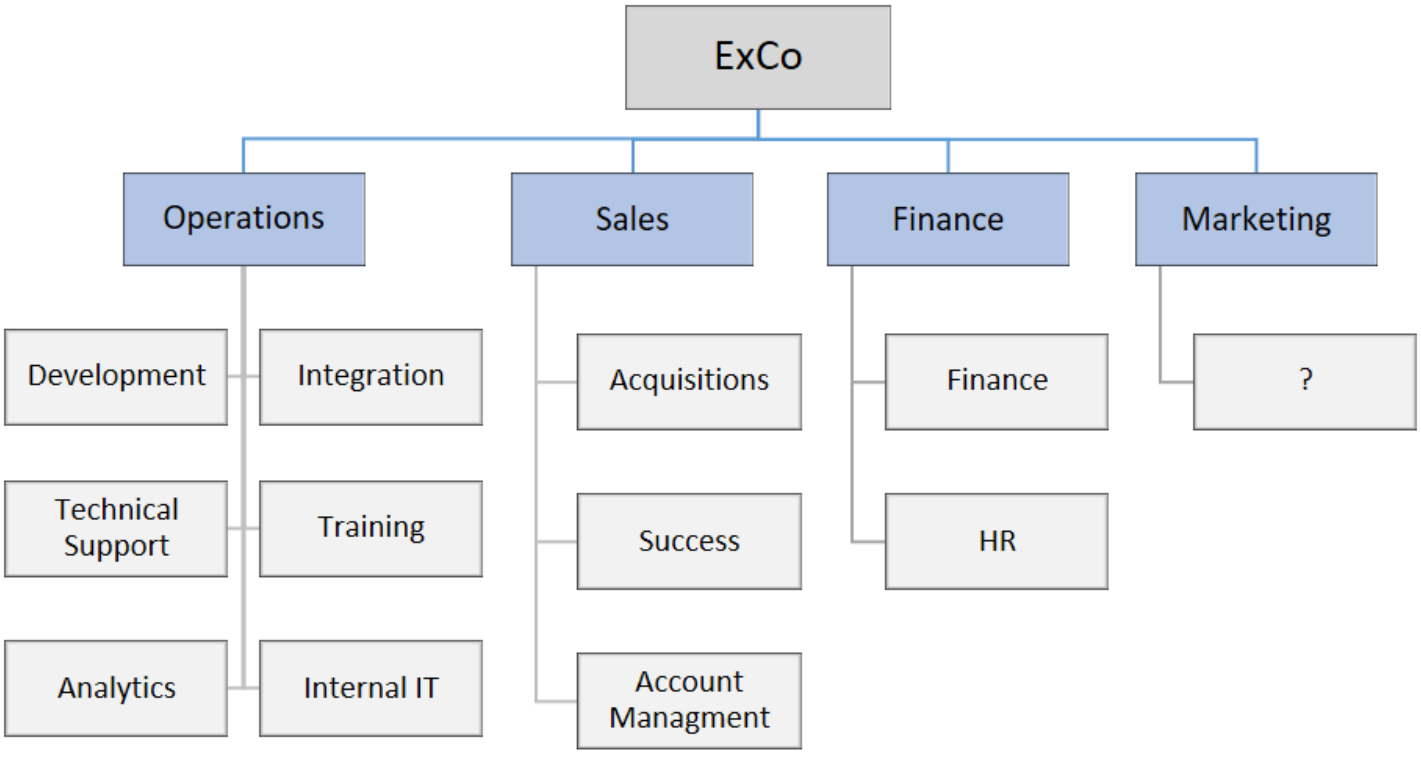
Product Innovation Process

From the onset Honeybee was a product of innovation. The development team of EMSS Consulting had identified that the competencies developed for the Site Inspector can be re-used outside of the traditional fields and markets of the then EMSS group. When the need for sales rep management was discovered, Honeybee was developed to meet this need.

The culture of innovation which had been developed within the EMSS Consulting development team was inherited by Honeybee. The core of the Honeybee team moved from EMSS Consulting to Honeybee. As new capabilities were required it was either developed in-house or acquired. Based on market needs or technical requirements the capabilities of Honeybee have expanded from software development to as diverse fields such as sales, training, technical support, etc.

Initially when only the core team was part of Honeybee, the innovation process was not managed in a formal manner. Ideas were discussed collectively, with the final decision resting with Sam Clarke. Everyone was thus directly involved in the innovation process. The informal system worked well until Honeybee reached an organisational complexity which necessitated a more structured approach.

An Executive Committee (ExCo) was established to manage innovation within Honeybee. The ExCo meets regularly and discuss available opportunities and weighs the opportunity costs against the potential rewards. The ExCo then tries to reach a consensus, if one cannot be reached the decision falls to Sam Clarke. The ExCo is made up of an assortment of eight team leaders from each of the different departments. Each member of the ExCo is expected to be an aggregator and disseminator of information within their respective teams. The three-tiered structure of the ExCo is shown below.



This multidisciplinary innovation decision making structure is unique within the Alphawave group. Most of the other companies in the group do not innovate over such a wide range of domains and focus mainly on hard technical capabilities for innovation. Each member of the ExCo is responsible to determine what opportunities are available out of their respective teams. They are also then responsible to implement and relay decisions made in the ExCo meetings to their teams. The minutes of all ExCo meetings are made available to all staff on an open Slack channel so that all staff have the opportunity to contribute to any open debate.

This structure lends itself very well to be used with the culture of collective innovation inherited from EMSS Consulting. There is an expectation from every employee that all the other employees are constantly trying to improve Honeybee. Ideas from all levels and teams are considered at least at some part of the structure. Good ideas are celebrated throughout the Honeybee community and rewarded based on the scale of the idea.

This structure and management style has fostered the culture of collective innovation inherited from the EMSS Consulting. This culture, in turn, has ensured that Honeybee innovates on a daily basis and remains a relevant and capable player in the local market, ready to enter the global market.

Core Competencies of Honeybee

As can be seen out of the multi-disciplinary nature of the ExCo, the core competencies of Honeybee are a mix of hard technical skills and softer capabilities. The two primary core competencies are software development and sales. There are also two secondary support competencies, which are vital for ensuring customer engagement with the product. These secondary competencies are training and technical support. Both of the secondary competencies have been developed from minor skills to strong capabilities, which can even be implemented independently and outside of Honeybee if required.

Honeybee is a much stronger software development organisation than their competitors, in terms of environment processes, quality of developers hired, etc. This organisational strength was mostly inherited from EMSS Consulting. As mentioned by Sam, *"It took EMSS ten years of doing it wrong to figure out how to do it right. And now we are just benefitting from it".* The overall development environment in Honeybee ensures that they not only get the best possible results from their developers, but also ensures that they attract the best possible developers.

The sales competency of Honeybee is also very strong. Sales have been growing at a significant pace since Honeybee was launched. Although the results of the sales competency are strong, the sales process is weak. Most of the sales capabilities are vested in one person, Fanie Joubert. Out of a sales team of 9 people more than 50% of the sales comes from one person. Not just is this a big risk of the entire sales system, but also it prevents Honeybee from scaling up their sales capacity. A lot of money and effort are being spent to replicate Fanie's success through better sales systems and processes. It is crucial that Fanie's success can be reproduced by other people if Honeybee hopes to not only keep up its current sales rate, but also to increase sales in order to reach their company goal.

Technical support was required from very early on, as is expected when developing software for use by non-technical clients. The capability was grown from the ground up. It started with members from within the development team assisting with customer queries up to an in-house designed and managed call centre. The call centre functions effectively and is trusted by the company and clients alike. The capability can easily be scaled as required.

Training on Honeybee was also required from early on. Initially training was presented by the sales team to new clients. An opportunity presented itself to employ someone solely responsible for training and a former high school science teacher was hired. The quality of training improved immediately, with immediate results. Clients understood the product better and could use it a lot more efficiently and the sales team had more time available to sell more products. The training capability was further improved by hiring in an experienced training manager. The entire training process and system was formalised and structured in such a way that hundreds of clients pass through Honeybee's different training centres.

These four competencies position Honeybee well for good growth prospects. However, there are serious deficiencies in marketing. There are only limited marketing capabilities available within Honeybee (and the Alphawave group as a whole) at the moment. Strong marketing can see Honeybee leapfrog their competitors, not just in the local market, but especially in their new ventures into global markets. It became clear that it would take too long to develop these capabilities, so the capabilities were acquired by hiring a marketing manager. After only two months, marketing is still a distance away from being a vested and scalable capability, but good progress has already been made.

Honeybee has proven themselves as a company that not only has strong capabilities, but also a company that continuously innovates to grow these capabilities. This innovation and growths ensures that they remain at the forefront of the cloud CRM market locally and, expectantly, in the global market in the foreseeable future.

Technology Analysis of Honeybee

See below a Technology Balance Sheet of how the different capabilities of Honeybee are currently utilised to create products for their existing market. Crosses indicate that a capability is either in place, but weak (lowercase x), or in place, and strong (uppercase **X**). Circles indicate outsourced technology. Blank cells do not necessarily indicate that the capability is absent, but rather that is underdeveloped.

Legend	
O	Outsourced
x	In place (weak)
X	In place (strong)
	Underdeveloped

TECHNOLOGY																MARKET	PRODUCT
Backend Development	Web Frontend Development	Mobile Frontend Development	Functional QA	Automated QA	Product Managment and Design	Technical Support	Training	Sales Acquisitions	Sales Success	Account Management	Marketing	Finance	HR	Integration	Analytics	PROCESS PHASES	Honeybee
						X	X	x		x				x	x	Recruitment	x
x	x	x	x	O	x	x	x	x	x		x	x	x	X	x	Ideation	x
x	x	x	x	O	x	x	X	x	x		x	x	x	X	x	Prototyping	x
X	x	x	X	O		x	x	X	x	x	x			x		Small Scale Impemenation	x
X	x	X	x	O		X	X			x		x		X		Large Scale Implementation	x

The technology balance sheet of Honeybee shows a wide range of technologies, but only the one product, Honeybee. Although Honeybee is only delivered to one market, their technology base is ever changing with new technologies regularly being added to Honeybee through their structured innovation processes. The technology section of the balance sheet will continue expanding, as new capabilities are required to keep Honeybee current in a dynamic market.

In contrast to the technology balance sheet drawn up for other companies in the Alphawave group, the process segment of the balance sheet has been adapted to rather reflect phases in the innovation process. This adaption is better suited to Honeybee's situation, as it better reflects how new technology is incorporated into the Honeybee family of products. The recruitment phase is included

as this can be seen as a general weakness of the Alphawave group. The balance sheet clearly shows that Honeybee has been more successful in recruiting in certain technologies than others.

Other than most of the other companies in the Alphawave group, Honeybee has a growing number of softer technological capabilities, e.g. sales, market, training, etc. They have not only established nominal capabilities, but have in some cases been able to expand these softer capabilities into fully fledged and scalable capabilities.

Honeybee's dynamic and innovative technology base has many potential benefits to the overall Alphawave group's technology base. Honeybee already shares their software capabilities and experience with other entities within the group, but several of their other capabilities could also prove invaluable if transferable between the various companies. Especially their established sales and growing marketing capabilities can be seen as valuable additions to other companies.

Honeybee has a varied and dynamic range of capabilities, which is a combination of hard technical skills and softer skills. This wide base of technology is supported by an innovation structure which enables the efficient expansion of available capabilities. The softer skills, in particular, are mostly unique to Honeybee in the group and if exploited correctly, can be invaluable to the Alphawave group as a whole.

Conclusion

Honeybee inherited a culture of innovation from EMSS. The very foundation of Honeybee is a product of this culture which prompted the core group of developers from EMSS Consulting to explore new possibilities.

This culture was, however, not just inherited, but actively fostered and constantly realigned with structures appropriate for the size of the company. Technologies not directly related to the traditional capabilities within the Alphawave group were developed due to the effective management of the innovation process. All employees from each level of the company are constantly trying to improve Honeybee in whichever way they can.

Honeybee has been able to create a team of exceptionally capable people and manage them in such a way that they remain leaders in their field. They have been able to harness the capabilities developed by EMSS and exploit new markets far outside the traditional markets of the Alphawave group.

Honeybee is at the vanguard of the Alphawave group using established capabilities into new markets. Not only is Honeybee successful in its own right, but the principles with which Honeybee was conceived and developed can be used at blueprints for future endeavours of the Alphawave group and also assist the rest of the companies in the Alphawave group in expanding their capabilities into new exciting markets.

Honeybee has now firmly established itself in the local market. By exploiting their culture of innovation and excellence they can confidently start to engage the global market. If they are able to keep the momentum and continually identify and address shortcomings in their own technological capabilities they will surely be able to reach their company goal, to become a $1 billion company by 2035.

B.4 Technology Management Analysis Report of EMSS Consulting

TECHNOLOGY MANAGEMENT ANALYSIS

OF

EMSS CONSULTING

(PART OF THE ALPHAWAVE TECHNOLOGY GROUP)

"The Alpha of Alphawave"

Author: Christo Visser

Edited by: Marnus van Wyk

Introduction

This report is intended as a summary of the status of technology management within EMSS Consulting. This report will explore the manner in which technological capabilities are identified, managed and exploited within EMSS Consulting and also how technology capabilities are shared between EMSS Consulting and other entities of the newly created Alphawave group.

The information contained within this report is based on an interview conducted by the author and Marnus van Wyk. Marnus van Wyk is the Managing Director of EMSS Consulting.

EMSS Consulting Business Environment

EMSS Consulting was born out of a technology transfer in 2005. By then EMSS (Electromagnetic Software and Systems) was already a successful company. Delivering both the world-class antenna modelling tool, FEKO, and electromagnetic consulting and research services to various clients, including one of the biggest mobile operators in South Africa.

EMSS Consulting was founded to service the then newly signed operational services contract with the above-mentioned operator, by employing the capabilities already developed within EMSS. EMSS Consulting remained part of the EMSS Group, which at the time the consisted of EMSS-SA (who continued with the development and sales of FEKO), EMSS Antennas (responsible for the design and production of the Meerkat feeders) and EMSS Consulting, although EMSS-SA was later sold to an international company, Altair, in 2014. Since its founding EMSS Consulting has developed into an independent and successful company in its own right.

The business operations of EMSS Consulting can be divided in to three distinct teams, each delivering their own products or services for their respective markets. These teams are the operational services team, the Ixus team and the Fieldsense team. All three of these teams are currently being rebranded as separate entities, but this change will not affect the basic operational structure of the respective teams, nor the EMSS Consulting management structure.

The operational services team (soon to become Alphawave Mobile Network Services) provides operational electromagnetic health and safety services to various clients in the mobile network industry. These clients include mobile network operators, infrastructure management companies and regulators both in South Africa and the rest of Africa. In addition to the operational services provided, EMSS Consulting also plays a consulting role to these clients as well as various other entities, city councils, members of the general public, etc. The consulting is not a major avenue of revenue, but rather a by-product of their position as a specialist company with local and international expertise in the area of electromagnetic health and safety.

The Ixus team (soon to become Alphawave Ventures) is the software development team of EMSS Consulting and develops software solutions for various entities within the Alphawave group. The longest standing product of the Ixus team is the Ixus software package, a compliance management tool incorporating a database system and an 3D simulation and modelling tool. Ixus is sold to various clients across the world, and mostly in Australia and Canada, and is also the primary tool used by the operational services team to deliver their services to their clients. In addition to Ixus, the team also develops software for two ETSE products (Farmranger and Farmtrack), as well as MySidekick (a software application for the retail industry).

The Fieldsense team (soon to form the core of Alphawave Mobile Network Products) is responsible for the development, manufacturing, marketing and sales of the Fieldsense personal RF monitor. Originally developed in conjunction with EMSS Antennas, the Fieldsense is an (relatively) inexpensive

monitor intended to be used primarily by RF contractors while working on various different sites, often close to RF transmitters. The Fielsense warns the user when the RF exposure reaches levels close to the relevant guidelines. The Fieldsense (now already in its second version) is a very successful product, especially in the US market. The current objective for Fieldsense is to break into the European market.

EMSS Consulting has proven themselves especially adept at quickly dominating markets where they are able to find a foothold. They have very little competition with their operational services in the local market. The Ixus software package is the de facto industry standard in Australia and has good market penetration in Canada. The sales of Fieldsense in the USA has been steadily growing. This success is closely related to Consulting's inherent culture of ensuring that the best possible product is delivered to the client, a product that services the specific functional needs of the client, not just perceived needs.

Although EMSS Consulting's main revenue generator, the operational services, has little pressure from competitors in their niche market, they are subject to normal business pressures. With a large range of clients, with different contractual needs and differing priorities, constant effort is required to ensure that all payments are up to date and that each client is serviced adequately. Worldwide the mobile network industry is under financial pressure, whether from increased competition, government regulations, etc. The mobile operators in South Africa are under constant pressure to lower their costs and transfers this pressure to their suppliers, including EMSS Consulting.

Even with these pressures, EMSS Consulting is well positioned in varied markets. They deliver their services and products in the same market segment, but to vastly different clients in different geographical markets. Even if one of their operations or products are threatened, it is unlikely that all of their different endeavours will be affected simultaneously.

EMSS Consulting's continued success over such a long term has made it the cornerstone of the Alphawave Group and the company is currently the largest revenue generator in the group. Without the stability of this regular revenue stream, the Alphawave Group would not have been able to diversify and expand its ventures into new products and markets.

Product Innovation Process

Innovation in EMSS Consulting is not limited to innovation only within the company itself. A number of the products of the Alphawave Group has either their roots in EMSS Consulting or EMSS Consulting had played a big part in ensuring that the product ideas become a reality.

With a steady revenue stream, EMSS Consulting has made numerous attempts to develop new and innovative ideas and products. Although not all of them have been successful, some of the most successful products in the group was developed from within EMSS Consulting. Fieldsense, Ixus and the newly established Honeybee were all developed from within the EMSS Consulting structures.

EMSS Consulting is at the forefront of developing new ideas and products for the Alphawave Group. The Ventures team, in particular, are actively involved in developing the software for many of the latest products being developed in the group as a whole. New ideas are obtained either from within EMSS Consulting, the greater Alphawave Group or even external partners. For example, the expertise within the Ventures team was crucial to develop software for both the ETSE Farmtrack and Farmranger products.

The products and services delivered by EMSS Consulting (Ixus, Fieldsense and operational services) are all mature products. Developments made to these products are generally incremental in nature,

mostly with inputs from the people actively using the products, i.e. clients and operational services personnel. Potential improvements are weighed monthly against requirements from external clients, other members of the Alphawave Group and internal requirements. These improvements include changes such as improving compatibility with national databases in Australia, incorporating surveyor management into established systems, updating measurement parameters to reflect changing spectrum allocations, etc. One of these improvements, the development of the Site Inspector to eliminate paperwork on site, eventually lead to the creation of Honeybee.

Within EMSS Consulting, the directors are tasked with actively searching for new opportunities to pursue. New avenues are constantly being pursued, but as EMSS Consulting is operating in a niche market, these opportunities are limited. With the exception of promoting Fieldsense, especially in Europe, EMSS Consulting does very little marketing of their products and services. Instead EMSS Consulting keeps themselves relevant by being actively involved with national and international entities, such as ITU and IEC working committees. These activities have the dual purpose of ensuring that EMSS Consulting stays up to date with the latest international advances and builds their network of potential clients. A number of EMSS Consulting's clients have either been identified from these networks or approached EMSS Consulting from these networks. EMSS Consulting is thus pro-active in keeping up to date with international advances, but reactive, albeit swiftly, when pursuing new clients.

Since both Ixus and the operational services are mature and scalable product lines, they can easily be implemented for new clients with minimal customisation required. The structure of each client for the operational services, for example, are fundamentally similar and can be, and indeed has been, easily reproduced for new clients. This means that new clients can easily be serviced by merely employing new personnel in already well-defined roles.

More radical forms of expansion, for example, into new markets or services are rather embarked in a more step-by-step manner. Investment into these new ventures start out small and only increases if the potential success of the venture can be proven with small scale success. If successful the venture is either incorporated into a new structure within the operational services or redeveloped into an entirely new entity, of which Honeybee is a recent example.

EMSS Consulting uses its mature and scalable products as the basis for searching for new ventures, not just for themselves, but for the Alphawave Group as a whole. They have spent large sums of money over the last few years to attempt to exploit new opportunities. Although not all of them have paid off yet, some, as such Honeybee, have already been developed into fully fledged independent businesses.

Core Competencies of EMSS Consulting

Historically the original EMSS Group's main competency has been electromagnetics. In order to support this competency EMSS actively developed an entirely new competency in the field of software development. EMSS Consulting inherited both of these competencies and especially applied them to the field of electromagnetic health and safety. With the valuable experience and knowledge of various markets, both local and globally, EMSS Consulting has been able to exploit their competencies efficiently in various different markets.

Naturally the respective teams of EMSS Consulting have their own distinct competencies. This notwithstanding, there is one competency that is shared by all three of the different teams, their unwavering emphasis on customer service. Each of the different teams have been able to gain the control of their respective markets by ensuring that they offer the best possible service or product to their clients.

Both the products and services of EMSS Consulting has been aligned to ensure that their respective clients' needs are addressed in the simplest and most efficient way possible. This not only ensures that they deliver the best possible product at competitive prices, but also that they remain a well-known player in the niche markets in which they operate.

There have been very little radical changes in competencies at EMSS Consulting over the years. Rather, all of these competencies have been grown incrementally and steadily throughout the years. The combination of their knowledge, both technical and market related, and their software development skills have ensured that their products and services are difficult to compete with, even on the global market. As they actively develop their own tools, they are able to fine tune their services and, in turn, develop products to specifically meet their customers specific needs. In particular, it is these competencies of software development and the effective development of client orientated products that are often shared with other entities within the Alphawave Group.

EMSS Consulting have been a successful business for many years and they have actively led the way in establishing the Alphawave Group. Their core competencies, especially of customer service and software development, has been the basis for the expansion of the Alphawave Group out of its initial electromagnetics base to exciting and innovative opportunities in entirely new markets.

Technology Analysis of Consulting

See below a Technology Balance Sheet of how the different capabilities of EMSS Consulting are currently utilised to create products for their existing markets. Crosses indicate that a capability is in place.

								PRODUCTS						
TECHNOLOGIES								Operational Services	Consulting / Advisory Services	Software Services	FieldSense	IXUS (Including Meas. Module)	Training	Interference
Assembly	Software Development	System / Procedure Design	Data Processing	Logistics	EM Regulatory Knowledge	Practical EM Principles	MARKETS/CLIENTS							
							Mobile Operators	X	X		X	X	X	X
							Infrastructure Companies/Contractors	X	X		X	X	X	
							Regulators		X			X	X	
							Software Buyers / Outsourced Development			X				
							Internal (Technology redeployed within Consulting)			X	X	X	X	
							PROCESSES							
	X	X	X				Software Development			X	X	X		
		X	X	X	X	X	(RF) Measurements	X	X		X		X	X
		X	X	X	X	X	Compliance Assessments	X	X			X	X	
	X	X			X	X	R&D				X	X		
X		X		X			Production				X			
		X	X			X	Quality Assurance	X			X			X

The strength of EMSS Consulting is not merely contained in their available technologies, but also in their well-established processes. Although not unique to only EMSS Consulting in the Alphawave

Group, EMSS Consulting is especially adept at reorganising their structures and operations to effectively exploit opportunities they uncover. The structure of the operational services, in particular, can easily be replicated to accommodate new clients. Automation has been implemented where practical, to ensure that complex and repetitive tasks can be performed by even non-technical personnel. If any task becomes too labour intensive, the company will try to update or automate their processes to keep it as lean and efficient as possible.

Other than their capabilities in the field of electromagnetics, most of the other capabilities were developed out of necessity. Logistics and data processing capabilities had to developed fast in order to visit and assess thousands of cellular base stations around South Africa. The entire operations structure was developed and built around these capabilities. Again, unique to Consulting, a large of number of their staff are working in geographically different locations on daily basis.

Similarly, their software development capabilities were developed to support their operational activities. Which in turn lead to new products which were commercialised and sold to external customers. The Site Inspector tool, which eliminated paperwork on site, was developed to improve the efficiency of gathering and documenting information on site, while at the same time ensuring that the information can electronically be sent back to the various offices much faster and more securely than before. This greatly improved the operational team's efficiency, but also eventually lead to the development of Honeybee.

Throughout the history of EMSS Consulting, technological capabilities have been shared between the different teams and also the different entities, first within the EMSS Group and now within the Alphawave Group. EMSS Consulting's established and entrenched capabilities are ideal to be shared with the different entities within the group. The success of Honeybee, the software user interfaces of the ETSE products, to name but a few, are some of the several examples which show how effectively EMSS Consulting can contribute to the expansion of capabilities within the rest of group.

No matter which of the technological capabilities of EMSS Consulting is considered, it is an established capability. Not just established, but incrementally growing. The company has successfully implemented and fostered a culture and system where the different teams and capabilities are constantly working together to improve themselves and each other. This along with the strong processes in place, ensure that their capabilities are effectively used to leverage competitive advantages in various markets. Not just in EMSS Consulting themselves, but, indeed, in the Alphawave Group as a whole.

Conclusion

EMSS Consulting has for a long time one of the success stories of first the EMSS Group and now the Alphawave Group. After the sale of EMSS-SA, EMSS Consulting became the flagship company of the group which would eventually become the Alphawave Group. By consolidating their market share wherever they are able to gain a foothold, they have been able to grow into a secure business. Although their growth is not the fastest in the group, theirs is the most stable and this reliable revenue stream forms the means for the Alphawave Group to find innovative new markets outside of their traditional fields of electromagnetics.

Each of the different teams of EMSS Consulting have different capabilities and are generally active in vastly different fields. They are, however, able to work together to identify and create solutions which

people both locally and globally are willing to pay for. The success of EMSS Consulting lies in that that they have been able to combine and recombine their different capabilities in different ways in such a way to ensure that they constantly meet the specific needs of their respective clients.

This continual interworking between the different teams in the company, ensures that these teams work together to continually grow the business of EMSS Consulting. This ability of EMSS Consulting to effectively translate operational services into commercial products is a cornerstone of the Alphawave Group and, as such, means that EMSS Consulting is well poised to continue to deliver ever better service and deliver ever better products. Not just their own, but also for the Alphawave Group as a whole. EMSS Consulting is truly the Alpha of Alphawave. This is where the group originated and is still the core which drives the group.