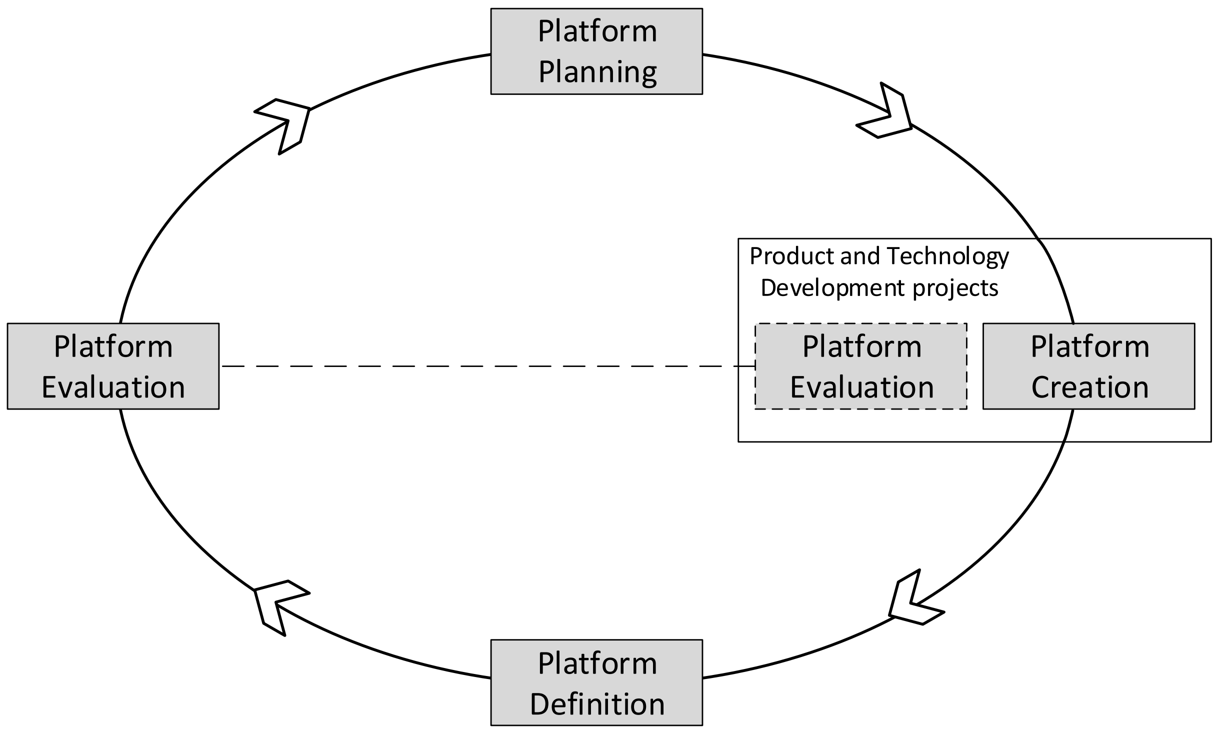

A Framework for Requirement-based Platform Development

Establishing needs for platform creation and use at a supplier in the aerospace industry

Master of Science Thesis in Product Development

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Department of Product and Production Development
Division of Product Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2013

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Cover:

[The cover art shows the PCDE phases of the proposed framework for platform-based product development, called the RBP framework. The four phases are Platform **P**lanning, Platform **C**reation, Platform **D**efinition and Platform **E**valuation.]

Chalmers Reproservice

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ABSTRACT

Platform development has received increasing interest from companies to gain competiveness in the industry. The way forward for suppliers developing complex, customized low-volume products has been unclear in terms of developing a platform vision, strategies for platform creation and use, and support for the same from IT tools. Needs in platform development for companies in such a situation have been addressed by conducting this empirical study at GKN Aerospace. The study establishes the current situation at the company with respect to platform development in general and particularly lays out needs and requirements of individuals involved in platform creation and use. A framework for platform-based product development is proposed. It is requirement-driven, combines two popular approaches to product family design – proactive and reactive approaches, and provides for carrying out platform development within product and technology development projects. The components of the proposed framework are: top-down management drive, setting up of a cross-functional platform team and the four phases of platform development PCDE (Planning, Creation, Definition and Evaluation). The concept of a platform scout is introduced for establishing ranges on platform specific requirements. The role of concurrent engineering, knowledge management and product lifecycle management in platform development is also discussed. The move for developing platforms is an organization-wide effort and the changes required need careful consideration.

Key Words: platform development, product development, technology development, organisational change, product life-cycle management, knowledge reuse, concurrent engineering

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Abbreviations

BOE	Bill of Equipment
BOM	Bill of Materials
BOP	Bill of Processes
CAD	Computer Aided Design
CAE	Computer Aided Engineering
DPS	Design Practise System
DRM	Design Research Methodology
ERP	Enterprise Resource Management
GE	General Electric
IMC	Intermediate Case
KBE	Knowledge-Based Engineering
KM	Knowledge Management
KMS	Knowledge Management System
LTA	Long Term Agreements
MRJ	Mitsubishi Regional Jet
OEMs	Original Equipment Manufacturers
OMS	Operational Management System
PCDE	Planning Creating Defining Evaluating
PDM	Product Data Management
PD	Product Development
PDLC	Product Development Life cycle
PFA	Product Family Architecture
PLC	Product Life cycle
PLM	Product Lifecycle Management
PPLC	Product Platform Life cycle
PW	Pratt & Whitney
RBP	Requirements-driven, Balanced approach, Product development based
RR	Rolls Royce
R&D	Research and Development
TEC	Turbine Exhaust Case
TRF	Turbine Rear Frame
TRL	Technology Readiness Level
VAC	Volvo Aero Corporation

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1 Introduction

This introduction presents the background and focus of the thesis. It presents the purpose of the research, problem definition and goals of the thesis. This section concludes with the thesis approach, its scope and delimitations.

1.1 Background

The success of a product development firm is gauged by its ability to deliver high quality, cost-effective products catering to diverse needs of different market segments. In doing so, a successful firm achieves resource efficiency and leverages its assets to create economies of scale. Resource efficiency through reuse of organizational assets is a fundamentally intuitive and commonplace activity, often pursued by individuals and teams in an opportunistic or ad hoc manner (Antelme *et al.*, 2000). Effective and appropriate reuse of assets provides a range of benefits including reduced time-to-market, reduced cost of development and manufacturing, increased agility and responsiveness to market needs, reduced risk, more effective deployment of resources, improved organizational learning and knowledge management.

Platforms can be used to efficiently meet varied customer requirements by optimizing the development process through the reuse of resources. Approaches vary in the use of platforms to leverage organizational assets and obtain a competitive advantage. These range from using configurator-based tools to creating product families to capitalizing on knowledge as a reusable asset. Industry faces a myriad of platform options and thus faces challenges in determining a platform approach, developing and implementing platforms.

1.2 Purpose

This study has been carried out as a master thesis in Product Development at Chalmers University of Technology; Gothenburg; Sweden and GKN Aerospace; Trollhättan, Sweden. The purpose of the research is to support the implementation of a platform-based approach to product development at GKN Aerospace. In doing so, the purpose is to understand the needs of the industry in the context of existing literature on platform development, and bridge the gap between industry and academia, if any.

The platform approach being adopted by GKN Aerospace is studied in light of the different platform approaches present in literature and those adopted in other similar industries. The current state of the platform initiative at GKN Aerospace and the organizational context in which the platform is being developed are studied with a focus on platform definitions used, strategies applied, stakeholders such as creators and users involved within the organization and their roles.

The purpose of this thesis project is to contribute to a systematic method for preparing and implementing a platform at GKN Aerospace. A prerequisite to effective platform implementation is platform planning. Understanding organizational needs for a platform as well as needs of platform creators and users is an essential step in platform planning. These needs can then form the basis for establishing requirements for the platform. Since the platform is used within an organizational context, mapping relations and representing the context within which the platform will be used is a next step to provide a systematic method for platform preparation and implementation. Closely related fields of Knowledge Management (KM) and Product Lifecycle Management (PLM) have also been studied to evaluate how they can contribute towards platform development at GKN Aerospace.

1.3 Company Background

This section describes the background of the organization in which the study has been carried out, specifically addressing the history, evolution, and recent developments.

1.3.1 An introduction to GKN Aerospace

GKN Aerospace Engine Systems located in Trollhättan is a second-tier supplier in the global aerospace industry that manufactures engine components. It is a part of GKN Aerospace which has its headquarters in England and is in turn a part of the GKN Group. GKN Aerospace, registered in Sweden as GKN Aerospace Sweden AB was formerly Volvo Aero Corporation (VAC) until October 2012. GKN Aerospace acquired the aero engine components business from AB Volvo, acquiring 100% of the equity. The acquired entities are together referred to as "GKN Aerospace Engine Systems" (GKN Aerospace, 2012). Throughout this thesis however, the company has been referred to as GKN Aerospace or GKN Aero in short.

GKN Aerospace designs, engineers, manufactures and supplies components and sub-assemblies for aircraft engine turbines to major aero engine manufacturers Rolls Royce (RR), Pratt & Whitney (PW) and General Electric (GE). GKN Aero employs about 3,000 people based in Sweden, Norway, United States and India. The enlarged GKN Aerospace is a world leader in both aero structures and aero engine components. Within aero engines, the Group's composite leadership and strong metal technology provides a unique offering to customers who focus on lightweight, high performance engine solutions. With regard to this acquisition GKN states that “positions on existing platforms and new programmes, together with a strong technology pipeline, offer a long-term platform for growth in the market” (GKN Aerospace, 2012).

1.3.2 Business Model

The commercial aerospace industry is the primary market for GKN Aerospace. It receives contracts for developing and manufacturing sub-systems or components of aircraft engines from engine manufacturers. Engine manufacturers in turn supply engines to aircraft manufacturers. The engine manufacturer supplies a single commercial engine to multiple aircraft manufacturers. Thus, GKN Aerospace is required to customize its components for multiple airline manufacturers within a single engine development programme.

For instance, Pratt & Whitney an engine manufacturer offers the PW1000G engine family. This has been selected for the Mitsubishi Regional Jet (MRJ), Bombardier CSeries and

A320neo aircraft. In this engine programme, GKN Aerospace has full responsibility for design, development and manufacture of the Intermediate Case (IMC) and Turbine Exhaust Case (TEC) as well as manufacturing the Low Pressure (LP) shaft. GKN Aerospace is also a partner in the PW1000G engine Risk-Revenue Sharing Program. It in turn uses a supplier network. (Pratt & Whitney, 2013)

1.3.3 Company History and Growth Strategy

The present GKN Aero or the former Volvo Aero Corporation (VAC) is a company founded in 1930 to supply aircraft engines to the Swedish Air Force and has had a strong tradition in technology development and R&D. In the 1970's the focus was broadened to enter new markets and product areas to ensure continued growth.

GKN Aerospace's product portfolio is characterized by several products that are developed on the backbone of several technologies. The process of developing these products and technologies is characterized by heavy investments, long lead times, multiple development teams, suppliers as well as numerous contractual and certification processes. This development process involves the participation of seven interdependent groups namely: the airlines, the airframers, the certification agencies and professional bodies, the government-funded laboratories and universities, the risk and revenue sharing partners, and the suppliers (Prencipe, 2004). This has been depicted in Figure 1.

Aircraft manufacturers, also known as system integrators, coordinate the activities of these groups. They are the customers of GKN Aerospace. Recently, over the last decade, the business-to-business relationships between these groups have become restricted to fewer companies. This has resulted in the situation for a supplier like GKN Aerospace to specialize in their product offering and work with several competing engine manufacturers. GKN Aerospace has traditionally been a supplier of manufacture-to-order parts but has recently been taking more responsibilities in design, for market penetration and growth.

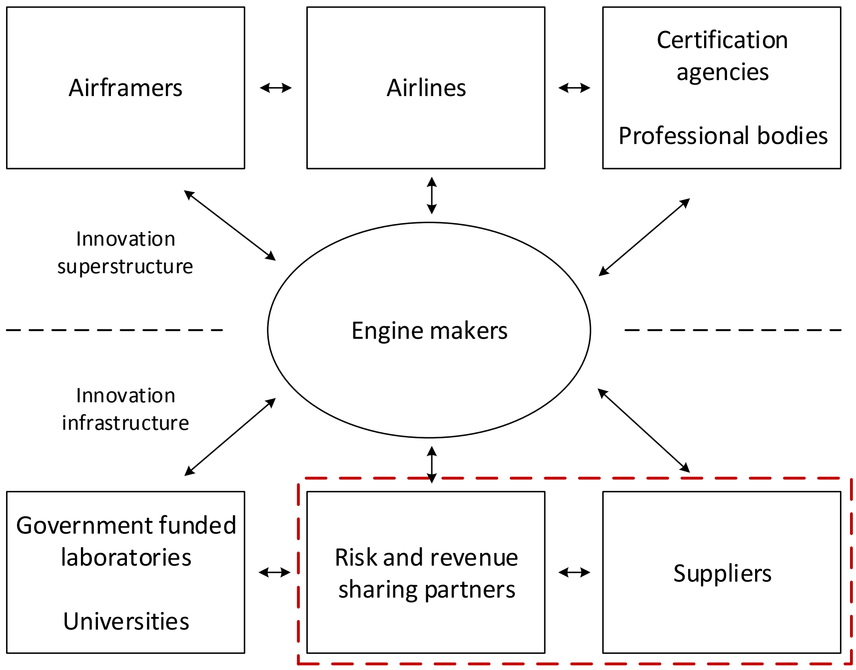

Figure 1. The aircraft engine industry meso-system. VAC (former GKN Aero) in red (Högman, 2011, Prencipe, 2004)

By taking up responsibilities in design GKN Aerospace wishes to take up the role of a system integrator in the future. A system integrator focuses on the task of integrating the various components while coordinating the activities of the supplier network. The external supplier network is a source of a range of capabilities and components that are combined to create the product offering which may be diverse or specific to a single market (Galbraith, 2002). The role of systems integration goes beyond assembling components as it involves responsibility for "general system design, selection and coordination of a network of external component suppliers, integration of components into a functioning system, and the development of technological knowledge needed for future systems upgrades" (Davies *et al*., 2007).

Thus, the current trend has been towards taking up full component or sub-system responsibility and investing in developing technologies. This has been possible through Risk and Revenue Sharing Programs with engine manufacturers. Engine manufacturers look towards GKN Aerospace for their product specialization in hot and cold static structures called turbine exhaust cases (TEC) or turbine rear frames (TRF), intermediate cases (IMC) and fan hub frames. Diversification has also been identified as a growth strategy through component development in other applications and markets by capitalising on the technologies that are being developed at GKN Aerospace. The stated corporate growth strategy for the future is:

- "a broader range of product families within our core structures, engine systems, transparencies and niche technology markets design and manufacture of higher level integrated aircraft assemblies / sub-assemblies for key OEM's and Tier One customers.

- expansion into adjacent markets with similar product technologies and manufacturing capabilities" (GKN Aerospace, 2012).

1.4 Problem Description

In order to achieve the above outlined growth GKN Aerospace has adopted a platform approach and has begun formulating the GKN Aerospace Platform. This is an integrated technology, product and production platform. This platform aims to facilitate reuse of knowledge, parts, processes and capabilities while ensuring optimum product quality and development process efficiency.

Platform development has been underway and the platform is already being used in product development projects. However, there are a number of challenges for the platform to deliver its intended benefits and aid growth.

These challenges stem from difficulties in defining the platform and its contents, describing and communicating the platform, implementing the platform for use in product development as well as establishing the limits and capabilities of the platform and its contents. These challenges need to be addressed systematically in light of GKN Aerospace's context and history, its position in the aerospace industry, market position, production technologies and product development processes. Thus, the current situation at GKN Aerospace needs to be determined and current literature on platform development needs to be studied in order to systematically support the platform-based product development at GKN Aerospace.

1.5 Research Goals

Platform development in an organization is inevitably tied to people fulfilling their organizational roles through formal or informal work processes. If the platform at GKN Aerospace is to be implemented at an operational level, then platform development should address organizational and individual needs of various stakeholders. Needs, targets and wishes when translated into measurable and verifiable requirements provide a way to asses if platform development is meeting its intended purpose. Thus, a primary goal for this study is to identify needs platform development. Based on identified needs, a second goal is to provide recommendations for continued platform-based product development at GKN Aerospace. The following are the specific objectives of the study:

Objective 1 — To determine needs for platform-based product development:

The objective is to determine organisational and individual needs for platform-based product development at GKN Aerospace. These needs are associated with the specific purpose of the platform at GKN Aerospace and the type of approach and strategies adopted for its creation. Needs could also arise from platform creators in the platform creation process. Desired use of the platform at an operational level also gives rise to needs. Finally, needs arise based on the systems used to support platform creation and use. All these needs can then be compiled and translated into a set of measurable and verifiable requirements for platform-based product development. Compilation of requirements for platform development will however not be carried out in this study.

Objective 2 — To make a recommendation for platform-based product development:

The objective is to make a recommendation for a systematic platform-based product development approach that addresses needs for platform vision, strategy, definition, intended use, creation process, operational implementation and supporting systems. In doing so, the aim is to bring forward to academia the challenges in platform development experienced in the industry. A second aim is to use the current literature in platform development for supporting the same in industry.

Meeting these objectives would contribute towards systematic development of a platform and its subsequent implementation.

1.6 Thesis Approach:

This study has been qualitative in nature. It began through discussions with individuals at Chalmers and GKN Aerospace employees who are involved with research in platform development. Previous research publications from GKN Aerospace were studied to get an understanding of company background and its platform development strategy. An extensive literature review on platforms was conducted which provided a theoretical frame of reference. Research questions were formulated based on this framework, gaps in the literature and problems in industry were identified. Data was collected by studying documentation on platforms at GKN Aerospace and through semi-structured personal interviews with employees from different departments involved in platform creation or use. The results of the interviews were analysed and discussed with the theoretical framework as a basis. Recommendations for a requirements-based platform approach were made based on the analysis.

1.7 Scope and Delimitations

GKN Aerospace's platform development efforts created the context for the study. The study was scoped to address the current needs of the platform development at GKN Aerospace and to meet the objectives within the framework of a master thesis.

The scope of the literature review was kept wide. It includes a review of literature on platform development from several industries; including ones where a platform enables mass-production and achieving economies of scale, to mass-customization and ones where the platform enables producing customized and complex products. Recommendation from theory on creation and implementation of platforms is however made keeping in mind the situation of a supplier in the aerospace industry. Organisational change and Product Lifecycle Management (PLM) has been introduced into the scope of the literature review to enable the understanding of the platform’s environment at an organisational and system level respectively.

Based on the background of the research and its goals, a qualitative research design was adopted. The scope was refined throughout the study to account for and incorporate new findings as well as to ensure the completion of the study within the decided time frame of five months. Maxwell’s (2005) interactive research design model was adopted as a methodological framework. The flexibility in this framework allowed influence from Design Research Methodology (Blessing & Chakrabarti, 2009) in creating a procedure for the study and guided the choice of methods. Data collection was limited to three sources: company documentation, individual interviews and a workshop. The participants in the study were limited to the employees at GKN Aerospace who are involved in preparing or using the platform. Websites of other companies were used to obtain information about GKN Aero’s position in the aerospace industry.

The outcomes of the study were partly validated through a workshop at the company and a final presentation at the company.

1.8 Outline of the report

The outline of the report is as follows:

Introduction: The introduction presents the background and focus of the thesis. It presents the purpose of the research, problem definition and goals of the thesis. It explains the overall approach and concludes with the scope and delimitations of this thesis.

Frame of Reference: This section presents a review of existing literature relevant to platform development. A conceptual framework visually representing key concepts in the literature review and relationships between them has also been presented.

Research Design: This section presents the research questions that have been formulated and answered during the course of the study. The research paradigm, design of the research and methodological framework adopted for the study are presented here. This is followed by a description of the procedure followed for the study, the methods and activities selected to carry out the study.

Results and Analysis: This section presents results from the interviews as well as the platform documentation that has been made available to the researchers for this study; and an analysis of these results based on the frame of reference.

Synthesis: The proposed framework for platform development and managerial implications for GKN Aerospace are presented.

Discussion: This section presents a discussion on the efforts taken to improve validity of the research and reflections on the generalizability of the conclusions.

Conclusion: In this section, the research questions are revisited, the advances in knowledge that emerge from the thesis are summarized, and opportunities for future work outlined.

Appendices: In Appendix A, the list of interviewees, their role in GKN Aerospace and in platform development is presented. Responses from interviews have also been categorised and presented in tables. Appendix B presents the interview guide that was used to carry out interviews for data collection.

2 Frame of Reference

This section presents a review of existing literature relevant to platform development. A conceptual framework visually representing key concepts from the literature review and relationships between them is presented. Research gaps identified in literature are also presented along with the conceptual framework.

2.1 Literature Review

This section captures important and relevant existing literature on platform development. An extensive literature review has helped capture several theories, concepts, phenomena and findings on platforms and related fields. In this study, the literature review meets the following purposes:

a) Provides a frame of reference for the study.

b) Highlights key findings, phenomena, theories, concepts, etc.

c) Helps identify gaps and inconsistencies in literature. These are used along with gaps in industry to formulate the research questions.

d) Helps in building a conceptual framework by establishing relationships between different key concepts.

The literature review has been divided into several sections. In each section, the key finding from literature on the topic have been summarized. This is shown in Figure 2.

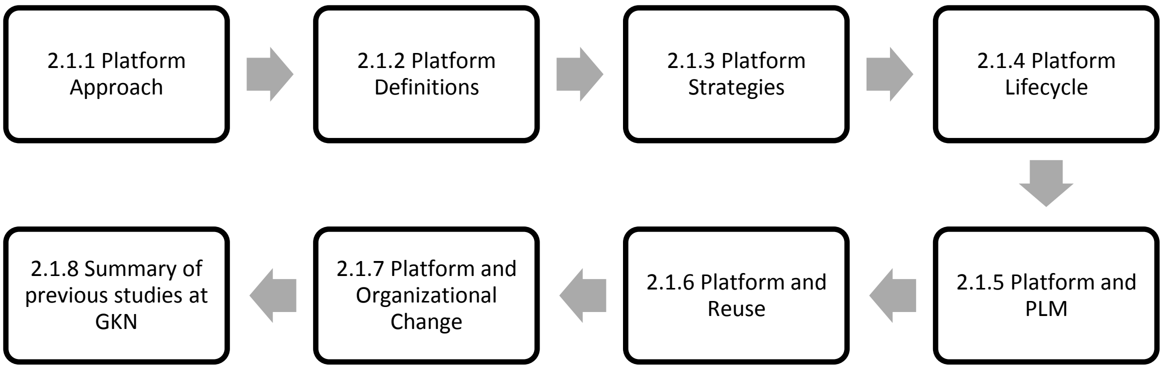

Figure 2. Topics covered in literature review

First, the general notion of platforms is discussed through examples of platform approaches and platform thinking. Platform approach or platform thinking is seen as a way for companies to obtain certain benefits that a conventional approach of single product development does not yield. This is followed by a summary of definitions of platform, product family, product platform, manufacturing platform and technology platform.

Literature on platform strategies employed in different types of industries to achieve different types of benefits has been studied and summarized.

A section on platform life cycles summarizes the need for focusing on the entire life cycle in a platform approach. Efficient resource utilization, effective integration of people and work processes and reuse of resources appear to be a common theme in platform development and closely related field of Product Lifecycle Management. Hence it has been studied to understand the support PLM systems can offer in platform development. A section on the concept of reuse and how reuse contributes to shaping a platform is discussed. A section on organizational change discusses the impact of platforms on organizational structure and work processes.

Finally, a section on previous platform research at GKN Aerospace summarizes the results of previous work conducted at Volvo Aero Corporation (former GKN Aerospace) on platform strategies for suppliers in the aerospace industry. Here, the integrated platform framework which is currently being adopted at GKN Aerospace is also discussed.

2.1.1 Platform Approach

The idea of platform approaches has been described in literature as a way of meeting varied customer and market requirements through optimisation of resources and re-use of commonalities in the development process. Platform approach has been understood to signify the purpose of a platform. Some examples of platform approach or platform thinking are described here:

a) "A platform approach is a way for companies to provide their customers with high quality products, faster than their competitors with as few resources as possible, i.e., a way for firms to manage the time, cost, quality conflict" (Levandowski, 2012). Thus, it is a way for companies to gain a competitive advantage through responsiveness and high quality offerings with optimized resource use.

b) Halman *et al.* (2003) provide a similar view in describing a platform approach. They define platform thinking as "identifying and exploiting commonalities among a firm's offerings, target markets, and the processes for creating and delivering offerings." Further, they describe it as a successful strategy for creating variety with an efficient use of resources.

c) Sawhney's (1998) definition of platform thinking also covers the two areas of variety and resource optimisation. He states that platform thinking is "the process of identifying and exploiting the shared logic and structure in a firm's activities and offerings to achieve leveraged growth and variety". This can be applied to the products, brands, target markets, geographical markets, and business processes. Finally, each dimension forms an area for the company to grow and deliver variety.

These examples demonstrate that the purpose of platforms is to be resource efficient while providing customers with a variety of offerings thereby creating a competitive advantage for the company. Also, a platform approach can include various organisational or business processes.

These descriptions of platform approach leave sufficient freedom for interpretation and adaptation for individual companies and industries. Adaptation is required as the platform approach differs for companies in different industries. Albas (2011) describes the situation for companies like GKN Aerospace that operate with complex products: “Industries that produce complex, capital-intensive and unique products differ, in terms of dynamics of innovation and nature of industrial coordination from those involved in mass-production of simple goods and even the more complex products such as automobiles. These differences then call for different approaches to applying platform theory in industrial practise”.

Below is a comprehensive list of potential benefits an organization can expect from successful platform planning and implementation. The list has been compiled by combining potential benefits cited in existing literature [(Simpson *et al.*, 2001), (Ulrich, 1995), (Muffatto, 1998)] on platforms, as well as results from case studies in industry.

a) Reduced development cost and time: One of the major benefits of a platform approach to product development is the possibility of reducing development time and cost. The reduction in time and cost comes from a planned reuse of assets.

b) Front-loading efforts in design and development: The deliberate and intentional planning of platforms contributes to reducing a large part of the uncertainty faced by designers in the initial fuzzy phases of the product development by frontloading the process. This in turn helps to improve system architecture.

c) Reduced manufacturing cost: Through a platform approach, particularly approach of using common components or parts in several products, a reduction in manufacturing cost is possible through economies of scale.

d) Reduced production investment: Machinery, equipment and processes can be shared or reused across different products and larger volumes.

e) Enhanced responsiveness to market dynamics: A platform approach allows companies to respond faster to changing market needs through the ability to quickly develop derivative products. It is also possible for companies to tailor products to needs of different market segments.

f) Lower risk: For each new product developed from a platform, there is decreased risk due to reuse of design solutions, parts or components and production processes.

g) Reduce system complexity: Exploiting commonalities allows reduction in the number of parts and processes, thereby enabling cost cutting in supply chain processes.

h) Variety in offering: High degree of variety and customer-oriented offers can be achieved through reuse of design solutions.

i) Entering new markets: Platforms can be used to capitalize on core capabilities of the firm in order to enter new markets where they are applicable.

j) Improved service: Sharing components across products allows companies to stock fewer parts in their production and service.

2.1.2 Platform Definitions

Platform terminology varies with the platform approach adopted. Terminology is generic in some cases and more specific in others. Thus, existing literature presents terminology with a varying scope and detail. Literature describes the term platform as well as product, process and technology platforms specifically. Following this logic, first the term platform has been defined and subsequently the product, process and technology platform terms have been clarified. In doing so, terms that are important to these definitions, such as product family, have also been discussed.

Platform

Robertson and Ulrich (1998) define a platform in terms of its contents stating that it is "the collection of assets that are shared by a set of products"; where these assets are divided into the categories of components, processes, knowledge, people and relationship.

Halman *et al.* (2003) also describe a platform in terms of its contents and the product family, which is the collection of products that share the same assets. A platform is therefore neither the same as an individual product, nor is it the same as a product family; it is the common basis of all individual products within a product family.

Product Family

As seen in the above definition, a product family is closely related to the definition of a platform. Due to this relation, existing definitions of product families have also been described here. Product families have been defined by Meyer and Lehnerd (1997) as a set of products that share common technology and address a related set of market applications.

Simpson *et al.* (2006) state that the product family is "a group of related products that is derived from a product platform to satisfy a variety of market niches" and Sawhney (1998) states that "the products within the product family can be seen as sharing a common gene pool". Simpson *et al.* (2006) and Sawhney (1998), thus also describe product families in terms of how they are derived from a common source, which is the platform.

Depending on the industry and the company, the scope of the platform approach can include product platforms, process platforms and technology platforms. Existing definitions of these individual platforms are now described here.

Product Platform

Meyer and Lehnerd (1997) state that "A product platform is a set of subsystems and interfaces developed to form a common structure from which a stream of derivative products can be efficiently developed and produced". McGrath (1995) includes technologies in the definition by stating that a product platform is "a collection of the common elements, especially the underlying core technology, implemented across a range of products". Simpson *et al.* (2001) define a product platform as a set of common parameters, features, and/or components that remain constant from product to product within a given product family. Meyer and Dalal (2002) define a product platform as "a common subsystem or subsystem interfaces that is leveraged across a series of individual products by means of shared product architecture". Muffatto and Roveda (2002) uses the definition "A product platform is a set of subsystems and interfaces intentionally planned and developed to form a common structure from which a stream of derivative products can be efficiently developed and produced".

As can be noticed, the above definitions of product platform vary with the scope and details of what a product platform can include. Some definitions of "product platform" are similar to definitions of simply a platform or a platform approach. Definitions sometimes specify technology, product architecture, derivatives and variants.

Process Platform

Process platforms have also been described in literature; for example Nilsson (2007) states that in a process platform, the production process, supply chain processes, etc. are standardized. This identifies criteria for optimization and building commonality, which then forms the basis for achieving variety. The variety delivered through process platforms is achieved by varying design parameters that do not upset the production efficiency.

Process platform is described as the production system setup that is used to easily produce a desired variety of products. The production system can include flexible equipment, such as programmable automation, computerized scheduling, flexible supply chain systems, and customised inventory systems (Halman *et al.*, 2003).

Looking from the perspective of processes, Sawhney (1998) describes platform thinking as the development of product families and associated process families to attain variety keeping up economies of scale. Here process families (and their respective process variants) refer to a set of similar processes that are derived from a single platform that cater towards individual customer requirements. Thus, the product platform and the associated process platform together align the efforts of the organization.

Jiao *et al.* (2000) describe the three aspects of a process platform: "(1) a common process structure (usually in the form of routings) shared by all process variants; (2) derivation of specific process variants from the common structure; and (3) correspondence between product and process variants, which resemble the correlation between the product and process platforms, namely variety synchronization".

Technology Platform

McGrath defines a technology platform as a "set of initiatives organized around a macro level functionality that helps to manage and optimize technology investments across multiple product platforms" (McGrath, 1995). He stresses that product platforms establish the required planning, decision-making and strategic thinking for product development. Integral to this are the technologies that form the basis for the platform approach. “In any product platform, one element above all others usually defines the real nature of that platform. It defines the platform’s capabilities and limitations. It defines the unique characteristic of all products developed from that platform. The life cycle of the platform is usually dependent on the continuing strength of that element. We refer to this as the defining technology. While several technologies may be necessary to create a successful product, the defining technology is most critical” (McGrath, 1995).

Jolly and Nasiriyar claim that a technology platform represents the technological competencies developed to meet a wide variety of market opportunities (Jolly & Nasiriyar, 2007). Similar to the definitions of product platform described above, technology platforms are said to encompass a related set of technologies that are common to different businesses and their respective products and processes. It is considered to be a basis for developing products resulting in market diversification. In this sense, technology platforms are broader than product and process platforms.

Technology platforms address challenges arising from diverse product portfolio where the reuse of specific components is not feasible (Shapiro, 2006). Technology development aims to build knowledge on feasibility of technologies. These technologies are then combined in product development which has concrete goals for realizing commercial products. Thus in comparison, technology platforms consist of a broad range of general and specific knowledge on all elements that could be physical or nonphysical. A well-known example of a company that uses a technology platform to drive innovations is 3M. Figure 3 shows the Technology platform used at 3M, which derives its core strength from 52 different technology elements, such as adhesives, abrasives, and vapour processing (Shapiro, 2006).

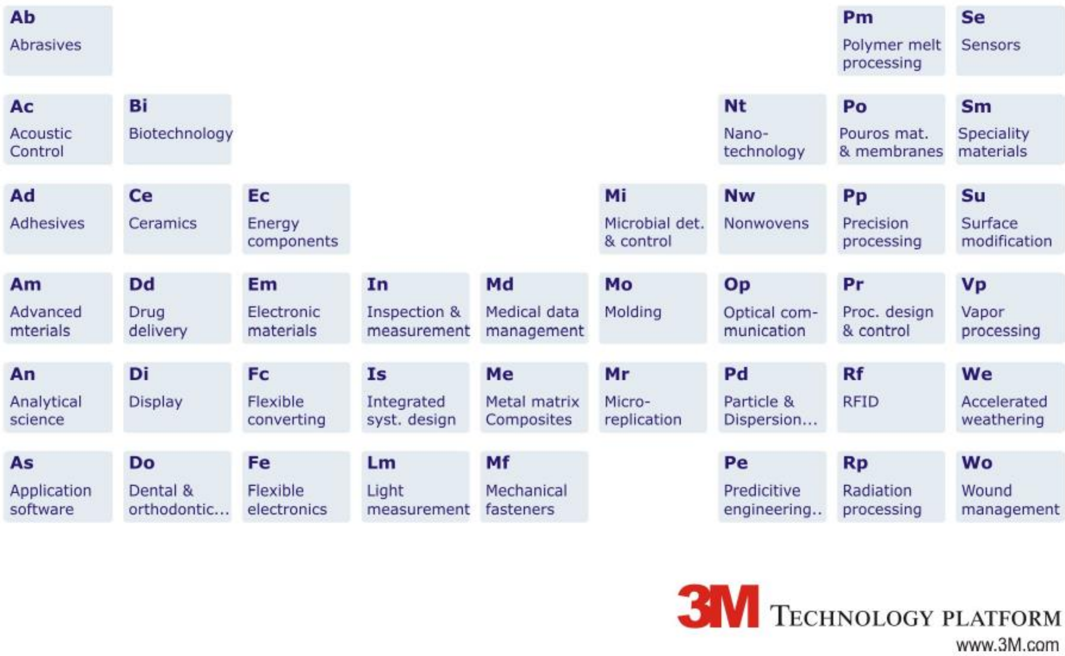

Figure 3. Technology Platform used at 3M (Shapiro, 2006)

Muffatto's research suggests that these definitions for platforms could be complemented with highlighting the need for intentionally planning the long-term development of the platform (Muffatto, 1999). Thus, platform life cycle has received interest as a research topic and has been discussed later in Section 2.1.4 on Platform Lifecycle. Nilsson (2007) states that "While there appears to be consensus about what the mindset behind a platform approach is, there are differing opinions about what one platform itself is. Some view platforms more loosely as a measure of synergy effects between developed products, thus implying all companies would benefit from platforms. Others have a narrower view that sees platforms as a tool among many that may or may not suit particular companies." The case studies conducted by Halman, *et al.* in three companies (in the power tools, semiconductor and digital printing industry) show that the narrower view including sub-systems, product families, product architecture and technologies is more predominant in industry. The wider view of platforms as reusable assets (assets include components, processes, knowledge, and people and relationships) shared by a set of products is more predominant in literature. It was also found that knowledge transfer from literature to industry has not taken place sufficiently in the companies studied, indicating a need to bridge gaps between what is prescribed in literature and its adoption in industry (Halman *et al.*, 2003).

2.1.3 Platform Strategies

While the section on platform approach describes the intention of a business with using a platform, the section on platform definitions discusses platforms in terms of its contents. In this section on platform strategies, the question of how platforms can be used to attain sought benefits is discussed.

In Section 2.1.1, the list of benefits that firms seek from platforms shows that share a cause and effect relationship with one another. However, there are aspects that do not share this cause and effect relationship and could potentially conflict one another, in the sense that the achievement of one requires a compromise to be made on another. A classic example of this is the trade-off between exploiting commonality and simultaneously delivering variety to customers. Thus, firms need to inevitably identify and define the key benefits that they are seeking, ensure that they are aligned with the overall business goals and strategies and accordingly formulate their platform strategies.

Platform strategies have received substantial attention in literature from both industry and academia resulting in variations of views on the matter. The perspectives from industry are significant due to their focus on the implementation aspect of platform principles through these strategies.

Berglund *et al.* (2008) states that the process of defining a platform strategy or leveraging an existing platform to obtain desired benefits is seldom straightforward. Development of a platform strategy is "a long-term effort that needs to be done while managing existing product portfolios and rapidly changing demands". As a consequence, creating a platform strategy not only entails long-term technical decisions but is also strongly linked to business processes and how the firm operates.

Robertson and Ulrich emphasize that a platform strategy must balance the trade-off between commonality and distinctiveness (Robertson & Ulrich, 1998). It has been widely acknowledged that to gain synergies in product development, a product platform should be shared across a wide range of products [(Meyer & Lehnerd, 1997), (Meyer & Utterback, 1993), (Robertson & Ulrich, 1998)].

Muffatto stresses the importance of planning the platform generation before the development of a whole product range is started. In his study he finds that when platform development is unplanned, striving to satisfy needs in product distinctiveness results in excessively constraining the new products that have un-optimized interfaces between components. He concludes that the evolution of the product ranges over the years has to be planned to realize the benefits of a platform and not fall prey to its pitfalls (Muffatto & Roveda, 2002).

Nilsson describes one of the traditional platform strategies where a set of generic design solutions to be used in product variants is specified by a product family architecture (PFA). It is the PFA that needs to be optimized to obtain variety by exploiting commonality. In doing so, the entire supply chain must be considered to find areas of commonality. He also finds in his study that the generic solutions are intentionally planned for before designing the PFA and the design rules. In this strategy, the design of the product variants requires less effort once the PFA has been defined. Thus, a development process is decided for the entire product family (Nilsson, 2007). Miller adds that, throughout the life cycle of the platform the core technology and the functional architecture must be stable (Miller, 2001).

Nilsson states that goals for commonality are necessary for identifying what will remain constant in the product family. This is usually done by identifying areas where variety has a high cost to the company but a low value to the customer. Finally, based on the elements of commonality, variety, and complexity, suitable product and process architectures should be designed. Thus, an efficient process can be developed for creating variety (Nilsson, 2007).

Pedersen arrives at a similar conclusion regarding platform strategy in his study stating that "the degree of reuse and the degree of encapsulation is different in a product platform approach compared to a traditional single product development approach." Here encapsulation is the process of breaking down a system into smaller pieces and making these pieces relatively independent. According to Pederson, platform strategy decision makers have to:

a) know why the platform is pursued, i.e. behavioural aspects,

b) know how the effects are obtained, i.e. procedural aspects, and

c) know what the platform contents and interrelations are, i.e. constitutive aspects.

He classifies these as fundamental prerequisites being crucial for the success of a platform approach (Pedersen, 2010).

Simpson recounts two basic approaches to product family design - top down and bottom up. In a top down approach a family of products is intentionally and strategically developed from a platform. In a bottom-up approach a group of existing products are consolidated and their components are standardized to enable higher economies of scale. Either approach is associated with one of the two basic platform models, module-based and scale-based. In a module-based platform "product family members are instantiated by adding, substituting, and/or removing one or more functional modules from the platform", whereas in a scale-based platform, "one or more scaling variables are used to 'stretch' or 'shrink' the platform in one or more dimensions to satisfy a variety of market niches." (Simpson, 2004).

Alizon *et al.* (2009) describes two strategies to develop product families: a platform-driven strategy and a product-driven strategy. In a platform driven process, the platform is specified at the beginning and all products in the family are developed and launched at the same time based on this platform. In a product driven process, only one product goes through the product development process from design to manufacturing and is then launched in the market. So the platform is not directly specified and the initial product is used as the basis for future variants.

Pedersen mentions Bladwin & Clark's study (Baldwin & Clark, 1997) in stating that companies may choose either of two following strategies for a platform:

a) Setting an architectural standard that specifies rules on designs and interfaces within which sub suppliers can function.

b) Delivering modules that conform to the architectural standard of another company (Pedersen, 2010).

Formulation of platform strategy can be done through platform planning. Ulrich *et al.* (1993) describes platform planning to be an iterative cross-functional activity that is generally carried out by core representatives from product planning, marketing, design, and manufacturing functions with support from experienced staff. The strong role of top management support is imperative in this process because platform decisions have significant bearing for the organization at a corporate level, deciding the course of the business over the short-term and long-term future, cutting across product lines and divisional boundaries, requiring resolution of cross-functional conflict. Functions that focus on customer features are in conflict with functions focusing on production processes and top management is required to impart a perspective which enables making the complex trade-offs necessary for achieving the best overall solution. Intentional prior platform planning is necessary for implementing platforms. "Just as good product engineering involves up-front consideration of manufacturing issues, good platform planning requires up-front consideration of design and manufacturing issues". Product plans, differentiating plans and commonality plans have been suggested for planning platforms.

The use of a product-process matrix has also been suggested for strategic planning of platforms where product structure and process structure combinations are studied. The horizontal axis of the matrix represents stages of the product life cycle, and the vertical axis represents the process life cycle ranging from flexible but inefficient processes to inflexible but efficient processes (Hayes & Wheelwright, 1979).

2.1.4 Platform Lifecycle

Literature on platforms is largely centred on platform strategies for creating platforms to obtain different kinds of organizational benefits. There is however little focus on long-term platform strategies for platform use, maintenance and renewal to ensure that implementation of platforms will meet long-term business goals. In this section, the existing literature on platform lifecycles and its relation to product and product development lifecycles is discussed.

A lifecycle is a pattern of predictable changes. Products as well as organizations evolve through a standardized sequence of transitions over time. For instance, product life cycles follow transitions from initiation, first version, market launch, to end-of-life. Since platform development is an approach to leveraging development of product instances, platforms must accordingly evolve through stages of a life cycle to accommodate for changes from new and improved design, process knowledge and technologies (Alblas, 2011).

Pedersen outlines three fundamental phases in the development of a platform: platform preparation, platform execution, and platform maintenance (Pedersen, 2010). Platform preparation involves creating the platform as well as the knowledge base required to do so. This involves among other activities, formulation of a vision for the platform and strategies for how to use it. If the platform is prepared correctly, then execution of the platform is the relatively easier phase of actually creating the product. Platform execution depends on the vision for the platform and the strategies for its functioning. It could involve on one extreme the automated creation of variants. On the other extreme it could be the creation of solution concept proposals that require further development for both product design and manufacturing systems. In between, lays a number of other cases such as assembly of pre-defined modules; creation of solutions using configurable components and interfaces; creation of a quotation for replying to a customer order, for example. In all cases, execution involves using the output of the platform preparation activities to execute the vision for the platform through the previously defined strategies.

Alblas describes and distinguishes three lifecycles – product, product development and platform lifecycle. It is common for the aerospace industry that produces complex products and systems, to not make a clear distinction between the product development lifecycle (PDLC) and product platform lifecycle (PPLC). According to the case studies conducted by Alblas in this industry, there is often no explicit product platform that specifies interfaces between main components of the plane in a separate product platform life cycle (PPLC). If the platform (i.e. the specification of the interfaces) is distinguished properly from the existing version of the plane, a more sophisticated change management can be enabled and it becomes possible for instance, to discuss whether a proposed new version will still satisfy the interface definition of the platform (Alblas, 2011). The relationship between life cycles of products, product development and product platforms is shown in Figure 4.

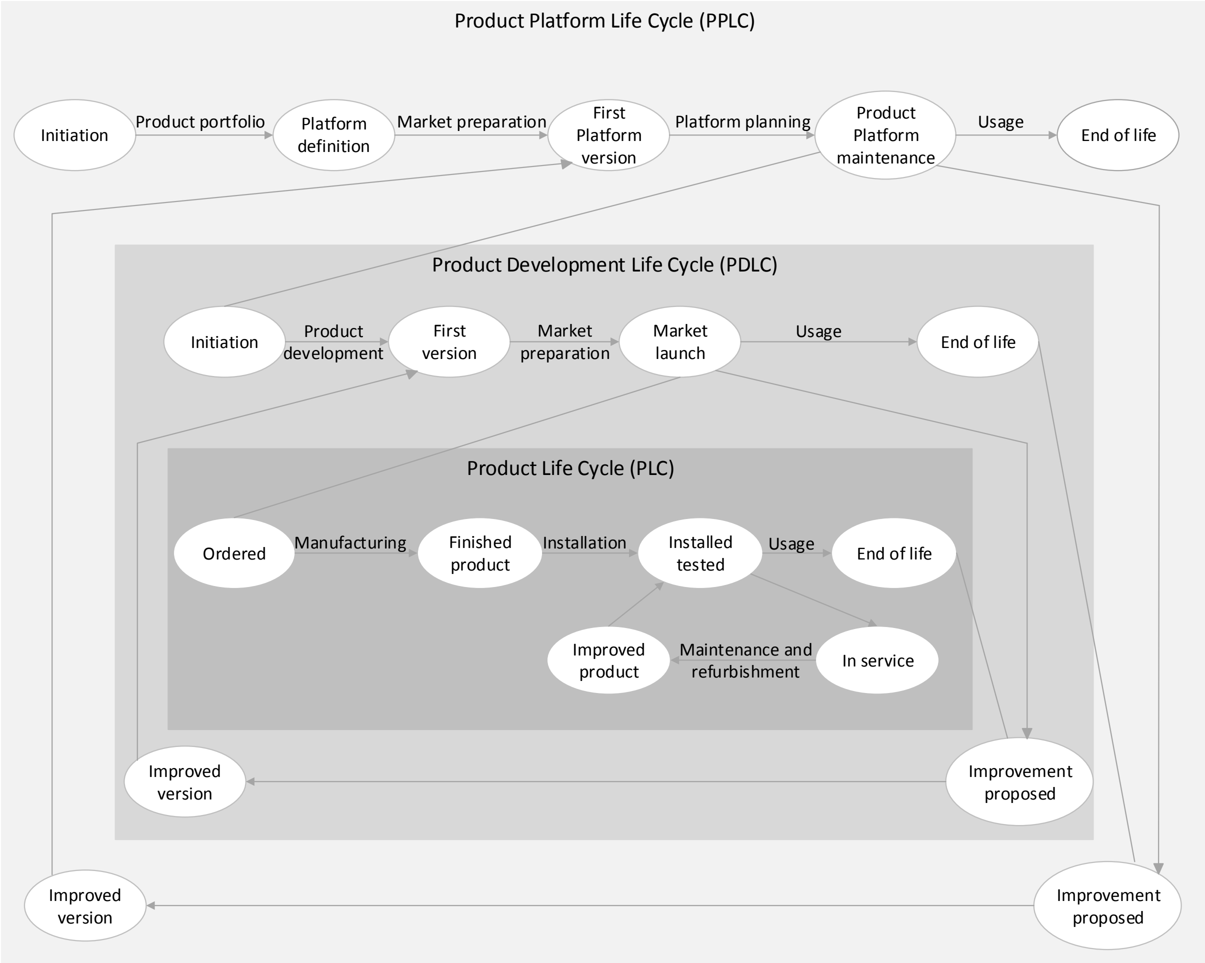

Figure 4. Relationship between product, product development and platform lifecycles (Alblas, 2011)

Similar to Pedersen's definition of the lifecycle, Alblas suggests that a development process in a platform-based industry should begin with the planning and development of a platform. He then goes on to suggest that the first version of a platform sets design margins for the product development lifecycle, which involves the development of a range of products. These design margins arise from the limits and opportunities in a current version of the platform in developing a desired range of products. Changes that are caused by new design knowledge should be aligned with the platform. In this way, the design knowledge extracted from improved version of the design will be systematically reused by the platform. Similarly, the product development lifecycle should set the margins for individual designs. Systematically, information feedback from the individual product documents to the design and platform documents is essential for structured information reuse. In this way, individual product knowledge is reused (Alblas, 2011).

2.1.5 Platform and PLM

"Product Lifecycle Management (PLM) is an integrated, information-driven approach comprised of people, processes/practices, and technology to all aspects of a product's life, from its design through manufacture, deployment and maintenance - culminating in the product's removal from service and final disposal" (Grieves, 2005). Stark highlights that PLM includes products, data, applications, processes, people, work methods and equipment (Stark, 2011). Descriptions of a PLM system by Svensson *et al.* (1999) also develops on the same components. PLM focuses efforts of the organization in a "joined-up" way; this means that it simultaneously addresses what used to be separate and independent processes, disciplines, functions and applications. With respect to implementation of PLM systems, Stark notes that it causes changes in organizational structures, processes and applications. It calls for adapting the approach for defining and structuring products and product data. And to bring about these significant changes, it is common to implement formally defined PLM Projects. (Stark, 2011).

Mesihovic *et al.* (2004) describes the role of Product Data Management (PDM) systems as keeping track of the masses of data and information required to design, manufacture, deliver and maintain products during the entire product lifecycle. They find that PDM systems include product information such as "part definitions and other design data, engineering drawings, software components of products, product specifications, production specifications (tools, methods, production control software), analysis results, correspondence, bills of materials". They also enable providing the wanted information, in the required format to the right people. In this way they play a part in the workflow.

Pedersen (2010) finds that "PLM systems have the prime purpose to combine different viewpoints and often a role of integration between the domains of the other IT systems (CAD, PDM, ERP etc.)." Johannesson & Gedell (2006) describes the role of PDM systems for product platforms to be a carrier and manager of parts, documents and information that belongs to the platform. It is the natural integrator of the IT support in a product development environment and functions as a workflow manager.

From these definitions of PDM and PLM it can be seen that PLM systems also incorporate the information authoring tools, the people who use them and the processes involved. Abramovici & Sieg (2002) further clarifies this view by stating that "PLM is the extension of PDM towards a comprehensive approach for product related information and knowledge management within an enterprise. This includes planning and controlling of processes that are required for managing data, documents and enterprise resources throughout the entire product lifecycle".

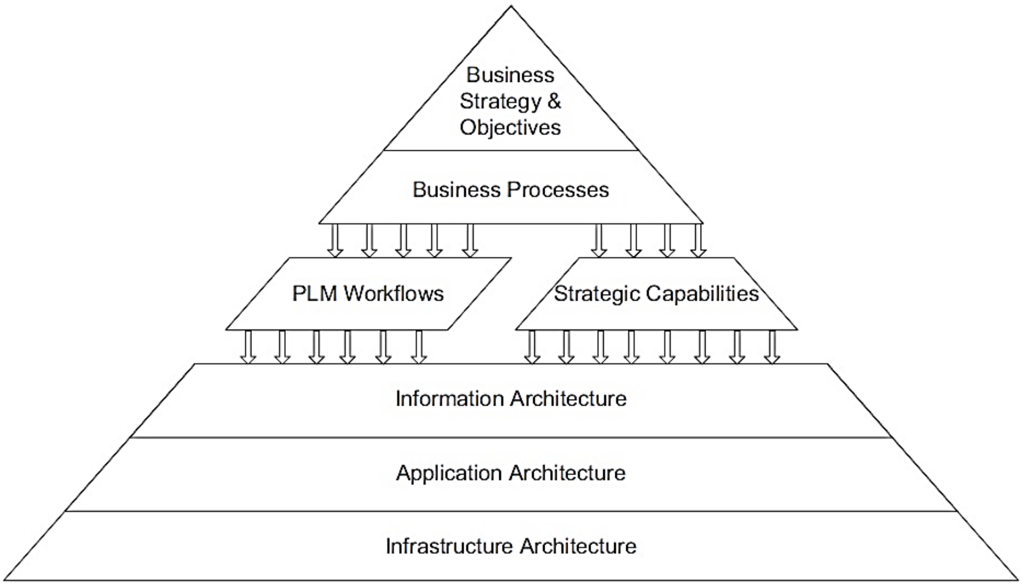

Figure 5. Description of PLM architectures, adapted from (Zimmerman, 2008) by (Catic, 2011)

PLM architecture is defined as an IT-centric enterprise architecture that comprises of several layers or sub-architectures as described in the Figure 5. The application layer manages the use of several IT applications by assigning tasks to each of them (Catic, 2011).

Simpson *et al.* (2006) finds that PLM solutions have become important to companies enabling them to manage product information from various life cycles. The currently available tools do not facilitate knowledge sharing for product platforms and there are many opportunities for knowledge management to support platforms.

Levadowski points out that PDM solutions are limited in their offerings as they are currently best suited for individual products and not complete product platforms. Also, given the other challenges inherent in platforms such as the balance between commonality and variety; there is a need for fresh approaches in platform descriptions and the IT solutions that support them. He states: "What is needed is an integrating tool that handles all knowledge related to the whole platform system as well as to its contained sub-systems and components, the relations between contained items and the rules governing the use of the contained knowledge for different purposes during the platform lifecycle." The support required might even extend beyond the products and their life cycles. The relationship of the platform with its context such as the work processes, work flow, project set-ups also need to be managed. This requirement is within the scope of PLM solutions but currently available ones still do not satisfy this requirement (Levandowski, 2012).

Given the wide scope of PLM solutions and the support that they could provide to platforms, Levandowski states it is still unclear how different tools in a PLM framework would work together in Engineering Change Management and other functions for which the entire design space has to be represented and analysed (Levandowski, 2012). Pedersen also finds that "the different commercially available IT-systems provide many strong opportunities in relation to product platform modeling, yet the use of them often results in shortcomings in a product platform context" (Pedersen, 2010).

Pedersen (2010) observes that commercial IT-systems are often meant for use at a concrete and detailed level and are unsuitable for conceptual level work. Often, several systems tend to be used for the same purpose (e.g. two CAD system brands used with parallel sets of models). Similar but different product models could be present in different IT systems, such as bill of materials in the Product Data Management (PDM) and Enterprise Resource Planning (ERP) systems. These different systems are often not suitably integrated and require considerable manual information exchange. This can happen in manufacturing companies where the IT systems are not appropriately planned from before, posing problems to the use of these systems in platform preparation and execution.

2.1.6 Platform and Reuse

Engineers intuitively reuse previous designs and knowledge either on an abstract level through the use of concepts or knowledge, or through the use of carry-over parts when performing new design tasks.

Effective engineering reuse entails reusing an organization's assets such as modules, designs, processes, suppliers and teams. The major premise for reuse is lowered cost of engineering, innovation and technology management process in the firm when successfully applied (Antelme *et al.*, 2000). The following, as examples are cited for successful reuse of assets: reusing product platforms in order to gain reduced time to market for new products and increased market coverage, reusing designs to reduce development time, cost and risk, standardizing parts to gain advantages of high volumes

Davis (1994) emphasizes the importance of an organization's commitment to a reuse strategy in addition to the availability of reusable assets. Five components of a reuse strategy as listed by Davis are as follows:

a) deciding what products should be developed with reuse and what products should be developed for reuse,

b) how the business model should be adapted and how the creation of reusable assets should be financed,

c) decide on what processes, methods and tools are needed to manage reusable assets,

d) how organizational structure, roles and responsibilities are affected, and

e) how to plan for transition into reuse-based development.

From the Section 2.1.1, it was seen that platform approaches described in literature and adopted in industries are largely based on exploiting reusable assets. Depending on the vision and benefits sought, the suitable assets to be reused could be concrete like components and manufacturing equipment; tangible like design solutions and production processes; or intangible and abstract like knowledge and expertise.

Based on reuse methodologies for software development, Duffy *et al.* propose a model for improving reuse effectiveness and argue that the use of a formal approach would improve understanding of the reuse process. The model divides reuse into three processes - design by reuse, domain exploration and design for reuse. While ‘design by reuse’ involves designing by applying previous knowledge, ‘domain exploration’ and ‘design for reuse’ involve creation of reusable knowledge. The purpose of these processes is to first recognize the required knowledge and then to document it for effective reuse (Duffy *et al.*, 1995)

Antelme *et al.* (2000) outline a framework for engineering reuse where physical artefacts, processes, core competences and capabilities are reusable assets. They state that, all reusable assets can be included in the broad umbrella of ‘technology’ and define engineering reuse as technology reuse. The framework supports and facilitates engineering reuse, taking technological assets as a central example. It has three core elements, namely - Technology Creation, Technology Specification Management and Technology Utilisation. It facilitates obtaining an understanding of the flow of data and business consequences for reuse of an asset. In addition, they propose an operational level guide to provide practical support to a business for reuse of any type of asset. This consists of two phases: the creation of a reuse strategy and the implementation of reuse concepts.

Hunt *et al.* have built upon this framework developed by Antelme *et al.* by suggesting a process that firms can follow for creating a reuse strategy and a plan for its implementation (Figure 6). It starts with identifying a business need for reuse, which is important for backing financial decisions about resource allocation to reusability efforts. Next, available assets are identified and an evaluation of options for reusing them is made. This is followed by a phase during which specific and detailed plans are made to implement the most viable options. Although it is not specified, there is an implied existence of other processes for further developing those assets that have potential for reuse (Antelme *et al.,* 2000).

The development of platforms is seen as one of the most prominent approaches to development for reuse and development with reuse. Development with reuse is the strategy of defining common characteristics in a family of products and thereby reducing their technical variation while maintaining or increasing diversity in terms of functions that can be achieved and offered to a broad market base (Corin Stig, 2013). There are two views on platforms as an approach to reuse. The first one is focused on sharing and reusing physical elements among a number of products which constitute a family of products. The other view focuses on a more broad approach to reuse including logic, knowledge and people possessing and using the knowledge (Jiao *et al*., 2007).

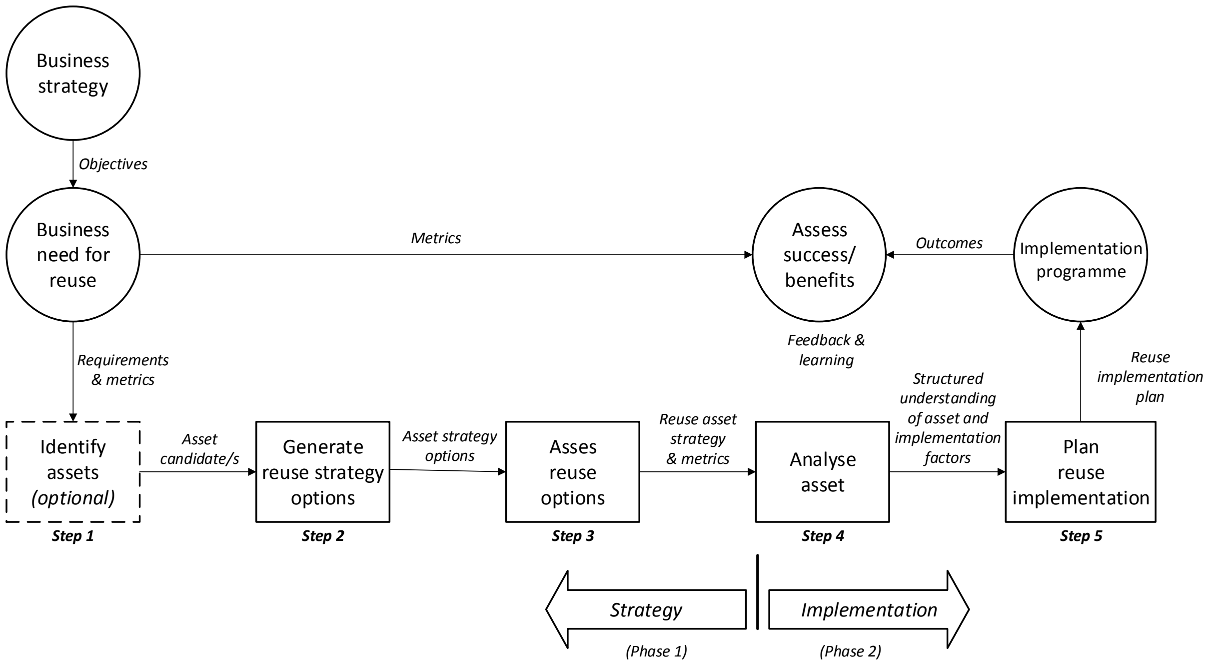

Figure 6. Process for creating and implementing a reuse strategy adapted by Hunt *et al.* (Antelme *et al.*, 2000)

Pedersen captures a similar view through the concepts of reuse and encapsulation. Encapsulation is the process of breaking down a system into smaller pieces and making these pieces relatively independent. However the manner in which this independency takes place is not specified thereby not implying a physical demarcation. According to Pedersen, reuse and encapsulation are the two most fundamental characteristics of a platform. However, they can take place in companies even without a platform approach. The degree of reuse and encapsulation is different in a product platform approach in comparison to the development of a single product. Consequently, what makes a product platform unique is the deliberate and planned reuse and encapsulation (Pedersen, 2010).

As part of a case study conducted at VAC (former GKN Aerospace), Corin Stig (2013) found that the reuse of technologies faces the following challenges:

a) Difficulty in locating, transferring and deploying knowledge gained from previous development projects

b) uncertainty in forecasting what technologies to develop for future reuse

c) the need to adapt technologies before introducing new applications.

2.1.7 Platforms and Organizational Change

Adopting platform-based development can be seen as a way to reduce the disadvantages of offering high product variety. In this regard Galsworth (1994) states that “dismantling organizational complexity is the first step in reducing the negative effects of product variety”. Amburgey *et al.* (1993) find that “in most cases, organizations strongly resist change”. This could be because organizations are embedded in the institutional and technical structures of their environment (Granovetter, 1985).

Keen (1981) refers to social inertia as not being able to make things happen despite trying. In relation to information systems he lists the main causes for inertia. One of the primary causes is that information represents a small part of the organizational decision process. Processing of this information is experiential and requires simplification of information by a human. Another cause is that change is inherently incremental and evolutionary. Given the complexity of organization, large increments are avoided and even resisted. Finally, he also states that data is a "political resource, whose redistribution through new information systems affects the interests of particular groups."

Hannan and Freeman (1984) state that the existence of organizations is due to their ability to perform with reliability and rationally justify their working. This reliability and accountability increases with the institutionalization of organizational goals and with the degree of routines in their activity. It is this institutionalization and reutilization that cause the inertia against organizational change thus reducing the probability of change. From the perspective of internal and external stakeholders, organizational change has also been referred to as hazardous because they disrupt internal routines and external linkages directly or indirectly. These elements have been said to define the activity and knowledge of the organization [(Levitt & March, 1988), (Nelson & Sidney, 2005)]. Organizational change increases the failure rate of organizations, independent of the effects of the changed characteristics (Amburgey *et al.*, 1993). Organizational change and organizational strategy being closely related [(Brunes, 2004), (Rieley & Clarkson, 2001)], the introduction of a platform at GKN Aerospace could also be seen in the light of an organizational change deliberated through the implementation of a platform strategy.

Structured approaches to address organizational change have also been described in literature. Change management has been defined as "the process of continually renewing an organization's direction, structure, and capabilities to serve the ever-changing needs of external and internal customers" (Moran & Brightman, 2001). Balogun and Hope Hailey (2004) states that 70 per cent of all change programmes in organizations fail. This could be because of the "fundamental lack of a valid framework of how to implement and manage organizational change as what is currently available to academics and practitioners is a wide range of contradictory and confusing theories and approaches" (Brunes, 2004).

Muffatto points out that the relationship between platform organization and product innovation through platform-based development is very important. Looking at platforms from an organizational perspective in the automotive industry, Muffatto states that platforms provide the means for developing cross-functional teams or platform teams within product development, doing so by adopting various product aggregation criteria. Usually technical product criteria take precedence but market segments and supply chain are also considered. The platform strategy adopted has effects on the product development process and the organizational structure (Muffatto, 1999).

Muffatto identifies that the general pattern in automotive industry has been to derive platforms from existing products. Here Muffatto mentions that "companies with a broad definition of platform need to take more account of the platform concept within the overall development process”. Co-location of platform teams is possible and varies from one firm to another. It is also stressed that the “existence of consolidated organization structures, whose validity is recognized, can prove a disincentive to experiment with new structures such as those based on platform teams” (Muffatto, 1998).

Nilsson highlights that most platform strategies discussed in literature [e.g. (Meyer & Lehnerd, 1997); (Dahmus *et al*., 2001); (Krishnan & Gupta, 2001)] “are top-down in nature and require company-wide realignments.” In the example of Black and Deceker’s power-tool product platform, the management dealt with the power tool product line as a whole. They bridged engineering and manufacturing simultaneously redesigning both products and processes. The most important action that drove the platform development was the “long-term vision of the senior management for whom this initiative was a top priority” (Meyer & Lehnerd, 1997). While considering the organizational aspects of platforms it is important to note that a company’s development culture influences the platform strategy. Muffatto finds that the high autonomy among Honda work groups makes sharing a challenge. Likewise, the presence of powerful project managers at Honda makes adoption of platform concept difficult (Muffatto, 1998).

Simpson (2006) shares a similar view that introduction of platforms is an enterprise wide initiative that goes beyond planning and product development, thus making it an organizational change. He goes on to refer to upper management as a catalyst for change and notes that reorganization around platforms with fail without strong support from upper management. He gives an example of IBM’s successful reorganization around product platforms by stating that it “produced dramatic results, but it was only because IBM’s CEO at the time, Louis V. Gerstner, spearheaded the culture change by appointing senior management to lead the effort and commit the required resources”.

Pedersen notes that this results in a “corporate culture change in the sense that people and working patterns change and the organizations have to change the way functional and business units are separated in order to ensure sharing and reuse of knowledge across departmental and organizational borders” (Pedersen, 2010). Platform initiatives affect the entire lifecycle and of the product and require planning of other phases such as purchasing, fabrication, assembly, distribution. Thus, the cross functional nature of platform teams and platform development follows naturally.

The issue of the context in which platforms exist receives attention from the need voiced by industry. Industry has called for approaches and methods to transform the organization in order to support platform strategies (Simpson *et al.,* 2006). He even goes as far as saying that “If the purpose of a company is to produce products to generate profit (based on platforms), then perhaps the organization should be designed around the platform rather than the other way around.” This appears to be a drastic reformation of the organization and might not be necessary at GKN Aerospace but it nonetheless points towards the importance of considering the organizational context in which the platform exists. Meyer and Lehnerd (1997) also states that organizational change can be the biggest challenge where one has to obtain the support and involvement from the entire organization for developing and using the platform.

It is important to take into account, the people of the organization when planning for the platform. This is especially important because people are creators of the platform, users of the platform and sometimes the objects of the platform as well (Pedersen, 2010). Introduction of new tools and IT systems is a major issue. However, these issues are still small compared to those presented by the organizational change. This makes imperative, a revision of working processes (inevitably tied to people) in line with platform-based thinking. Establishing viable processes for creating reusable knowledge and accompanying processes for using this resource still presents a major hurdle in the path of platform-based product development.

2.1.8 Previous studies on platforms at GKN

From previous studies on platforms at VAC (former GKN Aerospace) it has been found that formulating a product platform consisting of common modules or components is not a fruitful strategy. The lack of control over the entire system architecture and the highly customized nature of products, which are governed by design drivers such as weight or overall system performance, make a modular product platform approach unsuitable. This is also because there is a risk of investing too much in reuse of methods and tools that are too specific to a certain architecture which may then be inapplicable in future a project (Berglund *et al.*, 2008).

A platform strategy for technology development was proposed by Högman as shown in Figure 7. It includes "a technology platform consisting of general knowledge on core technology assets embodied in either humans, organizations, processes, information or methods, and a product platform, incorporating product specific elements that could be re-used when developing new components for a particular product line. When developing a new product, knowledge and capabilities are drawn from both the formulated product platform and the technology" (Högman, 2011).

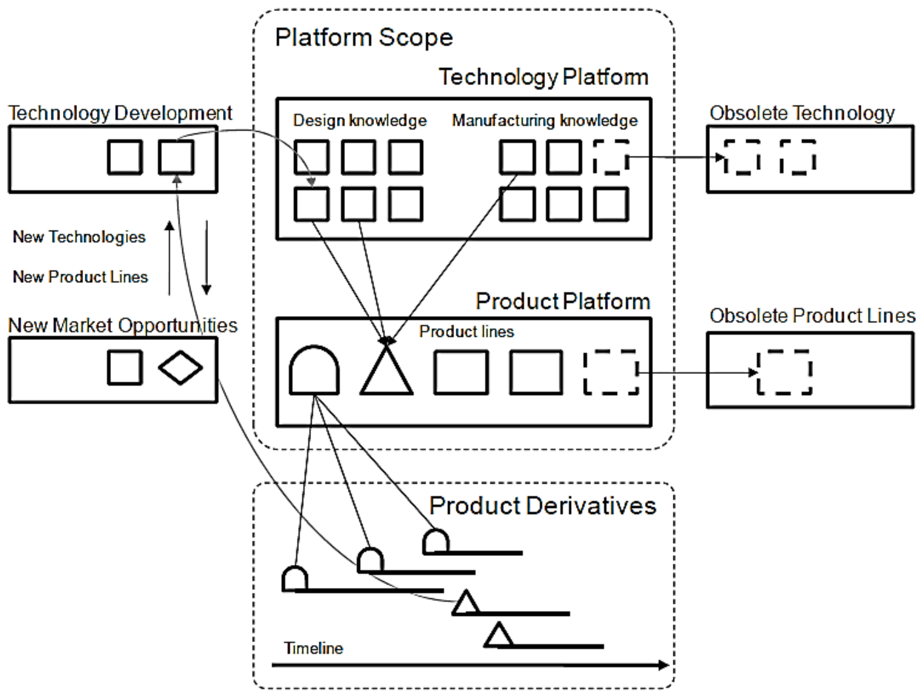

Figure 7. A proposed platform strategy for GKN Aero, including technology and product platform (Högman, 2011)

Reuse of assets in the organization was found mostly at levels of higher abstraction. Four dimensions of reuse were identified, including reusability between products with different applications, reusability between different generations of the same product, reusability of similar products in different sizes and reusability of similar components offered to different customers. Within each dimension, reusability of 11 different types of elements was investigated. The elements of higher potential for reuse included people (employees with competences, expertise), support systems (routines, standardised work processes, reusable models) and materials (material characteristic data, material applicability in different application, etc.). Manufacturing and simulation methods were found to have medium to high reusability. Manufacturing equipment, structural designs, design elements and interfaces were found to have relatively low reusability except in similar components offered to different customers (Högman *et al.*, 2009).

As part of recommendations for GKN Aerospace, Corin Stig (2013) proposes a Wiki based technology catalogue to support the integrated technology and product platform development. This would be accessible as an additional layer of information to find detailed information on technologies. Requirements for using such a tool have been identified as:

i. Establishing roles and organizational entities that would be responsible for managing the technology information and the Wiki interface and maintaining ease of use.

ii. Developing a company culture and establishing explicit requirements to encourage the entry of information and lessons learned from the various stakeholders. Also, incorporating readiness metrics (such as Technology Readiness Levels) for different applications to enable application of developing technologies in product development.

iii. Providing traceability through 'Yellow Pages' information on the experts who possess tacit knowledge on the different technologies present in the Wiki pages.

iv. Developing a company culture and work processes that direct employees to search for previous knowledge before starting development.

Claesson describes platform as "a common knowledge based configurable system model containing system design rationales (including requirements, generic design concepts and decision history) and rule based models for variant instantiation plus common resources used by the configurable system model." In Claesson's definition, the knowledge-based platform which consists of configurable sub-systems forming system structures, provides more configuration flexibility than a part based defined platform. The Configurable Component (CC) concept proposed by Claesson aims to deviate from the physical parts paradigm in order to support the use of the platform as a configurable system model. This deviation is made because of the inability of a physical parts based platform to provide adequate support in early phases of product development. Here, term platform refers to the product platform (Claesson, 2006).

The role of the above-mentioned Wiki based solution (Corin Stig, 2013), CC concept (Claesson, 2006) and technology platform (Högman, 2011) is shown in the platform framework proposed by Lewandowski *et al.* (2013) in Figure 8.

The framework is constituted of a core platform and related components. The core platform contains the high value reusable assets of the company. A product platform, a production platform, and a technology platform together form the core or integrated platform. The product platform contains product families and design concepts and the production platform contains production methods and concepts. Manufactured components, machines in the factory, and immature technologies are not consider as reusable assets and are not part of the platform. These reusable assets of the platform are used to develop new product and production concepts. Also matured technologies are tested through different applications. The platform is expected to support synchronization of product development and production by providing process support for parallel development. Finally, the platform framework is used to address knowledge gaps, prioritize development projects and spread new knowledge within the company.

The technology platform is proposed to be implemented using a wiki within a PLM environment. In this definition, the product platform proposed is based on a PLM architecture incorporating the CC concept. This concept uses reconfigurable sub-systems to configure product variants as per customer requirements (Levandowski *et al.*, 2013). Figure 9 shows technology development using a technology platform and product variant development using a product platform and the IT support required.

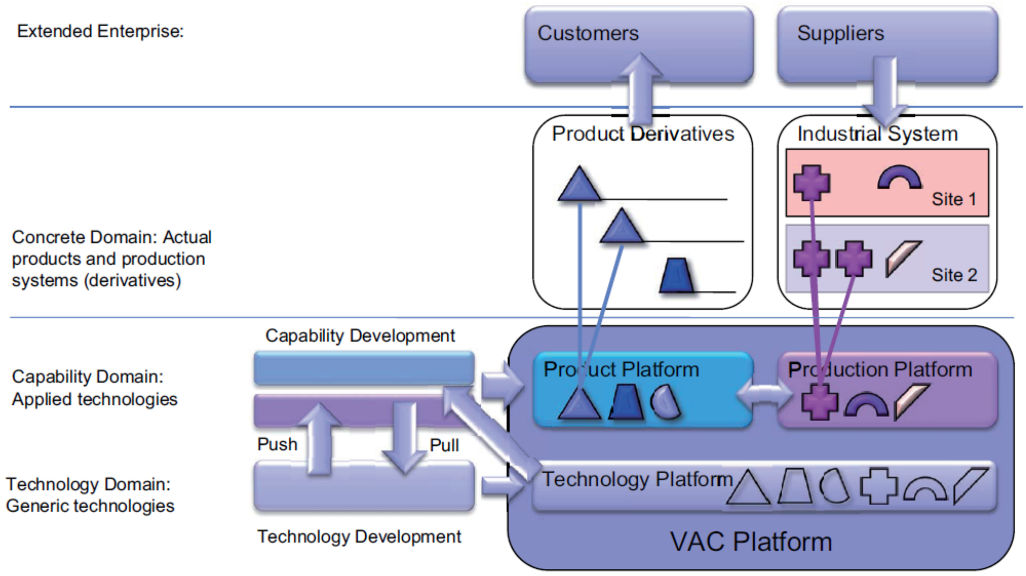

Figure 8. VAC platform framework proposed by (Levandowski, *et al.*, 2013)

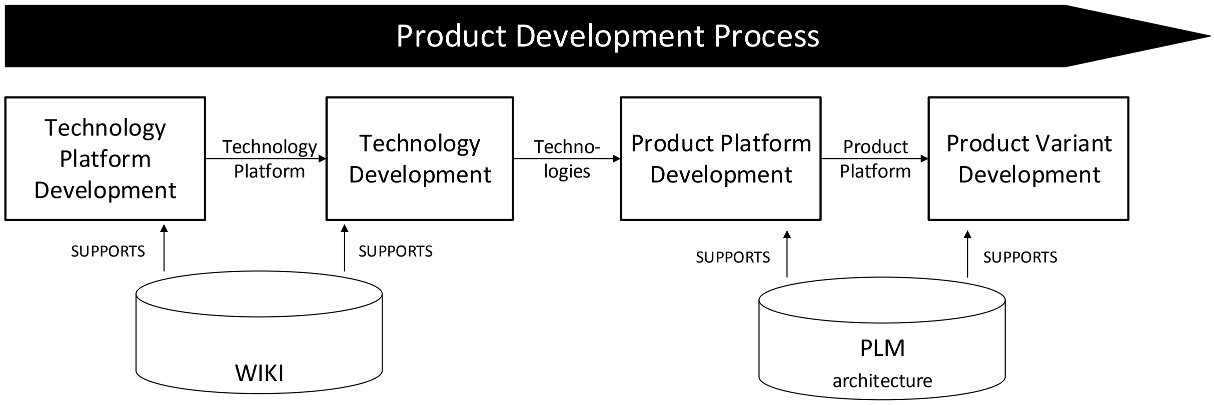

Figure 9. A simplified product development process using platforms proposed by (Levandowski *et al.*, 2013)

Platform Preparation and Execution

Here, the proposal is that results from advanced engineering department within GKN Aerospace be made generic and included in technology platform development projects. This helps in preparing the technology platform. The technology platform would then provide a base for developing new technologies that are to be incorporated in new products. This in turn helps in creating a product platform that consists of reusable technologies. This development is continuous and concurrent and is supported by the Wiki.

The product platform supports product development in conceptual and detailed design by providing reusable and configurable assets such as the technologies developed and parametric or scalable models. The platform supports scoping of new development projects during start-up, making estimates and ensuring producibility of variants. The proposed PLM architecture includes integrated CAD system, two CAE systems, one configurator, and one PDM system.

In this report, when the term platform is used in the context of GKN Aerospace, it refers to this integrated platform framework (Figure 8), unless otherwise stated.

2.2 Conceptual Framework

This section presents a conceptual framework for the study. “A conceptual framework is a visual or written product that explains either graphically or in narrative form the main things to be the studied i.e., the key factors, concepts, or variables and the presumed relationships among them” (Maxwell, 2005). The framework was built by combining the various concept maps drawn for each concept described in the literature review, and identifying relationships between them.

The purpose of constructing a conceptual framework as proposed by Maxwell is to:

a) Obtain an understanding of existing theory and research relevant to the study and use it to identify and address a need or unanswered question.

b) Create a logical connecting thread between several approaches, lines of investigation, theories and concepts already developed in the field and its related areas.

c) Lay down assumptions which govern the methods chosen for data collection and analysis.

d) Visually or graphically represent the above in an easily understandable manner (Maxwell, 2005).

After a preliminary review of literature, three fundamental question were identified that must be answered in the development of a platform

- *Why* is a platform approach being adopted?
- *How* can such a platform be created and used?
- *What* kind of constituents must a platform have to meet its intended benefits?

The conceptual framework is shown in Figure 10 and has been built based on literature, problem identified and the research goals. It is accordingly divided into three major chunks, each addressing one of the three fundamental questions: why, how and what.

Platform approach and vision address the *why* aspects of the study. Within existing literature on platforms, a gap has been identified between platform approaches and strategies prescribed. While approaches deal with the reason for choosing platforms on a broad visionary level, theory fails to provide adequate support in the form of tools, methods, guidelines for decision-making in platform vision formulation. For instance, guidelines, methods and tools to carry out economic analyses on platform aspects within an organization, which would in turn help determine if investing in a platform is the way forward, were found to be lacking in literature on platform approaches and strategies. Thus, the first research gap found was the lack of sufficient literature on metrics, tools, methods and processes that support the formulation of a platform vision. This research gap was also found by Halman *et al.* (2003) in their case study, where companies pointed at a lack of support in platform decision-making and valuation support.

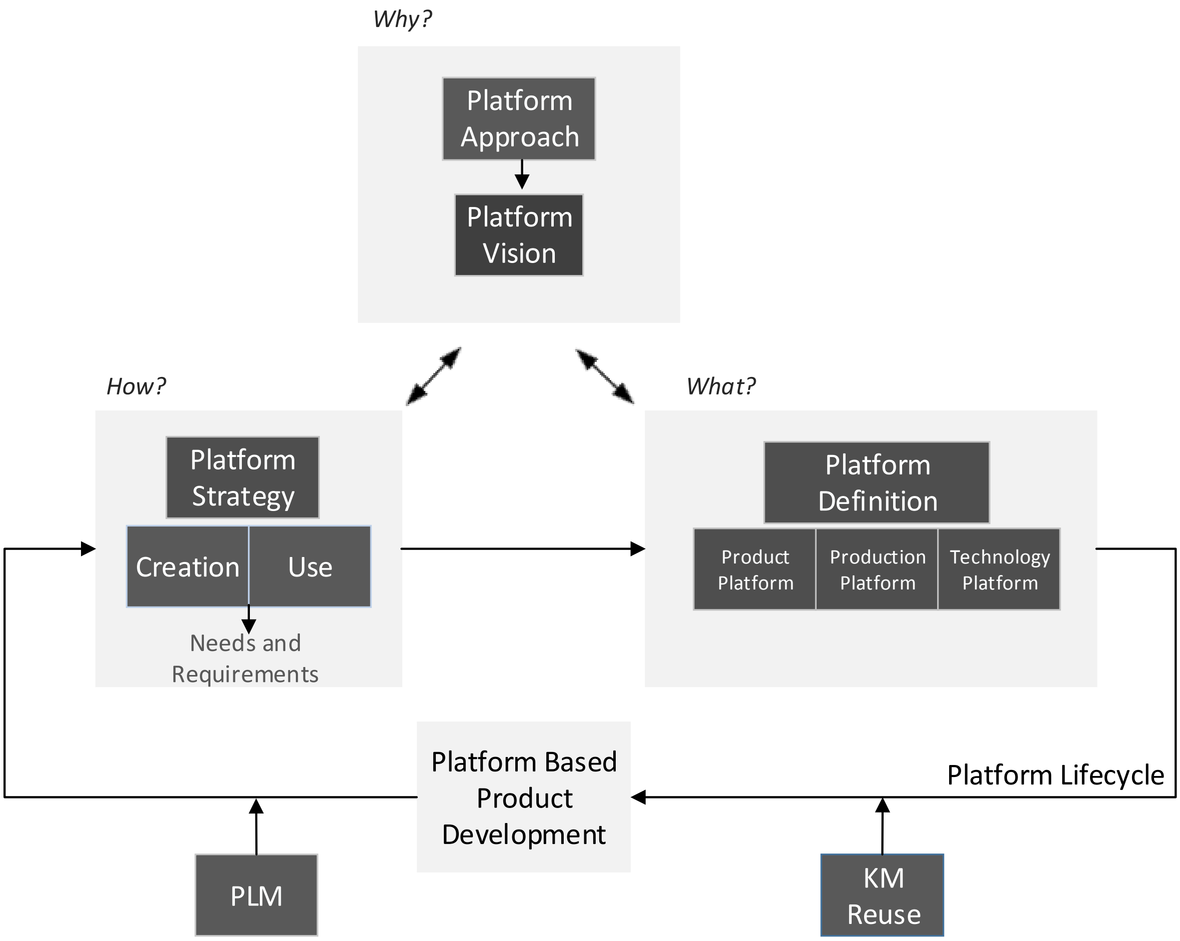

Figure 10. Conceptual Framework for study.

Once the *why* aspects are dealt with, formulation of platform strategies can slowly start taking shape in the organization, thereby addressing the *how* aspects of platform development. It has been identified in literature that platform creation involves understanding and making complex trade-offs and requires cross-functional efforts. However, the operational level guidance for doing so has been found to be limited. In the conceptual framework, the formulation of a platform strategy has been split into strategies for creation and strategies for use. This is motivated by the iterative nature of platform development, where a platform can be created while an older version of the platform is being used in product development. This is in line with the product-driven approach to platforms identified in theory (Alizon *et al.*, 2009). Proactive and reactive strategies to product family design are described in literature, but guidance for applicability of a balanced or mixed approach has also been found to be lacking.

Clarification of *why* and *how* aspects then helps shed light on the more detailed aspects of *what* contents the platform should be populated with in order for it to meet its intended benefits. At this point, there is must be enough clarity on the higher level *why* and *how* aspects, to be able to lay down an explicit platform definition, identify and justify a platform structure.

A defined platform can then be used in platform-based product development. The knowledge created during the process of developing a new product by using a platform in turn feeds into the strategy formulation for platform creation and use. Thus, there is a continuous renewal of the platform through feedback from product development. The successive concretization of the platform concept, from platform vision to strategy formulation to platform definition and product development also has a reverse flow, with current product development influencing future platform strategies and definition, which in turn demand a revision of the vision. This cyclical and iterative creation, use and renewal constitute the platform lifecycle. Although the concept of a platform lifecycle addresses the relationship between platform creation and use, sufficient literature on platform strategies that support the simultaneous (not sequential) creation and use of platforms was not found. This forms the basis for second research gap discussed above.

The platform can receive support throughout its lifecycle from Product Lifecycle Management (PLM) tools as well as reuse strategies that focus on facilitating and leveraging reuse of organizational assets. Finally, the systematic capture of reusable information using Knowledge Management (KM) methods and tools is also seen to beneficial in supporting the platform throughout its lifecycle.

Therefore, the research gaps identified in this study can be summarized as follows:

> **Research Gap 1:** A gap is identified between platform approaches and strategies prescribed in literature. The gap arises from a lack of adequate support for decision making in platform development in the form of metrics, tools, methods and processes. In particular, support has been found lacking on formulating a suitable platform vision and consequently suitable strategies for creating and using platform contents, in companies producing complex, customized and low-volume products.
>
> **Research Gap 2:** This gap arises from a lack of guidance on formulating platform strategies that deal with simultaneous and iterative creation and use of platforms. This is connected to combining elements of proactive, top-down platform strategies and reactive, bottom-up approaches. Further, the creation of a new version of the platform within and during product and technology development, while simultaneously using an existing version of the platform has not been addressed in literature.

3 Research Design

This chapter introduces the specific research questions that will be answered in this study, the methodology adopted and methods used to carry out the study.

3.1 Research Questions

In the previous sections, the overall motivation for carrying out this study, problems that can be addressed through the outcomes of the study and specific research goals were described. In this section, the research questions that will be answered in this study are presented.

In Section 1.3.3, GKN Aero's position in the aero engine industry and the business-to-business relationship that it shares with other entities in the industry is discussed. GKN Aero's position as a supplier to engine manufacturers creates challenges in its product development process which in turn pose difficulties in application of a platform strategy. Pedersen states three fundamental prerequisites for success of a platform strategy, described in Section 2.1.3. Influenced by this and the research goals, Research Question 1 deals with understanding the current situation of platform development at GKN from a ‘know why - know how - know what’ perspective. Further, a needs and requirements-based approach is adopted to identify requirements for an appropriate platform development process by identifying the needs of people involved in the process. Accordingly,

Research Question 1 is:

What is the current status of platform development at GKN Aerospace with respect to

a) the platform vision,

b) strategies for creation and use,

c) the relationship between platform development and product development, and

d) tools used to support platform creation and use;

and what are the needs of people involved in platform development, with respect to the above aspects?

Research Question 2 addresses the research objective of providing support to the platform development process at GKN Aerospace.

Research Question 2 is:

What is a suitable framework for platform-based product development at GKN Aero?

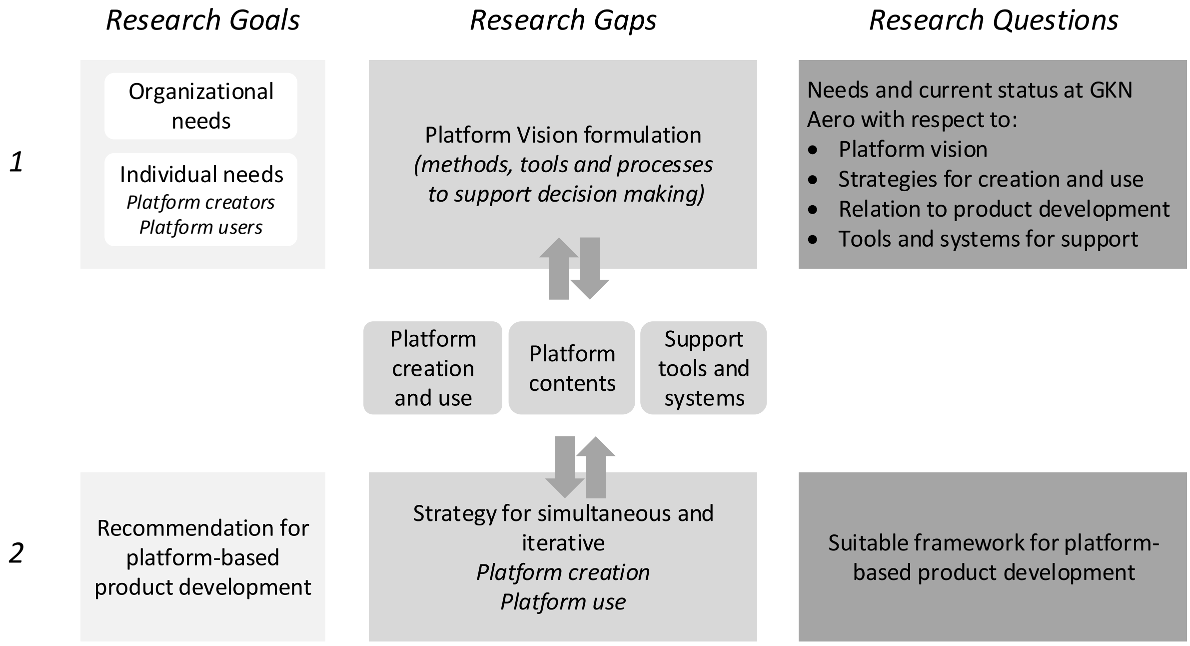

Figure 11 Overview of research goals, gaps and questions

At this juncture, it is useful to revisit the research goals, gaps identified from literature review and their relationship to the formulated research questions. An overview of these has been visualized in Figure 11. Questions raised by Research gap 1 focus on platform vision and these can be answered by studying the needs and current situation at GKN Aerospace with respect to platform vision. However, as seen in the conceptual framework (Figure 10) platform vision is closely related to and impacts strategies for platform creation and use, platform structure, definition and contents as well as the tools and systems required to support creation and use. As a result, Research question 1 addresses organizational and individual needs (Research goal 1) and the current status at GKN Aerospace with respect to the above mentioned aspects.

Research gap 2 raises questions regarding iterative and simultaneous creation and use of platforms. These questions could be answered with the identified needs as a basis, culminating in a set of recommendations for a suitable framework for platform-based product development (Research goal and question 2).

3.2 Research Paradigm, Methodology and Methods

Research is broadly defined as a "systematic inquiry into aspects of our world". It is distinguished from everyday contemplation in the application of a deliberate and purposeful method of inquiry (Fellows of Harvard, 2008). Paradigms are worldviews or belief systems based upon which researchers build the research. Therefore, the research paradigm determines the methodology and methods applied (Blessing & Chakrabarti, 2009). Maxwell (2005) refers to paradigm as "a set of underlying philosophical assumptions about the nature of the world – ontology; and how we can understand it – epistemology". The adoption of a single paradigm is not necessary, and further the selection of a given paradigm is not entirely a free choice of the researcher. A qualitative research approach is applied typically when the nature of phenomena is to be investigated (Blessing & Chakrabarti, 2009). Given the research goals and scope of the study, it was decided that a limited number of rich verbal descriptions will be used as a primary source of data, making this a qualitative study.

Carter and Little (2007) identify epistemology, methodology and method as the three major facets of research. Their proposed model based on these facets is shown in Figure 12 and provides a framework for planning and implementing qualitative research study. This model has been used to describe the design of this research.

Epistemology is concerned with the nature of knowledge and the process by which it is acquired and justified. It is impossible to engage in the pursuit of knowledge without having at least an implicit understanding of what knowledge is and what it is constructed of (Carter & Little, 2007).

Methodology is the "analysis of assumptions, principles and procedures in a particular approach to inquiry". Thereby, it provides justification to methods, while methods are the "procedures, tools and techniques of research" (Schwandt, 2001). Schwandt's description of what a methodology provides has been used by Carter & Little in describing the facets of research.

As seen in Figure 12, the use of procedures, tools and techniques (i.e., methods) is justified by methodology and produces a set of data. Data and its analysis help in creating a certain body of knowledge. The epistemological paradigm adopted in a research study helps to evaluate and justify this body of knowledge, which in turn dictates modification in methodology if needed. For this study, Maxwell's interactive research design model has been used as a methodological framework along with influences from Design Research Methodology (DRM) (Blessing & Chakrabarti, 2009).

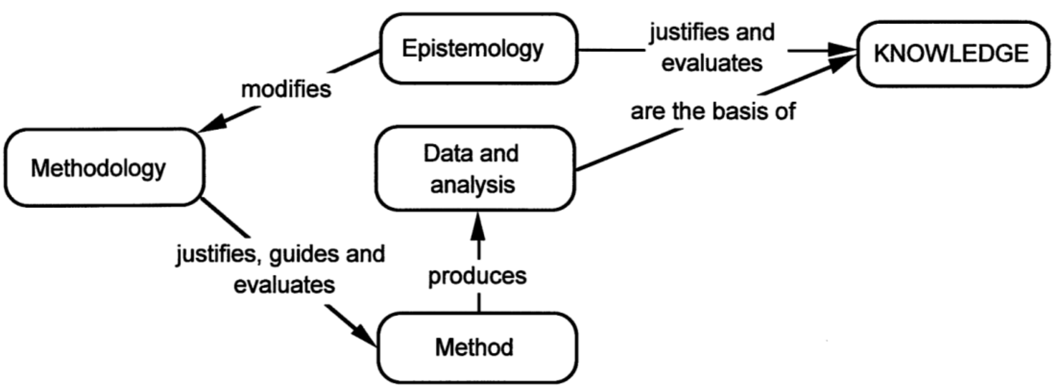

Figure 12. Simple relationship between Epistemology, Methodology and Method (Carter & Miles, 2007)

3.2.1 Research Paradigm

The researchers have subscribed to the philosophy that, in observing a piece of reality, what an observer ‘sees’ is not determined by its characteristics alone, but also by the perspective of the observer. This along with an independence from quantitative data or creation of general trends thereof, makes the study more relativistic in its approach than positivistic. Given the goal of understanding a certain organizational process, multiple perspectives from people involved in the platform development process at GKN Aerospace were sought. This fits into a constructivist philosophy of using research participants as contributors to constructing reality along with the researchers. Therefor a qualitative, relativistic and constructivist approach has been adopted in the study. Also, a flexible approach has maintained allowing for changes in underlying assumptions and beliefs held by researchers during the course of the research, in light of emerging information.

Based on the mode of inquiry, a continuum of strategies can be adopted that are grounded in theory or data. The extremities of this continuum are constituted of inductive and deductive reasoning. In deductive reasoning a conclusion follows logically form a premise, wherein the conclusion must be true if the premise is true. However, in inductive reasoning a researcher begins with a set of collected data, detects patterns and relations and draws conclusions based on them (Van de Ven, 2007). This study adopts an inductive approach, where conclusions are inferred based on a set of collected information.

3.2.2 Research Methodology

Maxwell’s interactive model for research design shown in Figure 14 has been used as the methodological framework with influences from DRM shown in Figure 13. Maxwell’s model provides a flexible structure to designing a qualitative research wherein its different modules share a cyclical and interactive relationship. The flexibility in this methodological framework has allowed the researchers to refine methods throughout the course of the study. The flexibility has also allowed influences from DRM to be incorporated. The first three stages in the Design Research Methodology framework (Research Clarification, Descriptive Study 1 and Prescriptive Study) proposed by Blessing and Chakrabarti (2009) provided guidelines for creating a procedure for the study.

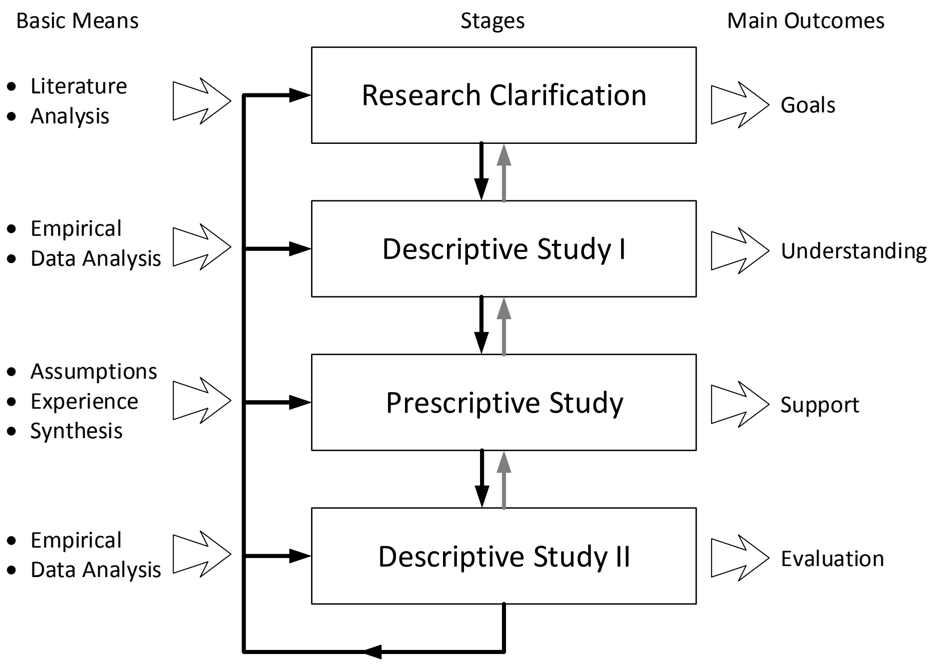

Figure 13. DRM framework (Blessing & Chakrabarti, 2009)

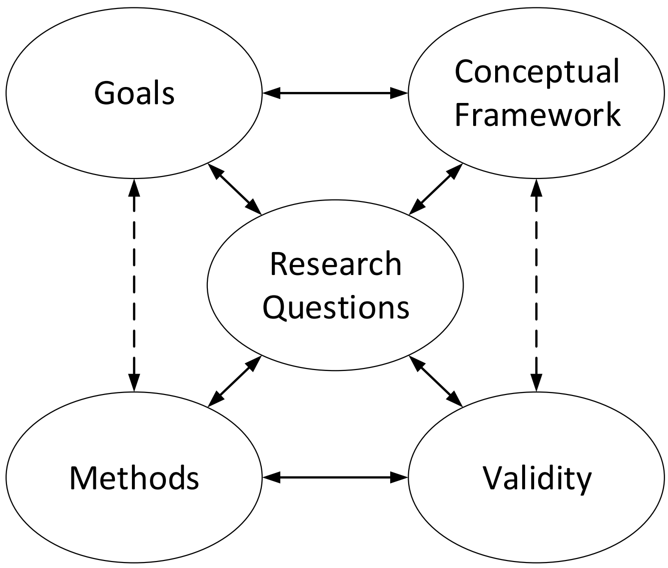

Figure 14. An Interactive Model of Research Design (Maxwell , 2005)

3.2.3 Research Methods

This section describes the procedures, processes and tools employed in carrying out the study. Maxwell calls attention to two types of approaches in using research methods — the structured and unstructured approaches. A structured approach is useful to “ensure comparability of data across individuals, time, settings and researchers and are thus useful in answering variance questions”. Unstructured approaches allow researchers to focus on a very specific phenomena being studied and hence require individually tailored methods. They trade generalizability and comparability for internal validity and contextual understanding

(Maxwell, 2005). An unstructured approach was chosen for this study as it ensured the possibility of responding to evolving ideas and emerging insights. Methods chosen for the study were influenced by the suggestions made in the DRM framework for the Research Clarification, Descriptive Study 1 and Prescriptive Study stages.

Summary of Procedure

The procedure used in the study is as shown in Figure 15. In accordance with Maxwell's Interactive Model and DRM framework, different steps in the procedure were carried out iteratively.

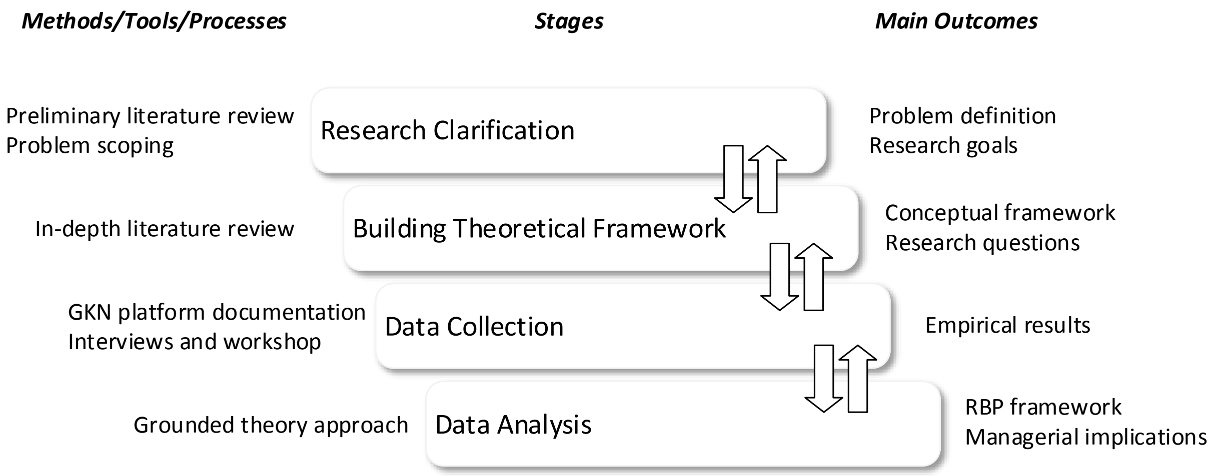

Figure 15. Outline of procedure followed in the study

A preliminary problem scoping was carried out by discussing the problem as it is perceived by people who have been involved in platform development initiatives at GKN Aerospace and Chalmers University of Technology, and by conducting a preliminary review of literature. This focused largely on previous platform related studies carried out at GKN Aerospace. An important outcome of this stage was a planning report which captured the background, a preliminary problem definition, objective of the study, activities to be carried out, methods to be used and a time plan for the study.

Areas requiring a more in-depth investigation were identified and an extensive literature review was carried out. Gaps in existing literature and in knowledge on platform development at GKN Aerospace were identified and used to formulate specific research questions. A conceptual framework was created to serve as a frame of reference for the study as well as to visualize relationships between different concepts, theories and phenomena identified in literature review.

Data collection was carried out by reviewing GKN Aerospace platform documentation and interviewing GKN Aerospace employees involved in platform development efforts. Data collected was analysed and used to plan a workshop to present and discuss the results from data collection with participants of interviews. Results from data collection, analysis and interpretation were used to synthesize a framework for platform-based product development and corresponding managerial implications for adoption of the framework at GKN Aerospace.

Literature Review

The literature review was carried during several phases of the study. A preliminary review of literature on previous platform related studies carried out at VAC (now GKN Aero) helped identify several interesting areas that required in-depth scrutiny. The literature review sections of previous publications helped identify a set of authors in the field, whose work has contributed to what can be called a backbone for theory on platforms. Although no formal search strategy was used when searching for resources on the Internet, a method implicitly followed by the researchers was to use keywords from publications. Information about GKN Aero was available from the company website, its annual reports as well as publications from previous studies at the company. Documentation on existing platforms at the company was also available for review and was instrumental in identifying knowledge gaps to refine research questions as well as shaping the data collection process.

Concept Maps

Concept map of a theory is a visual representation the theory, highlighting the most important concepts (Maxwell, 2005). During the literature review, rough concept maps were made to consolidate and visualize the theory. Concept maps helped identify relationships between different concepts and thereby find gaps in existing theory. These rough concept maps when were then put together to build the conceptual framework.

Conceptual Framework

Maxwell makes a distinction between conducting a literature review and building a conceptual framework. A literature review involves investigating existing literature in order to understand, critically analyse and synthesize a context for the study. Building a conceptual framework, however additionally involves critically evaluating the relevance of existing research and theory to the problem at hand and establishing relationships between different concepts, theories, phenomena and lines of investigation. Existing theory and research thus serve as modules in the conceptual framework which can be used to guide and inform the study (Maxwell, 2005).

Concept maps created during literature review, were put together to make visible the relationships between different concepts. The iterative nature of the methodology adopted allowed the concept maps to be continuously refined, and hence the conceptual framework to take its final shape only after data collection and a preliminary data analysis were concluded.

Formulation of Research Questions

Research questions have been continuously modified and refined throughout the study. This was done iteratively, during literature review and data collection. A set of tentative questions were framed based on a preliminary literature study. The tentative questions went through a significant modification after reviewing GKN platform documentation and were further refined after an extensive literature review. Data collected during interviews helped refine the research questions because it changed the researchers’ understanding of the nature and status of platform efforts at GKN Aerospace.

Data collection

The selection of data collection methods depend on the kind of data being sought, from whom and under what circumstances (Robson, 2002). Due to the qualitative nature of the study, the methods to be used do not follow as a logical conclusion from the research questions raised. However, interviewing was identified as a potential method for primary data collection early during the study as it was clear that verbal descriptions of the platform initiative at GKN Aerospace and multiple perspectives on the issue are to be sought.

The choice of an interviewing technique was based on the following considerations:

a) Contextual information regarding the platform initiative is being sought in the study and hence depth in data collected is a requirement;

b) Open ended nature of information being sought requires a flexible interview process which facilitates discussion rather than a one-way recount.

Among the different options available for the types of interviews to use for data collection, a semi-structured interview style was used for the following reasons:

a) A semi-structured interview has predetermined questions, but the order in which they are asked can be modified to guide the interview in a manner that the interviewer sees most appropriate.

b) The semi-structured interview takes into account the fact that the interviewer, interviewee, and interview setting together create a unique and dynamic scenario, and that cannot be generalized for each interviewee.

An interview guide was prepared to map out the contents of the interviews and the most logical sequence in which they must be asked. Based on the research questions and literature review, six major themes were identified which required investigation in the interviews. A platform lifecycle sequence was chosen starting with the platform idea and ending with platform renewal and maintenance. This helped create a logical flow from one question to the next. The effectiveness of the interview structure and guide was tested in a pilot interview and refined before using for the subsequent interviews. The pilot interview also helped identify other potential candidates for the interviews. 15 individual interviews were conducted. Interview participants were chosen to ensure that each participant would provide a unique perspective on platform initiative, reflecting the background or department to which they belong and the capacity in which they are involved in the platform initiative. The list of interviewees can be seen in Table 1.

Interviewing is an effective method for data collection because it provides an interviewer better control over the breadth and depth of data collected when compared to questionnaires or focus groups. Therefore, for an exploratory study interviewing is a suitable data collection technique. Each interview was recorded in addition to taking notes. This was done after confirming with the participants that they are comfortable with the discussion being taped. Each audio recording was then transcribed and transcriptions were used as a starting point for data analysis. This required investment of a large amount of time for collecting and compiling raw data before it could be analysed.

Data Analysis and Formulation of Results

Qualitative data which takes the shape of text has an advantage over numerical data because it is "rich, full and real" (Robson, 2002). A grounded theory approach to qualitative analysis was chosen for this study. In accordance with the research paradigms and methodology, grounded theory approach allows a more interpretive and flexible approach in analysing data. The grounded theory approach helps generate a theory to explain what is central in the data. It is carried out in three stages:

a) sorting data into a set of conceptual categories,

b) finding relationships between the categories, and

c) conceptualizing and accounting for the relationship by finding core categories.

In this study, a modified grounded theory approach was adopted for analysing the data collected. This was carried out in two steps – open and axial coding. Open coding was carried out by reading through each interview and lifting out statements from the interview into conceptual categories. Since most interviews followed the planned sequence and structure, the same categories as used in the interview guide were used in this preliminary analysis step.

A separate category was created for lifting parts from the interview which served as a background to the platform initiative at GKN Aerospace. This process was carried out for each interview.

The next step involved axial coding, where information from each interview and category was consolidated. This was done by clustering together the different categories into four central themes – why, how, what and related fields. The *why* category consists of data related to the vision and reason for adopting a platform approach, *how* category addresses the strategies for creation and use and people involved in creation and use of the platform. *What* category consists of data related to contents of the platform and *related fields* category captured information on related initiatives at GKN Aerospace in areas of Product Lifecycle Management and Knowledge Management, and the role of platform development as a source of organizational change.

The data from each interview and category was then copied into a Microsoft Office Excel sheet consisting of four columns for each theme and fifteen rows for each interviewee. This provided an effective way of consolidating all the data and visually representing it to make it readable. Based on patterns and conflicts identified, the data was summarized into a textual description centred on the background, current situation and needs associated with the platform initiative at GKN Aerospace.

Workshop

After data analysis, a workshop was conducted with interviewees in order to present the empirical results from the interviews, a preliminary interpretation of these results and ideas for recommendations for future platform development. The workshop was attended by 8 of the 15 interviewees. A brief summary of the results and analysis was presented highlighting the most important findings and interpretations, followed by a presentation of the preliminary recommendations. Interviewees were asked to present their views on the analysis and recommendations. In doing so, the purpose was to initiate a discussion among the interviewees around these topics and use information from this discussion to feedback into further refinement of the analysis and recommendation.

Audio recording and notes were used to document the discussion, and results from the discussion were used in evaluating and further refining the analysis and recommendation.

4 Results and Analysis

This section presents results from the interviews as well as GKN platform documentation made available to the researchers for this study. A background to the results is provided by a description of the challenges in platform and product development at GKN Aero. This is followed by presenting results pertaining to platform vision, creation and use. Each of these three sections is followed by an analysis and discussion based on reviewed literature.

Interviews were conducted with 15 GKN Aerospace employees from different departments, involved in platform development in different capacities. Table 1 in Appendix A shows a list of interviewees, their organizational role and their involvement in platform development. In interest of keeping the identity disclosed, interviewees are referred to as Interviewee 1 (I1), Interviewee 2 (I2) etc., in the order in which interviews were conducted.

4.1 Challenges in Product and Platform Development

Results from the interviews and GKN Aerospace platform documentation have been used to compile a description of the product and platform development process at GKN Aero and the challenges that are encountered in these processes. It has been synthesized based on interviewees' account of these processes.

4.1.1 Product Development

GKN Aero enters commercial projects in the preliminary product definition phase, after the system engineering and the system concept phases are past. At this juncture, customers have already defined all boundaries on the parameters, meaning that system level decisions on the engine have also been made. Thus, GKN Aero does not have an opportunity to influence system parameters in order to impact component development.

Inherent to projects are uncertainties in detailed product requirements, methods to develop the detailed product design, technologies required to manufacture the designed product and methods to evaluate and test the product. Consequently, there are inherent uncertainties with respect to a product's lead time and development cost. A project is undertaken based on the organisation's estimates on these uncertainties.

When the marketing department negotiates with customers, it faces demands on lower weight and short lead times. Currently, marketing makes compromises between the customer's demands and best estimates of what can be delivered by GKN Aero. The uncertainties in these areas have often led to overestimating the capability of what can be delivered. The gap between estimated and actual capabilities remains unnoticed until detailed design, production planning, testing and verification, when it is too late to reposition the requirements within known solution spaces. An example is the requirement for high operating temperatures agreed upon at the beginning of a project. Problems are discovered only during detailed design when the solution space of the material properties at a certain thickness, stress and temperature, are explored. This could often result in a change of the material which in in turn has implications on the manufacturing methods used, ultimately significantly altering cost estimates.

4.1.2 Platform Development

Traditionally, GKN Aero has started with a blank page so as to develop customized solutions to meet the unique needs of its customers. However, recently one of a primary aims within product development projects has been to reuse previously developed capabilities.

Once a conceptual solution, derived by reusing capabilities from previous or demonstrator projects has been selected in a project, it is said to have become a part of the platform. Therefore, in GKN Aero's context, the capabilities from past projects are referred to as the platform. With an incremental growth of documented capabilities, the expectation for the platform concept is to enable a systematic exploration of design space that can significantly benefit the conceptual stages of the product development process. With well-defined design concepts the subsequent detailed design phase is also expected to converge faster within the product development process.

Thus, platform development at GKN Aero is currently an informal one occurring within product development projects. Platform development activities do not have formally specified goals, deliverables, and timelines associated with them. In this informal process, conflicting requirements that arise from the commercial projects and platform development become challenging to manage. For instance, the fundamental goal of incorporating generic solutions is in conflict with the customer's wishes for unique product requirements.

The expected relationship between commercial projects and platform development is one of constant exchange. However, GKN Aero does not have unrestricted access to information regarding the engine programmes that their products become a part of. In addition, the limited information made available to GKN Aero is not made available across commercial projects in the various engine programmes as GKN Aero's customers are competitors to one other in the aerospace industry. Thus, platform development suffers from the lack of valuable information in three areas:

a) information on how future engines are going to be developed,

b) system level information from current engine manufacturers, and

c) sub-system level information from different engine programmes.

The intention for the product platform is that it should be constituted of generic solutions and knowledge from the past commercial projects. Currently there are two product platforms, one for hot structures (Turbine Exhaust Case/Turbine Rear Frame) and one for cold structures (Intermediate Cases, outer diameter less than 1270 mm). Standardizing the product decomposition (into physical parts and functions) has been identified as a key factor in reusing design solutions. In the current situation, each project choses its own convention for product breakdown and there is no coherence across projects. For example, there is no system to classify and name or number the different vanes within the Turbine Exhaust Case.

Sometimes they are numbered starting from 1, 2, 3, so on and other times they are grouped as mount vanes and other vanes. Thus, this does not create a logical information structure across projects. It has been stated that the platform needs to create a commonly agreed template view to be used in product design. Also, a better functional perspective on how the product works is needed so as to include performance characteristics of components in the product platform (I10).

Production platform documentation for hot structures consists of a product breakdown in to a Generic Production Bill of Materials, Bill of Processes for manufacturing the products, Bill of Equipment that is capable of supporting the processes, procured parts, standard parts, supply base and logistics, design guidelines for manufacturing and manufacturing preparation methods.

The technology platform has been stated to be at a conceptual level (I1). A few interviewees (I2, I3, I5, I8, I9, I13) stated that they were unfamiliar with the current status and how its creation is being organized, while others (I4, I6) state that it is has been in use.

4.2 GKN Platform Vision

In this section, different views on the future vision for an overall GKN Aero platform are presented. Some interviewees chose to express views only on the platform they were familiar with, in which case a distinction is made on whether the presented view refers to the product, production or technology platform. Table 2 in Appendix A shows different views on the platform vision.

4.2.1 Recurring Views

A summary of key findings on GKN Platform Vision can be seen in Figure 17. At a higher level, a majority of the interviewees expressed that platform is a way to reduce costs (I1, I2, I5, I6, I7, I8, I10, I11, I14), mitigate risks (I2, I3, I5, I7, I8, I10, I12, I15) and reuse knowledge and technology (I2, I3, I4, I8, I13).

'Reduce costs' is a phrase being used to collectively refer to reducing total costs, product costs or enabling predictability of costs. 'Reduce risk' is a phrase being used to collectively refer to risk mitigation, reducing programme risks and avoiding late surprises. The term 'reuse of knowledge' is being used to collectively refer to reusing knowledge and technology, capturing project knowledge and best knowledge about product.

Interviewees (I3, I5, I6, I13, I15) stated that a platform is a way to reuse equipment, deign in order to fit the industrial structure and specify manufacturing limits and manufacture parts in the same way. I4, I5, I6, and I9 mentioned that platform is a way of obtaining a common understanding, common view and is expected to align everyone to work in a unified direction. Reducing lead time, having predictable project timelines and delivery were also mentioned (I1, I6, I7, I10, I11, I14). Interviewees (I6, I9, I11, I12) also stated that platform is a way to balance the three requirements of functional requirements, product cost and producibility as shown in Figure 16.

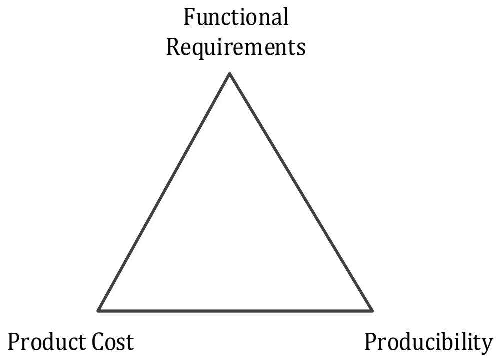

Figure 16. Requirements balancing

Figure 17 Key findings on GKN Platform Vision

It was stated that the platform visions lacks clarity (I2, I9). I12 stated that the alignment is required in how the platform should work and who will use it and explained that the vision is expected to slowly converge.

I4 stated *"we don't have an agreed idea on what the platform is, it has been described in many ways but not communicated"*.

4.2.2 Misaligned Views

Interviewees I6, I9, I15 stated that there must be a single platform. I6 stated that this single platform should be a product platform made by balancing product, production and technology aspects, I15 stated that there must be a single platform for the entire organization, in a single document with feedback between product and production aspects.

I10 and I14 stated that there must be more than one platform. I10 stated that a single platform could potentially risk sub-optimizing the product, production or technology aspects, while I14 mentioned that there should be several platforms for different products that are developed with the customers and updated continuously. Figure 18 shows these different views.

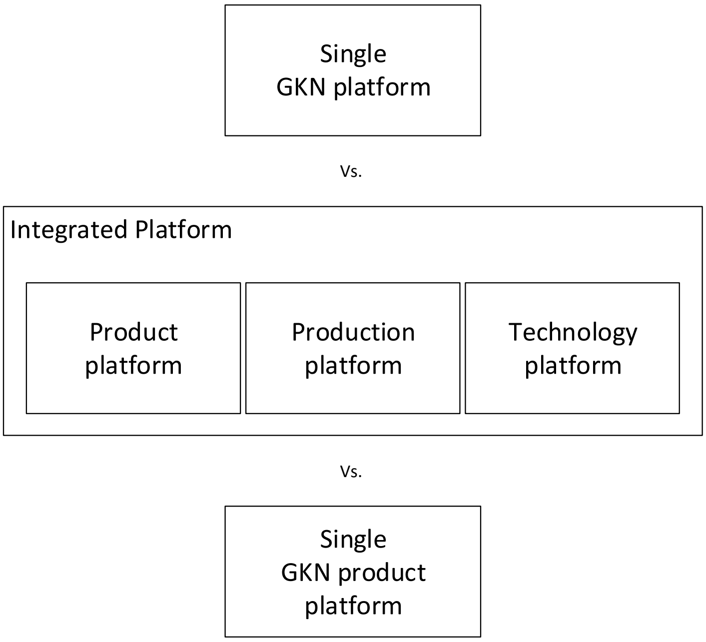

Figure 18 Views on number of platforms at GKN Aerospace

4.2.3 Analysis of GKN Platform Vision

From Table 2, it is seen that there are roughly 25 different aspects of GKN platform vision that are mentioned by interviewees. Some of these aspects share causal relationships with one another, such that the fulfilment of one would either enable or ensure fulfilment of other aspects. For instance, if product design is to fit within the existing industrial structure it implies that the production equipment would be reused. Similarly, capturing knowledge from projects would be done with the aim of reusing it in future projects. The reuse of knowledge and mitigation of risks can be carried out in order to ultimately achieve cost reduction.

However, aspects that misalign could be a potential risk in smooth platform development. Robertson & Ulrich state that "top managers should recognize that the organization may be in fundamental disagreement about the goals of the platform and that a top management perspective may be required to achieve the best overall solutions" (Robertson & Ulrich, 1998). For instance, it is detrimental to a balanced platform development if the employees directly involved in creating the platform strive for three platforms (product, production and technology) while others attempt to consolidate all platforms into one. If the approach is to create three platforms with the aim of eventually merging them into one integrated platform, then it follows that it must be a conscious decision, planned with deliberation, agreed upon and communicated.

Platform creators at GKN Aero are debating whether there should be a single, common platform (integrated platform proposed in previous studies at GKN Aero, discussed in Section

2.1.8) or only a single product platform or three individual platforms – technology, product and production platforms. This indicates the complexity of making decisions regarding a suitable platform framework to adopt and number of platforms to create. A shared or at least agreed view is seen to be required. Therefore, platform creators must be careful to distinguish between the input and output of platform planning and creation processes. Literature states that a common view is an outcome of the platform planning process which can then be an input to platform creation (Robertson & Ulrich, 1998). Therefore, when I4, I5, I6 and I9 state that the vision for the platform is to achieve a common view, it leaves unspecified if a common view and understanding is an output of platform creation or if it is required in order to create a platform. The relationship between top management drive, platform planning, obtaining a common view and platform creation is shown in Figure 19.

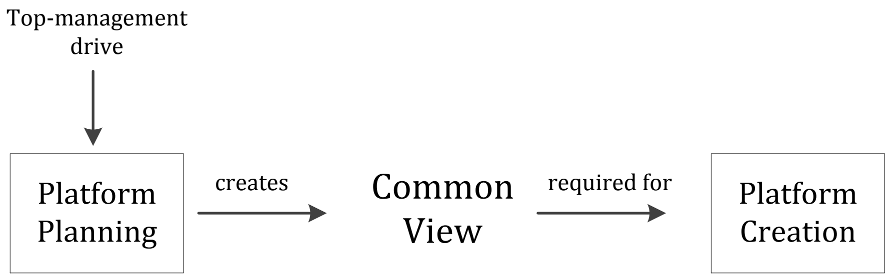

Figure 19. Relationship between platform planning, common view, platform creation

The first step to platform planning is visualization and articulation of a future state for the organization of which the platform will be a part. The explicit articulation and communication of the GKN Platform Vision which aligns with the overall organizational vision is seen to be of primary importance as it has a direct consequence on the platform approach that will adopted, which in turn has an influence on formulation of platform strategy and determination of platform contents. Larwood *et al.* (1995) find from their review of literature that an organizational vision is "important to leadership, strategy implementation and change". This can also be seen to be applicable for platform-based development, where a platform vision is important for platform strategy implementation and bringing about necessary organizational change.

4.3 GKN Platform Creation

This section presents results on GKN Aero's platform creation process. First, different views on how platforms are currently being created and needs for platform creation are presented. Table 3 summarizes these different perspectives. Next, interviewees' views on need for knowledge capture as a part of platform creation is summarized. Different views are presented in Table 4. Finally, Table 5 captures different views on type of approach currently being adopted towards product family design.

4.3.1 Needs for Platform Creation

I1 and I2 stated that the term platform has become a buzzword in the company. I2 mentioned that this has both a positive and negative impact on platform development because a larger number of people in the company talk about and think in terms of platforms, but it has also led to a number of potentially conflicting or competing good initiatives at a low level.

a) Need for Vision

When asked about an ideal creation process for GKN platforms, interviewees (I2, I4, I5, I7, I8, I9, I14 and I15) indicated a need to define the vision for the platform. Interviewees state that “there is a need to know where GKN intends to go with its products” and “the expectation to develop platforms was flowed down from management without any details on what the platform is and what the expectation is”.

b) Need for Platform Owner

Interviewees (I2, I3, I4, I8, I10) stated that there is a need for a platform owner or person responsible for platforms at a higher level in the organization. For instance, I3 stated that “A person in a strong position needs to be responsible for further platform development” and I4 stated that “Platform creation must be done at a company level, from top and bottom, but indicated from a high level”.

c) Need for Cross-Functional Collaboration

A need for cross-functional collaboration in platform creation was stated. I14 stated that platform creation requires a lot of resources and engineering power, and it is difficult to get access to the required people. I3 stated that platform creation needs skills, experience and a mix of people and I10 stated the need for a single team responsible for platform development. I9 observed that platform creation needs to be agreed upon process, and not just someone saying what should be done. I13 highlighted that a cross-functional approach was not useful in platform creation without a top management influence. This is because in situations of conflict, this has led to the inclusion of contents like immature or untested technologies that should not be in the production platform documentation.

d) Need for Platform Creation Strategy

More specifically with respect to the process of creation, I9 expressed that there is a need for clear instructions on how to create the platform so that platform creation can be done in a standardized way. I8 stated that if management lays down vision, goals and paths, then engineering organization could contribute to reaching these goals with requisite knowledge and experience. I15 stated that there is a need to have a strategy for how to develop platforms. Similarly, I11 stated that there is a need to understand how to document the platform. I10 stated the need for a platform documentation group. I14 stated in this regard that the existing procedures for creation will work well for similar projects, but it will be difficult to use them successfully in new projects. Sign off of platform documentation was also stated as a need (I9, I15).

e) Need for Flexibility

Interviewees (I2, I6, I12) stated the need for a platform that is rich, yet flexible. I12 stated that the current platform creation effort involved "trying to differentiate and capture explicit knowledge selectively into the platform to keep it rich, but not overload it with information". This flexibility and richness is needed from a long-term perspective (I2). Flexibility implies that the platform is detailed but coarse enough to ensure that it does not have to be recreated constantly (I6). In relation to depth, I9 mentioned that the platform needs to contain information on all aspects from material order to shipping to the customer information. However, I3 also mentioned that from a research perspective, there is a need to scope and balance, what can be accomplished with the platform.

f) Platform Development in Projects

A need for continuous development of platforms was stated (I4, I6). Interviewees (I3, I14) stated that platform creation should be a natural part of project work. Within a project, both platform and project goals need to be met. However, there are not formal enough platform requirements within a project (I14). I5 stated that there have been few platform requirements within projects, since the focus has been to get the product out in time. Similarly, a formal way of aligning platform and project work was stated as a need (I10).

4.3.2 Knowledge Capture for Platform Creation

As seen in Table 4, several interviewees state a need for systematic capture and reuse of knowledge. It was mentioned in the previous Section 4.2 on Platform Vision that at a high level, interviewees agreed on platforms as a way of reusing knowledge. With respect to this, I2 stated that "platform in one way or the other represents information in a usable way to build corporate knowledge and to bring value to the organization". However, some challenges in capturing such usable information were mentioned by interviewees (I3, I5, I6, I7, I10 and I14). For example, the lack of access to information from different commercial projects, due to issues with secrecy hinders the benefit of sharing input from different Original Equipment Manufacturers (OEMs). Also, when a project is completed, the project team is dispersed and people get allocated to new projects. This has limited the systematic capture of experiences from past and on-going projects. Strict standards on documentation have also been stated as a limiting factor in documenting knowledge, along with the lack of a common language to make documentation understandable to everyone (I5).

4.3.3 Platform Approach

Interviewees' views on the type of approach to product family design being adopted at GKN Aero are listed in Table 5 in the Appendix A. Top-down (or proactive) and bottom-up (or reactive) approaches to product family design were briefly explained by the researchers during the interviews and interviewees were asked to place GKN Aero's current approach on a continuum between these two extremes. Views on the current approach adopted and suitable approach for the future is depicted in Figure 20. There was general agreement that the approach adopted so far has been bottom-up. Some interviewees identified that adopting a more top-down approach could be beneficial for the future (I7, I8, and I11). From a production platform perspective, a bottom-up approach was stated to provide a bigger gain, while a top-down approach was viewed as more useful for creating design solutions for the product platform (I14). I3 stated that the largely bottom-up approach in creating the production platform has led the platform to become simply a description of Turbine Exhaust Case variants. I4 and I15 also stated that a balance or mixture of both approaches is desirable and should be encouraged. In support of a proactive approach, a need was stated for greater involvement with OEMs. I7 stated that there is a "need to go out and get input from the OEMs". I15 stated that there is "a need for co-located development programmes with OEMs".

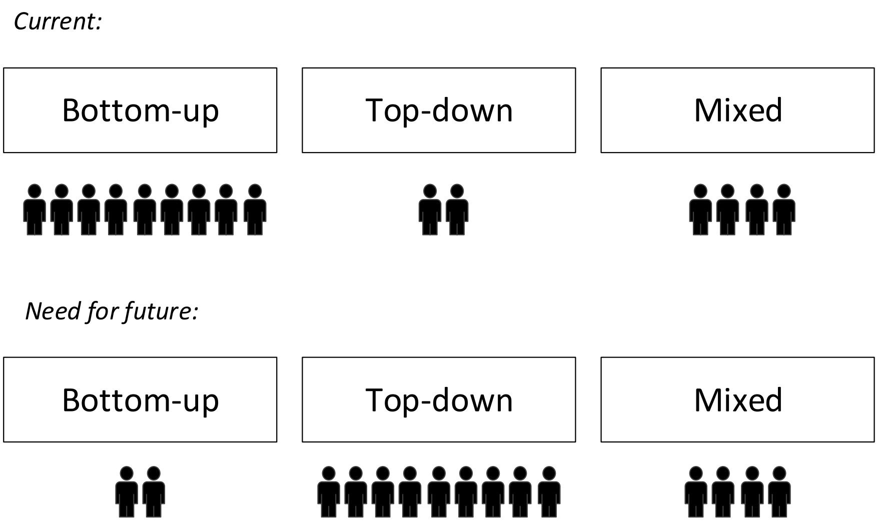

Figure 20 Views on current platform approach and need for future

4.3.4 Analysis of Platform Creation at GKN

Vision

It is seen from the results that interviewees mentioned a need for clarity on platform vision. The need for a platform vision has been discussed in detail in Section 4.2.3. The impact of a platform vision on the subsequent stages in platform planning and creation has been shown in Figure 21. A progressive scoping down of the platform concept aligns closely with the fundamental prerequisites identified by Pedersen (2010) that platform decision makers need to take into account. The three prerequisites that Pedersen identify are: (1) knowing why a platform is pursued, i.e., behavioural aspects (2) knowing how the effects are obtained, i.e., procedural aspects and (3) knowing what the contents and interrelations are, i.e., constitutive aspects.

It was identified from our literature review that due to the wide scope in platform terminology and the distinction between terminology used in academia and literature, there is a lack of clear differentiation in the terms "platform thinking", "platform strategies", "platform approach" and "platforms" themselves.

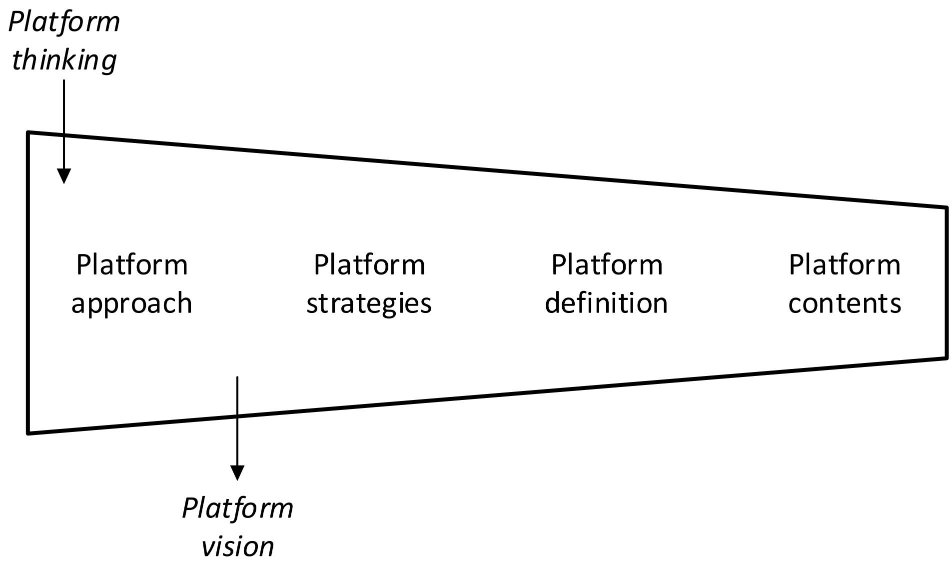

Figure 21. Progressive scoping down of platform concept

The researchers have defined platform thinking as the identification of aspects in the organization that can benefit from using platforms. At this point, the scope of the platform is very large, and is largely communicated through informal work processes, PowerPoint presentations, etc. For example, it was found from the interviews that in case of GKN Aero, platform thinking was triggered by influences from research and the automotive industry, but more specifically from identifying the possibility of reusing certain technologies, methods or capabilities in commercial projects (I1, I2, I6, I7, I14).

Platform thinking leads to a deeper investigation into the kind of approach that could be applicable to the given industry and organization. In identifying an appropriate approach, the organization scopes down by specifying the purpose of using a platform and benefits being sought. The approach adopted could lie anywhere between a top-down and bottom-up approach of product family design (Simpson *et al.,* 2001), or anywhere in between a product-driven and platform-driven approach (Alizon *et al.,* 2009). However, this must be a deliberate decision that must be agreed upon and communicated. In selecting an approach, the organization starts with the overall business goals and outlines the value that a platform brings to the fulfilment of these goals. At this point, the organization must be able to lay down its vision for the platform, which should align with and contribute towards the realization of overall corporate vision.

The next step of formulating platform strategies further narrows the scope. For example, if one of the aspects of the platform vision is to "use technologies to leverage market position and enter new markets", the platform strategy would outline the specific technologies and the type of market. A platform strategy could then be – "Use expertise in casting technology to enter the XYZ market in ABC industry". One of the interviewees (I5) stated with regard to platform vision and strategy:

"*We maybe should be clear on where we intend to go with our different products. Is it just cost that is important? Ok, then we should work much more with our supplier chains since*

80% of the cost is at the supplier. Why then work with the last 20% with technology here, when 80% is at the supplier. So it feels like we should be more clear with what we intend to do and then by that work with the gaps".

The platform concept will then go through a next level of scoping down by laying down a definition of platform. This is complemented with detailed plans for creation and implementation. A systematic plan would include details on who will create and use the platform, how it will be created and used, the resources needed to carry our creation and work processes involved, timelines, deliverables and measures to deal with organizational changes that are either prerequisites or consequences. Once this is known, it becomes easier to specify the platform in terms of its structure, contents and how they will be used.

Platform Owner

A need for a platform owner or person responsible for platform development was clearly stated by interviewees. It was suggested by interviewees that this should be a person in a strong position who has the ability to influence top-level decisions. With respect to the role of top management in platform planning, Robertson and Ulrich (1998) state that "Top management should play a strong role in the platform planning process for three reasons: (1) platform decisions are among the most important made by a company, (2) platform decisions may cut across several product lines or divisional boundaries, and (3) platform decisions frequently require the resolution of cross-functional conflict". Therefore, for the platform to have the desired company-wide impact, it is imperative that platform development is not only supported and encouraged, but is also owned, driven and directed by senior management.

Cross-functional collaboration

Robertson and Ulrich (1998) state that "Platform planning is a cross-functional activity involving at least the product planning, marketing, design, and manufacturing functions of the firm. In most cases platform planning is best carried out by a core team made up of representatives from each of these functions. For large development projects, each of these representatives is in turn supported by an experienced staff." Given that platform decisions cut across functional boundaries affecting all disciplines in the organization, it follows that these decisions must be taken collaboratively by a team of experts representing different disciplines. However, I13 also mentioned that currently conflicting ideas are often transmitted to the platform documentation when platform development activities are carried out in cross-functional teams. This is seen to occur due to the lack of a clear definition of what the platform must include and a higher position of authority to resolve such conflicts. Therefore, a cross-functional platform team would better contribute to a stable platform creation, if it had the support of top management.

Platforms have an impact on the product in all its lifecycles. The relationship between a product, product development and platform lifecycle (Alblas, 2011) has been discussed in Section 2.1.4 on Platform Lifecycle. Due to its impact on the entire lifecycle, a cross-functional effort is necessary not only in the creation of platform documentation, but also in the planning process.

Platform Strategy

From previous studies on platforms at Volvo Aero (former GKN Aero) it was found that the use of modular or configurable product platforms are unsuitable given GKN Aero's position in the aerospace industry in relation to engine and airline manufacturers (Figure 1) and the lack of complete control on system-level architecture. A platform strategy involving the use of a technology and product platform to support the development of product derivatives was suggested (Högman, 2011).

Existing literature on platform strategies are largely focused on platform strategies for product platforms. Abundant guidance exists in literature on how to formulate platform strategies for mass-customization and mass-production based industries. Low volume and high customization based suppliers in the aerospace industry however, have received little guidance in platform strategy formulation from literature. However, given that previous research at GKN Aero [(Berglund *et al.*, 2008), (Högman *et al.*, 2009)] has found reusable elements of higher abstraction levels to be more appropriate to use in platforms, reuse strategies [(Antelme *et al.*, 2000), (Duffy *et al.*, 1995)] in organization can be investigated further for applicability at GKN Aero. Here, higher abstraction refers to degree of independence from a physical structure. This means, design rationale is more abstract and generic in application than design solutions, which are in turn more abstract than physical components.

GKN Aero's current approach of planning, creating and using platforms in an iterative process fits into the model proposed by Duffy *et al.* based on reuse methodologies in software development. 'Design by reuse' occurs when knowledge from previous projects is applied in new commercial projects. 'Domain exploration' and 'Design for reuse' involve the creation of reusable knowledge. Challenges identified at GKN Aero with respect to these two processes include (1) capturing, transferring and successfully using knowledge in product development projects, (2) forecasting and determining what technologies can be developed for reuse in the future, (3) adapting these to make them applicable in new projects (Corin Stig, 2013).

Platform as a tool for capturing usable information has been in focus at GKN Aero. Previous studies and interviews in this study point in the direction of a need for systematic knowledge management methods, tools and processes. A significant amount of development taking place as a part of product development projects, with involvement of projects teams that disperse at the end of a customer project, make knowledge agent-bounded, in turn making it a bigger challenge to capture and document. Wiki based tools have been recommended as a part of previous studies at GKN Aero (Corin Stig, 2013). However, documenting of explicit as well as implicit knowledge has been found to be lacking. For instance, large gaps exist in the Design Practises system where the manufacturing aspects have been stated to be largely missing (I3).

Flexible platform

According to interviewees, a rich but flexible platform refers to a platform that is rich in usable information it captures, but flexible enough to ensure that it does not have to be constantly created anew. The definition of platforms has been treated with wide scope in literature, with platform consisting of a large number of reusable assets [(Halman *et al.*, 2003), (Robertson & Ulrich, 1998), (Sawhney, 1998)]. This wide scope in platform definition has also been found at GKN Aero, where interviewees have identified several platform contents. These are outlined in Section 4.4.3.

Irrespective of the scope, a decision on the balance between flexibility and richness depends on the type platform contents. If the platform is to contain knowledge, then identifying more specifically what type of knowledge is a necessary prerequisite to creating limits on depth and scope of the platform. As observed by one interviewee (I12), "If you say that the platform is basically equal to knowledge, then knowledge around this system is quite huge and everything is in the platform, which is not very useful". Since depth and scope of the platform are decided by platform contents, and contents are in turn seen to be directly influenced by the platform purpose or vision, it follows that formulation of the platform vision is crucial.

For example, interviewee I13 stated that the purpose of production platform is to ensure that design solutions fit the industrial structure in which heavy investments have been made by the organization. If it is assumed that the need for using standardized production processes and methods is superlative to exploring new markets to enter into with new offerings, then a production platform that is a rich library of usable information would serve the intended purpose better than a flexible platform that captures generic capabilities and assets to leverage and use in new markets. The production platform could then take the shape of a handbook or checklist of all production methods, capabilities and technologies available, offering design and manufacturing engineers with tips and tricks, dos and don'ts and detailed specifics on the product breakdown.

Another one way of making the trade-off or balance between depth and breadth is by dissociating the two. For instance, I9 stated that "the platform should contain information on entire chain from purchase to sale. If the platform contained information on quality requirements, then purchasing department will know what suppliers to choose". Similarly I13 stated that the platform should contain "tips and tricks, dos and don'ts and more specific facts". Then, a possible solution is to document such information in a knowledge repository, while the platform itself could consist of scalable or generic solutions to cater to the flexibility desired. The challenge is then to ensure that the knowledge repository is in alignment with the platform of generic solutions, but the disintegration of the two would enable a better understanding of the amount and nature of investment required in each.

Knowledge Capture

Barriers to successful knowledge management at GKN Aero have been studied previously [(Corin Stig, 2013), (Levandowski *et al.*, 2012)]. These barriers to knowledge capture and reuse were also indicated during interviews in this study. Primary barriers stated were:

i. a requirement to maintain secrecy between the various commercial jet engine programmes,

ii. hectic and long project schedules, and

iii. dispersal of project teams on completion of a project.

The intention at GKN Aero is to capture knowledge systematically and make the same available to other projects through the platform. However, if knowledge captured in a project is to be useful in a new context; for instance in developing new components or entering new markets; then it could potentially require additional processing. Data collected in this study did not shed light on how this will be taken into account in the platform strategy at GKN Aero. Knowledge capture has also been stated as part of the platform use process (i.e., the platform will be used in order to capture reusable knowledge) and at the same time as a part of platform creation process (i.e., the platform will be created by capturing reusable knowledge). A strategy for such knowledge capture was found to be lacking. Finally, companies today look to reuse knowledge for different purposes, such as for continuous improvement and to work towards a leaner organisation. It has been challenging to identify such an orientation in the current approach at GKN Aero.

Platform Approach

GKN Aero's current platform approach, when compared to approaches described in literature can be seen as a mix of the reactive bottom-up approach and proactive top-down approach to product family design described by Simpson *et al.* (2001). This can be seen in Figure 22. The approach at GKN Aero has been to gather knowledge on based on similarities, lesson learned, limits and capabilities from different commercial projects, standardize and reuse it in new projects. However, GKN Aero also adopts a proactive top-down approach by developing desired future capabilities to be incorporated in new projects. An example of this top-down approach is showcased by the push towards a fabrication strategy replacing castings. From Table 5, it can be seen that the overall approach has been stated by interviewees to be more bottom-up and there is a need for a shift towards a more top-down approach. The predominant bottom-up nature of the current approach can be attributed to GKN Aero's lack of control over the entire system architecture and a limitation to unrestricted access of information.

It is important to note here that since platform creation occurs during a product development project, meeting project deadlines and cost targets in projects takes a higher priority. This is similar to the product-driven strategy described by Alizon *et al.* (2009) shown in Figure 23. Here, the product goes through a development process from design to manufacturing, and is launched in the market; the platform is not directly specified but the initial product itself becomes the basis for future variants.

"Top-down" and "bottom-up" are terms used by Simpson *et al.* (2001) to describe product family design. However, it was found that the same terms represent a rather different facet of platform development at GKN. Top-down and bottom-up have been used by interviewees to indicate the source of drive and support in platform development efforts. When top management defines business needs for the future, the vision and intended use of the platform, it has been termed as a top-down activity. On the other hand, the expectation from engineers to identify requirements for the platform and create contents of the platform as per their needs has been termed as bottom-up activity.

Literature on product family design using platforms goes into detail on how a product, product family and platform differ from one another. Data from interviews and platform documentation show that a clear demarcation between a product, product family and platform has not been made at GKN Aero. Making this distinction would benefit scoping down the platform definition and thereby support strategy formulation.

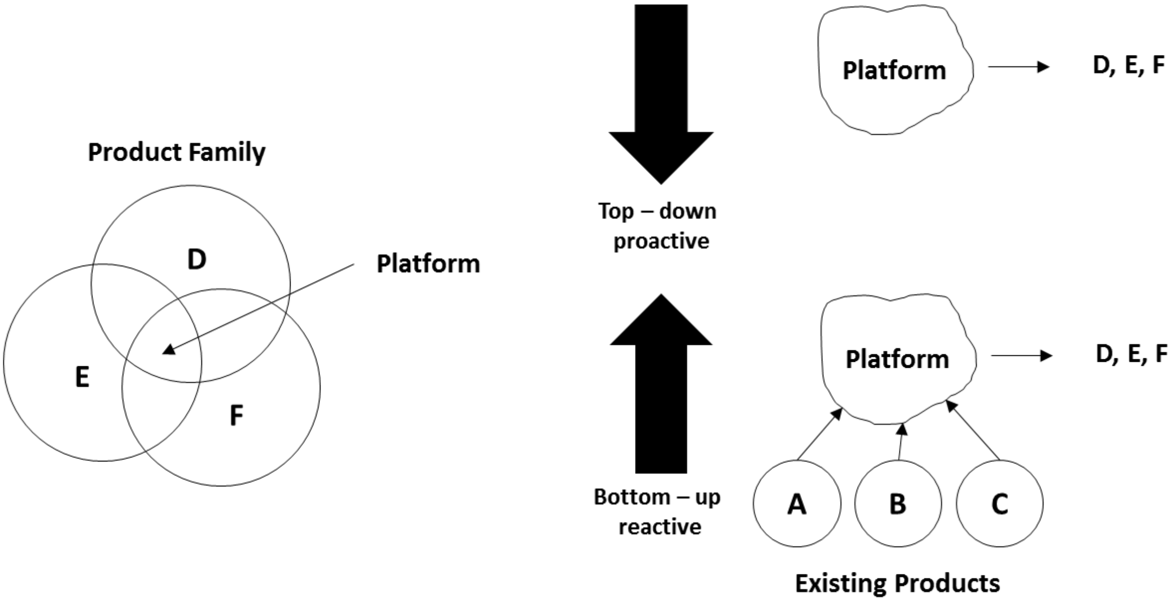

Figure 22 Top down and bottom up approaches to product family design as described by Simpson *et al.* (2001)

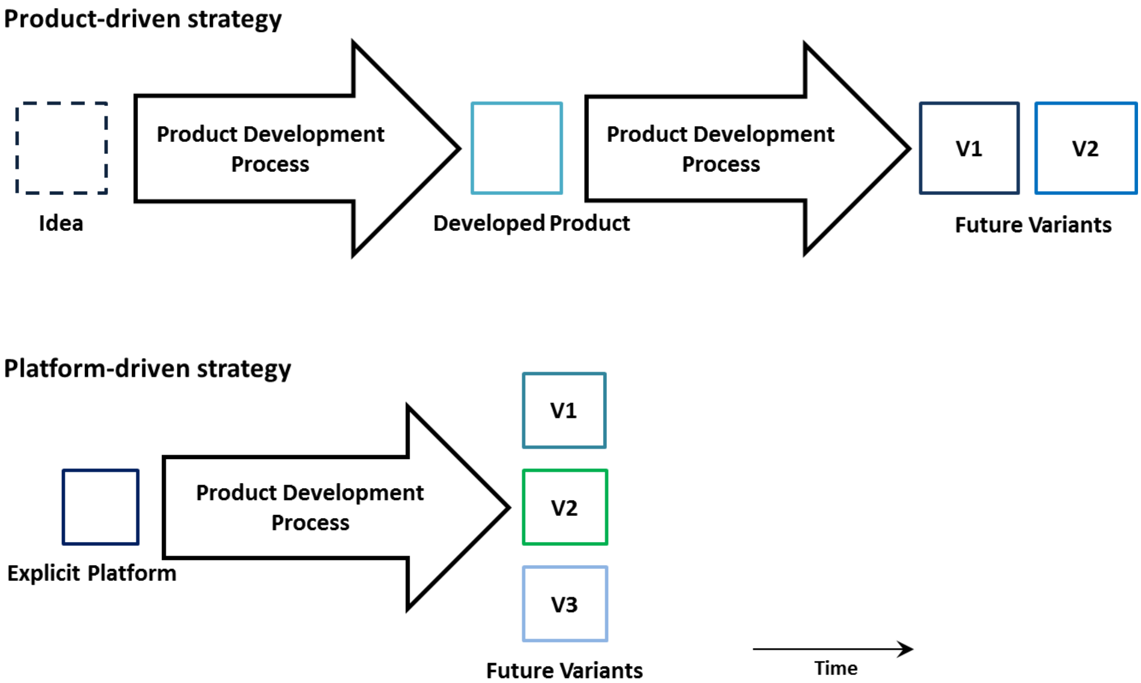

Figure 23 Product-driven and platform-driven strategies to product family design as described by Alizon *et al.* (2009)

4.4 GKN Platform Use

Results on platform use have been presented in the following sequence. First the current use of the platform is presented followed by the intended use of the platform. Next, the platform contents needed and the organisational changes brought about by platform use have been presented. Finally the views on PLM as a support in platform development have been presented. The different views provided by interviewees on platform use are summarized in Table 6.

4.4.1 Current Use of Platform

a) Need to define how to use platforms

Some interviewees felt that the aspects of how the platform is to be used and who will use the platform have not yet been defined. I8 stated he is, "Unsure exactly who uses and how product platform is being used." I2 stated, "We need to define intended use." I1 stated, "Knowledge on how to use the production platform documentation is lacking."

b) Current use in early stages

At the same time, interviewees stated that depending on what is considered to be the platform, it is already being used. It was stated to be used in early stages of product development. I1 stated that, "engineers use it in discussion with customers, as it provides better awareness of design solutions, and helps provide recommendations to customers etc." I2 stated that the platform is "used for making derivatives, marketing and bidding." I3 stated that the platform is "used for pre-study and concept development to answer question on how to determine future needs and define the market position of GKN Aero" I6 stated that with the help of the platform it is now "possible to better predict lead time and cost" and I15 stated that platform helps in "building business case and cost estimates."

c) Current Use in later stages

Some interviewees stated that the platform is used in later stages of product development. 13 stated that it is used as "input to conceptual and detailed design, design reviews, and BOP is used by manufacturing as a checklist/handbook." 14 and I9 respectively state that the platform is "already in use if Operational Management System (OMS) and Design Practise (DP) system are to be considered as a part of the platform" and that the "use of Design Practises is a platform requirement and so they are currently used."

4.4.2 Desired Use of Platform

a) Desired use in early stages

The intention to use the platform throughout the product lifecycle has been stated. I5 stated that "platform support is needed in phases where bulk of engineering work and decisions occur, for example early concept phase, to provide business intelligence with backup of engineering know how" and enabling in "design (department) knowing what manufacturing (department) can have and manufacturing (department) knowing what they could expect."

A number of uses in the early stages of product development were stated. These uses focussed on the quotation phase and conceptual design phase. For example I12 said platform can be used "during concept phase, to work with sets of design solutions than point solutions. Engineers should know from platform if the set of requirements (product cost-functional requirements-producibility) are within the knowledge boundaries, and get access to constraints." Similarly I2 also stated that it can be used in "in early concept phase and understanding the current portfolio" and "it would be easy to come in early in the project and talk about (product) requirements". I11also talked about balancing requirements stating that the "platform sets the box within which requirements are balanced, sets basic rules." Finally, it was stated that "it is be used in early concept phase to select solutions and not in detailed work. If it is to be used in detailed work, it is to choose manufacturing processes."

b) Desired use for manufacturing

In the detailed design phase, use for manufacturing and producibility was focussed on. I7 stated that the platform "should bring in suppliers early on as a network; support decision making like manufacturing methods to be used. Platform can be used to get volumes up and in turn get better prices from suppliers". I9 stated that it should help "reduce number of loops in iterations for manufacturability". And I13 stated that it would be used to "argue for design for producibility, being a starting point for manufacturing engineers it would be a support to argue for certain design solutions".

c) Desired use for design

Desired use during design was stated but to a lesser extent. I8 stated that it should be used as a "guideline giving limits, capabilities, opportunities; boundaries of design space and gaps in future technology. It is a way to provide flexibility and customised products".

Finally, there are also some other uses indicated, for instance by I12, "in technology development to fills technological gaps; to check if product fulfils functions in-service and loop back to development." Thus the platform is intended to be used throughout product development, starting from marketing and product planning, conceptual design to detail design, manufacturing, supply chain and technology development.

4.4.3 Platform Contents

In order to facilitate the desired uses of the platform there were statements of what the platform needs to contain, exhibiting a wide spread of contents. I8 also stated that the platform "should answer specific requirements but still be general, the specific technical requirements should be included."

a) Contents as Guidelines

I14 stated that the platform "could benefit from extended library of design interfaces, helping in leading discussions with customers" I2 stated that it needs to "have version control, maturity level of constituent technologies, should identify where platform definition is insufficient, should have rules for configurations for product platform, should identify restraints from production onto product platform and provide a designer with needs on range, validity, status, design rules and dependencies." I3 stated a need for "limitations on manufacturing methods, materials, requirements on product functionality and conceptual design, sourcing, pre-production preparation and Design for Manufacturability requirements." I3 added that the platform should "state opportunities and not only current capabilities especially with production requirements from product design perspective"

A number of interviewees mentioned Technology Readiness Levels (TRL) and Design Practices (DP) as platform contents (I15, I16). I14 expressed need for "technologies and TRLs, our DP system, it (platform) is everything from change management systems, to all our description instructions, in the production and so on, and it's our methods." Also, I14 makes a distinction between a platform description and the platform contents with the former being "how it (platform) fits together" and the latter being "how it's offered to the customer".

b) Contents from a design perspective

Requirements in design call for "CAD structure for visualisation" to be a part of platform. I8 and I9 also stated a need for "design requirements, boundaries for weight, geometry, producibility and conceptual models that are starting point for all work" as platform contents. I10 wanted "naming conventions, strict product structure and framework for decomposition of product"; "a common view of breakdown"; "a templated view of products allowing easier reuse" and verification or validation methods". I 11 stated that "off the shelf approved ideas that can be picked and used" and would be suitable platform contents. I2 stated that the platform "can be used as support for developing engineering design systems. It should be an executable model with defined relations."

c) Contents from a production perspective

I13, I14 and I15 mention contents that are required from a production perspective. I15 states that the platform should "contain industrial processes, machining time, weldability, producibility and information on supply chain." I13 stated the need for making the BOM, BOP very specific in the form of facts, tips and tricks and requirements on product platform, limits and capabilities on the industrial structure and a collection of best parts of all projects a part of the production platform, with only mature processes or technologies included. For platform contents I14 states "we have to pick up similar and predictable things, instead of final designs, we need the process of arriving at them." I14 adds that currently the production platform has dos, don'ts, BOM and BOP which could be "hard to use as is in a new project" while also stating that it is however "good to have them documented."

4.4.4 PLM Support for platform

Interviewees' views on PLM as a support for platform development have been summarized in Table 7 in the Appendix A. I1, I5, I8, I9, I10, I11 and I12 express that the platform will need IT tools for its use. I8 added that "I think it (platform) needs to be integrated in several systems because different departments work in different systems. Not every department works in CAD and PLM. Some departments work with SAP and I think you need to be very flexible. The platform should work for all departments and everybody should have access to it. Or people that need access should have access regardless of what IT system". Similarly, I11 and I12 respectively expressed that "it would be useful for manufacturing (department) to have access to design's (product platform)" and "platform should be supported by the system, all processes or ways to work with platform should be included in system." I6 stated that, "ultimately platform should be a part of daily work process made available through CAD system, configuration control system etc. that shows information from all functions".

I4 stated that the "platform strategy will help set up a good PLM system enabling tracking of data in projects, lifecycle documentation, and relation between data". I1 also stated that "PLM system should be more or less identical to the product, using same terminologies and structures".

4.4.5 Planning for PLM implementation

I10 described the current state of how IT and PLM systems are incorporated along with the need to plan their implementation. I10 stated with regard to PLM systems as a means to integrate people, processes, methods and tools: "a lot of that is sales talk from the PLM companies and it is easier to say and harder to do. And you can always question if it is worth the spending in moving the organization in all these PLM issues." I10 explained that the organisational change aspects and long term perspective is lacking at GKN Aero. "Couple of years ago they (VAC) were putting all their efforts into SAP, and now they want to move out from SAP into Teamcenter but not taking the time to fully evaluate, okay, what are the strategies that they have for doing this, does it fulfil our visions for the future. Currently it's a diversity of IT tools that has been implemented. SAP for configuration management, Teamcenter NX for CAD management and manufacturing layouts etc. And SAP as well for the ERP systems, requiring to some extent system integration and a lot of manual processes. By having different systems you will create different cultures on how to deal with data. That creates a cultural crack in the company creating a very unnecessary friction in the organisation. There has been no governance for PLM initiatives".

4.4.6 Knowledge Based Engineering Tools

Efforts are being made to develop a Knowledge-Based Engineering tool called Engineering Workbench. I8 states that "the objective is to see if we can find a way to work multidisciplinary in the early concept phase, which is very critical. This is where you have the chance to change the product. The chance to know if you want to change something with the customer as it's easiest to do it in the beginning rather than very late. So in this Knowledge-Based Engineering (KBE) project we are aiming to see if we can work multidisciplinary, across different departments like aero, thermal, structural department and design." "The platform should be the base for it."

I14 and I13 expressed the platform is far from being used as a configurator based on a generic BOM. I13 states that the platform "can be documents, integrated in DP or macro or part of PLM systems, but far from a configurator based on generic BOM".

4.4.7 Organisational Change due to Platform

While I6 expressed that there is "no foreseeable organisational change" that could occur from adopting a platform approach, few others expressed some potential changes. With regard to the formation of a group that could be responsible for platform development; I1 stated "we should set up a special unit focusing entirely on platforms; taking responsibility for the platform, and for platform management."

a) Platform as a constraint

I1 also stated that, "having a platform will constrain the organization." It will result in "less freedom for designers who start with platform instead of white paper". I11 agrees by stating that the "platform restricts creative ideas in concept phases; new creative ideas may not be necessary for similar projects but useful for different projects". On the other hand, I9 foresees that compilation of a large amount of project documentation will be done during platform creation and other pre-created information would be readily available for later use.

b) Influence on organisational culture

There were a number of changes stated by interviewees regarding the organisational culture. I10 stated that it is required to "create awareness so as to involve day to day activities of all". I7 stated that GKN Aero "needs to improve the way platform is visualized and communicated; currently it is mostly sitting with individuals and it (communication and visualization) will help make it more natural way of working." I5 adds that there is a "need change into platform way of thinking"; "people need to understand the benefit and importance, so people give and take from platform; and feel like they own it". I8 states that "everyone in the company: management to shop-floor should work with it; it affects everyone in company".

4.4.8 Analysis of Platform Use

a) Current situation and Use of Platform

In Section 4.2.3 and 4.3.4 it was described that at an operational level there is a lack of clarity on what the platform is supposed to achieve and what it must contain. This has consequently led to a lack of clarity on how to use the platform. Literature [(Pedersen, 2010), (Nilsson, 2007)] as well as the interviewees indicate that the use of the platform has to be defined.

Interviewees expressed that depending on what constitutes the platform; it is already being used, referring primarily to the existing product concepts and design practices. From literature, it is seen that the current use of the platform and the existing state of the platform merely forms portions of platform-based development. Outlining a few aspects for instance, currently at GKN Aero there lacks explicit definition of the shared assets (Robertson & Ulrich, 1998), the product family [(Sawhney, 1998) and (Simpson *et al.*, 2006)], a set of sub-systems and interfaces [(Meyer & Lehnerd, 1997), (Meyer & Dalal, 2002), (Muffatto & Roveda, 2002)], common process structure, associated product and process families [

(Sawhney, 1998) and (Jiao *et al.*, 2000)], production system supporting the desired variety of products (Halman *et al*., 2003) and underlying core technology (McGrath, 1995).

b) Desired Use of Platform and Contents Required

Collecting statements across the interviewees, a wide spread in the desired to use of the platform was obtained. How the platform balances this wide spread of desired uses was however found to be lacking, with desired uses arising from the different stages of product development and different departments.

Robertson and Ulrich (1998) emphasise the need to balance the intended benefits sought from the platform, which calls for making complex trade-offs. Nilsson (2007) suggests the optimization of the product family architecture but this is not feasible for a supplier delivering customised complex aero-engine parts. However, identifying areas where variety has a high cost to the company but a low value to the customer could help making trade-offs. Simpson *et al.* (2006) as well as Pedersen (2010) suggest that management's influence and cross functional platform efforts can help make these trade-offs. Both these aspects were found to be unaddressed and require attention at GKN Aero.

Interviewees expressed their wish for platform contents, which on compilation represent a large number of organisational assets and resources. Among these, the particular set of assets and capabilities that the organisation wishes to share across the different products is not clear.

c) PLM Support for Platform

It was mentioned that PLM initiatives have failed to receive requisite planning. Use of PLM support for platforms is primarily restricted to providing access to information throughout the organisation and serving the function of document control. Literature shows that PDM support is better suited for individual products and not complete product platforms [(Levandowski *et al.*, 2012), (Pedersen, 2010), (Simpson *et al.*, 2006)] and requires an extensive knowledge base to make the support better suited. This has also been the case at GKN Aero, with exploration into KBE tools for which the platform is being considered as the base.

d) Organisational Change due to Platform

Granovetter (1985) states that most organisations strongly resist change. At GKN Aero it appears that at an overall level, there has been acceptance of the idea of implementing a platform-based approach. But, the resistance to creating and implementing platforms could manifest when the platform beings to have a more significant influence at an operational level. Muffatto's (1999) finding that the platform strategy adopted has effects on the product development process and organizational structure is particularly relevant at GKN Aero as the current approach involves creating the platform within commercial product development projects.

The vast expanse of desired uses and contents presented in Sections 4.4.2 and 4.4.3 exhibit that the harsh compromises that are required in platform planning have not been made yet.

These harsh compromises could become a potential source of resistance for implementing platforms. For example, the existing production platform documentation indicates that this could be the case, with some interviewees pointing out that it is too detailed, and does not offer the variety, flexibility and opportunities expected from the production system. In such cases, in accordance with Keen (1981) that data is a political resource whose redistribution through new information systems affects the interests of particular groups; it mentioned by one of the interviewees (I13) that the production platform documentation would be used to argue for certain solutions during meetings with design leads. Meyer and Lehnerd (1997), Muffatto (1999), Nilsson (2007), Simpson *et al*. (2001) all describe company-wide realignments when adopting a platform but the interviewees did not express such a need. Interviewees however indicated that the existing product development process would need to change, and the organisational culture would need to ramp up, starting with believing in the platform, owning it, and thinking from a platform perspective to ultimately using it on a day-to-day basis.

4.5 **Summary of Results**

Based on empirical results, **Error! Reference source not found.** shows the current status of Integrated Platform at GKN Aerospace. The platform contents shown are both currently existing and desired contents for the future. The '?' on the arrows indicate that sufficient evidence was not found on the relationship between individual platforms, and how they are being developed collaboratively to create the integrated platform that was proposed in previous studies at GKN Aerospace.

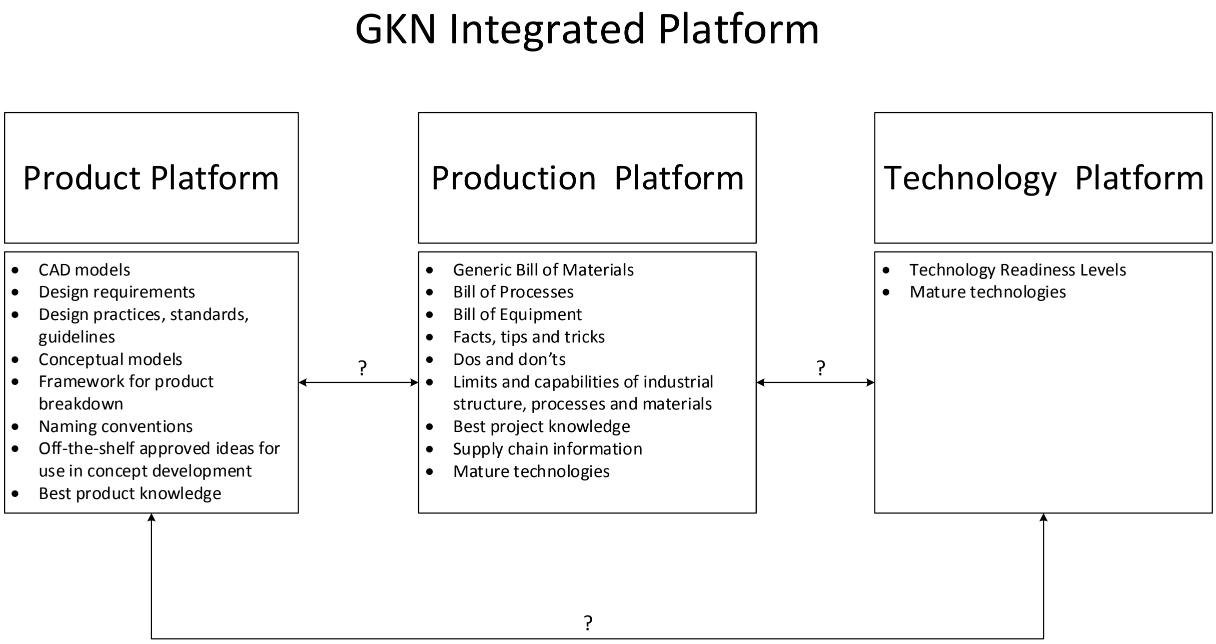

Figure 24 Current and desired contents of the Integrated Platform at GKN Aerospace

The main findings that answer Research Question 1, which are used in the analysis and subsequent recommendations are summarized as follows.

4.5.1 Platform Vision

1) At a higher level there is agreement on the vision for GKN Aero's platform, with reducing costs, reusing technologies and knowledge, and mitigating risks as recurrent views. However, at a lower level, around 25 unique aspects were mentioned by interviewees as components of the GKN platform vision. An overview of this can be seen in Figure 17 and in Table 2, in detail.

2) Conflicting views have been presented by interviewees regarding the number of platforms at GKN Aero. Some interviewees stated that the integrated platform is or should be composed of product, production and technology platforms while few others stated it is or should be a single GKN platform, and others stated that it should be a single product platform (Figure 18).

4.5.2 Platform Creation

1) Different views stated by interviewees on platform creation have been categorised under six labels, reflecting different types of needs in platform creation. These needs are for: a platform vision, a platform owner, cross-functional collaboration, a platform creation strategy, flexibility and finally needs associated with the development of platforms within product development projects. Views on platform creation can be found in detail in Table 3.

2) Knowledge Capture: A need for systematic knowledge capture has been stated by several interviewees. This aligns with the views stated by interviewees on reuse of knowledge as a vision for the platform. Lack of access to information from different projects due to secrecy issues, dispersal of project teams at the completion of projects and strict standards on documenting knowledge were stated as challenges in capture and reuse of knowledge. Views on knowledge management can be found in Table 4.

3) Platform Approach: There was a general agreement among interviewees regarding GKN Aero's current approach to product family design, with several interviewees identifying it to be similar to the reactive bottom-up approach. A few stated that a more top-down approach is needed for the future, while a few others stated that a balanced or mixed approach is needed (Figure 20). Further, in order to enable adopting a more proactive approach, a need for better integration and possible co-location with OEMs was stated. Views on platform approach can be found in Table 5.

4.5.3 Platform Use

1) A need to define intended use and how to use the platform was stated by a few interviewees.

2) Current use: Current use of the platform is in early phases and detailed design phases of product development projects. In early phases, it is used as a support in discussions with customers, for better prediction of lead time and cost, for building business case, determining future needs and defining GKN Aero's market position. In later phases of product development projects, the platform is used as an input in conceptual and

detailed design, in design reviews and in manufacturing as a checklist or handbook that provides information on mature or tested manufacturing methods recommended by the manufacturing department. Different views can be found in Table 6.

3) Desired Use: Desired uses for the platform spanned from use in marketing, product planning, conceptual design, and detailed design, to manage supply chain and technology development. Bringing in suppliers early on as a network, getting better prices from suppliers by getting volumes up and supporting decision making for choosing manufacturing methods have been stated as intended uses for the platform from a manufacturing perspective. From a design perspective, a desired use of the platform is that it is expected to give guidelines on limits, capabilities, opportunities and boundaries of design space and gaps in future technologies. It was also stated that the platform will help check if the product meets its functionality in-service, and loop it back to development. Different views can be found in Table 6.

4) Platform Contents: A wide range of constituents have been stated form design and manufacturing perspective. Among other things, the stated constituents are tips, tricks, dos and don’ts, BOM, BOP, information on supply chain, best knowledge form projects, CAD structures for visualization, DPs, TRLs, naming conventions for product decomposition, template views of products for reuse.

5) PLM support: Several interviewees have stated a possibility of using PLM tools to support platform development. A few interviewees expressed a need to investigate the perceived gain for such an investment further. A few others stated that it did not matter whether the platform is in the form of a document, PowerPoint or accessible via an IT tool like Teamcenter. Different views can be found in Table 7.

6) Organizational Change: Platform is seen to bring about organizational change by constraining the organization. This is seen to occur during early concept phases by restricting creative ideas. It is also seen as a way to make project documentation easier. A change in organizational culture has been stated as a need. This includes need for awareness; need to understand platform benefit and importance; need for it to become a natural way of working and need for entire organization to work with it.

4.6 Summary of Analysis

Based on the key findings in Section 4.5 and literature review, a list of needs has been formulated. The following needs have been used as a basis in synthesizing the RBP framework. Therefore, addressing these needs is identified as a crucial step in platform development at GKN Aerospace.

1. Need for Aligned Corporate Growth and Platform Vision

A need for a platform vision that aligns with overall corporate vision and growth strategies has been identified. Roughly 25 different aspects have been stated on the GKN platform vision. These can be seen in Table 2. Aspects that misalign could create a potential risk in smooth development of platforms. Theory suggests the needs for top management involvement in understanding and resolving disagreements regarding platform goals. Several authors have emphasized on top management involvement in resolving disagreements for a balanced overall platform solution [(Robertson & Ulrich, 1998), (Halman *et al.,* 2003); (Simpson *et al.,* 2006)].

2. Need for Platform Scoping

From results, it was seen that an understanding of needs of platform planners, creators and users is necessary to ensure that the platform has an influence at an operational level. Further, determining needs of platform planners, creators and users can also be useful to highlight aspects of alignment and divergence, thereby supporting the scoping of platform concept.

Responses from interviewees on the need for clarity on platform vision as a prerequisite to platform creation has also been corroborated in literature. Pedersen identifies three fundamental prerequisites for success of a platform approach: knowing *why* platform is pursued, knowing *how* the pursued effects can be obtained and knowing *what* contents are needed and what interrelations between contents will provide these effects (Pedersen, 2010). Following this line of reasoning, a possible way of progressively scoping down the platform is by determining the desired approach to creation, articulating a vision, formulating strategies to achieve this vision, defining the platform structure and determining the contents. As a result, this will help answer what specific organizational assets and resources will be used in the platform. This has been illustrated in Figure 21.

3. Need for a Platform Owner

Need for a platform owner and a person or group responsible for the platform is also supported by literature. Robertson and Ulrich suggest that "Top management should play a strong role in the platform planning process for three reasons: (1) platform decisions are among the most important made by a company, (2) platform decisions may cut across several product lines or divisional boundaries, and (3) platform decisions frequently require the resolution of cross-functional conflict" (Robertson & Ulrich, 1998).

4. Need for Cross-functional Platform Development

Need for cross-functional collaboration has also been mentioned by Robertson and Ulrich who state that "Platform planning is a cross-functional activity involving at least the product planning, marketing, design, and manufacturing functions of the firm. In most cases platform planning is best carried out by a core team made up of representatives from each of these functions. For large development projects, each of these representatives is in turn supported by an experienced staff." (Robertson & Ulrich, 1998).

The need for cross-functional effort in platform planning also arises from the fact that the platform has an impact on the product in all its lifecycle phases (Alblas, 2011) and requires complex trade-offs to be made in the planning process [(Robertson & Ulrich, 1998), (Simpson *et al.,* 2006)].

5. Need for a Balanced, product-development based approach

Results show that the current platform approach has been to gather knowledge based on similarities, lessons learned, limits and capabilities from different commercial projects and use this knowledge base as the platform, corresponding to a reactive bottom-up approach described in platform literature (Simpson *et al.,* 2001). A proactive, top-down approach is also adopted by proactively developing capabilities and technology for new projects. Further, the development of the platform within product development projects corresponds with the product-driven platform strategy described by Alizon *et al.* (2009). Results show that in an effort to strike a balance between reactive and proactive approaches, GKN Aero has adopted an approach of simultaneous and iterative creation and use of the platform. Therefore, formulating strategies for a mixed or balanced approach can be useful in GKN Aerospace's situation. Such a balanced approach would combine the merits of proactive and reactive approaches; and platform-driven and product-driven strategies.

6. Need for Organizational Change

Developing platforms and implementing platform-based development brings about a fundamental change in the organisational culture. The roles and responsibilities of departments and individuals undergo significant changes. Careful efforts are needed to plan and implement the change [(Muffatto, 1999), (Pedersen, 2010), (Simpson *et al.,* 2006)].

5 Synthesis

Based on the empirical results and analysis, a framework has been synthesized to addresses the challenges and needs identified at GKN Aerospace with respect to platform development efforts. It is thus recommended as a possible solution for evaluation, testing and adoption in future platform development efforts. Managerial Implications for adoption of such a framework are also discussed.

5.1 The RBP Framework for Platform Development

In order to address the needs highlighted in Section 4.6 and the challenges in product and platform development identified in Section 4.1, the RBP framework for platform-based development has been proposed. The three components of the RBP (**R**equirement-driven, **B**alanced-approach, **P**roduct development-based) framework can be seen in Figure 25, Figure 28 and Figure 30. The purpose of the RBP framework is to provide a systematic and structured method for platform-based product development in an organization that faces challenges and has needs similar to the ones identified in this study.

Requirement-driven:

The framework is requirement-driven as it uses requirements as an input in platform development. Although requirements have not been specified in this study, needs for platform-based development have been identified which can be used as a basis for establishing requirements.

This is motivated by a systems engineering approach which "focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem" (International Council on Systems Engineering, 2006).

Thus, the study forms a basis for employing systems engineering approach to platform-based product development at GKN Aerospace by identifying the needs of people involved in platform development. A next step would be the compilation of a more comprehensive list of needs which can then be used in creating a requirement specification with specific, measurable, attainable, relevant and traceable (SMART) platform requirements. This is however out of the scope of this study.

Balanced-approach:

The framework borrows aspects of top-down proactive approach as well as bottom-up reactive approach to product family design. Thus, the framework allows for standardization of existing products to create generic solutions for the platform as well as proactively building reusable knowledge to continuously incorporate in the platform.

Product development-based:

In this framework, creation, use and evaluation of the platform take place within product and technology development projects. Thus, the goal of the framework is to facilitate platform development by carrying its creation and use within product and technology development projects.

There is a deviation here from classical platform approaches described in literature where a platform is first created and then used in product development projects to create product variants. The deviation is made by taking into consideration: (i) type of desired platform contents (like knowledge, technologies); (ii) provide an approach that can support a transition from a reactive, product-driven strategy to a proactive, platform-driven strategy. Here product-driven and platform-driven strategies refer to the platform strategies proposed by Alizon *et al*. (2009).

The RBP framework consists of Top-Down Management Drive, setting up of a Platform Team and prescribing the PCDE (Platform **P**lanning, Platform **C**reation, Platform **D**efinition and Platform **E**valuation) phases of Platform Development. Managerial implications of adopting this framework at GKN Aerospace have also been described.

5.1.1 Top-Down Management Drive

Within the proposed RBP framework, the role of top-down management drive is described here. As seen in Figure 25, top management performs three major functions in platform development: Creation and communication of a platform vision that aligns with the overall corporate vision; driving platform development efforts to ensure that they are undertaken as an organization wide effort; and setting up of a platform team. The first two functions are described below. The platform team is discussed in detail in Section 5.1.2.

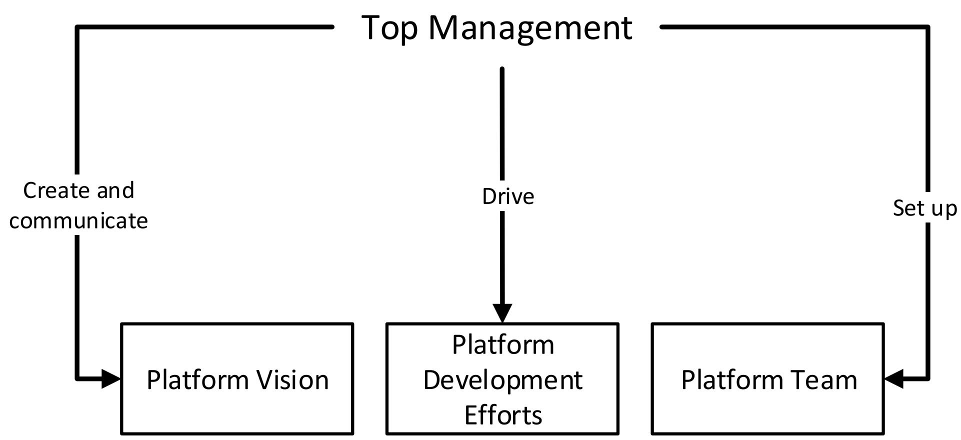

Figure 25. Role of Top-down management drive

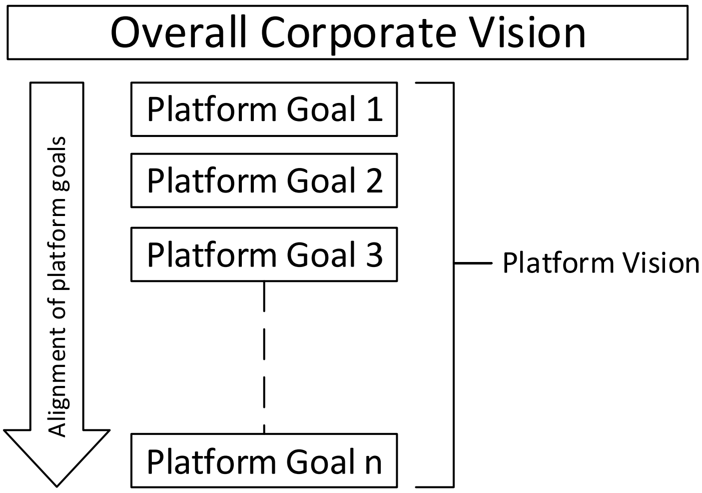

Figure 26. Alignment within platform vision and with overall corporate vision

a) **Creation and communication of Platform Vision**: Top management defines the purpose and vision for platform development. Platform vision is formulated by ensuring an alignment with overall corporate vision. This can be seen in Figure 26. This sets a broad scope for the platform, which is progressively scoped down. Short-term and long-term decisions concerning the overall organisation influence this broad scope. For example, an organisation could wish to keep long-term investments to a minimum meaning that investments in the production facilities would be limited. However, short-term investments could be possible. Such a decision would mean that the production equipment would be maintained constant, and investment in supplier base or short-term human resource recruitment could be an alternative.

b) **Driving Platform Development Efforts:** Top management is required to lead the platform development effort. The purpose and vision for the platform are to be communicated and its development is to be carried out as an organisation-wide effort. Communication of the platform vision through senior management is expected to bring about a common understanding on why a platform approach is being pursued. This is seen in Figure 27.

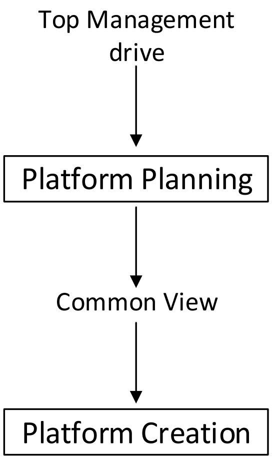

Figure 27. Role of Top Management drive in creating common view

The formulation of platform vision is a complex process that demands rigorous economic analyses. This secures that investing in a platform approach is a way forward for addressing the challenges faced in product development and other needs of the organization. Some essential steps in platform vision formulation are: (a) building a business case model, (b) carrying out a Cost-Benefit Analysis (CBA), (c) building product, market and feature plans to understand the current and desired market position and product portfolio. The process of strategy formulation and suitable methods and tools that can be used to support this process has not been investigated as it lies outside the scope of this study.

The following example, however illustrates the importance of a systematic approach of proceeding from vision to strategies to operational level creation. Three recurrent platform goals were observed in empirical results - reduction of costs, mitigation of risks and reuse of knowledge and technologies. As an example, it is assumed that the GKN platform vision is to "*create an extensive knowledge platform in order to minimize program costs through reduction of program risks*". Accordingly, methods can be employed to carry out risk accounting and identify areas where program risks are highest. Costing methods can be used to identify engine products and services that are unprofitable. And cost reduction can be focussed to specific areas of the product development life cycle. Creation of the knowledge platform can be focussed to those specific areas, to begin with.

Therefore, top-down management drive addresses the need for:

a) Explicitly stated and communicated platform vision

b) Alignment within platform vision and with overall corporate vision

c) Common view on platform development efforts

d) Platform owner (through setting up of the platform team)

Here, it is useful to revisit literature on organizational change to emphasize the significance of top management support in platform development. Meyer and Lehnerd (1997) notes in connection to the implementation of a product platform at Black and Decker: "the most important action that drove the platform development was the long-term vision of the senior management for whom this initiative was a top priority". Simpson cites an example of the successful reorganization around product platforms at IBM and states that it "produced dramatic results, but it was only because IBM's CEO at the time, Louis V. Gerstner, spearheaded the culture change by appointing senior management to lead the effort and commit the required resources" (Simpson *et al*., 2006).

Robertson and Ulrich state: "Top management should play a strong role in the platform planning process for three reasons: (1) platform decisions are among the most important made by a company, (2) platform decisions may cut across several product lines or divisional boundaries, and (3) platform decisions frequently require the resolution of cross-functional conflict" (Robertson & Ulrich, 1998).

5.1.2 Platform Team

Top management drive also results in the creation of a cross-functional platform team that is responsible for platform development. The team is allocated required resources for platform development. The constituents of the platform team and its interaction with other stakeholders in platform development can be seen in Figure 28. Management assigns to this team the responsibility and authority for progressively reducing platform scope. This team takes ownership of the platform and is accountable to management for periodic evaluations.

The cross-functional platform team should consist of experienced and skilled representatives from research and development, product planning, marketing, design and manufacturing functions of the organization. This team owns the platform, its structure and contents and is also responsible for establishing clear goals, deliverables and deadlines for platform development. Thus, a platform team balances two kinds of requirements: requirements for creating platforms and requirements in commercial projects (referred to as project requirements). In doing so, the platform team is able to provide a demarcation between platform development and product development.

A platform team is the core of the platform development process. It carries out the activities of Platform Planning, Platform Definition and Platform Evaluation and is responsible for managing the activities of Platform Creation. This management is achieved by collaborating with functional departments and product development teams belonging to commercial projects. In this manner, the platform team branches out into its representative departments for operational level support and influence.

A new concept of a platform scout is introduced here. A platform scout functions as a part of the platform team; and is located at the interface between an organisation and its customers (OEMs), suppliers and competitors. A platform scout gathers information on platform specific requirements from engine manufacturers, airline manufacturers, suppliers and competitors. By doing so the scout equips the platform team with information to make proactive decisions for the platform. A proactive function of the platform scout is illustrated by the following example.

The temperature which the TEC has to withstand is a critical factor for the material used which in turn has a significant bearing on the design and production solution developed. A change in material could increase the development cost drastically. In this example, the platform scout can proactively seek estimates on the temperature to obtain a temperature range or interval that can be flowed down to the platform team. The platform team has the ability to prepare the platform accordingly. This would allow the platform team to address the probable risks during contract negotiations. Similarly, platform scouts are also assigned the task of scouting for platform specific requirements within the organization, from various functional department and R&D.

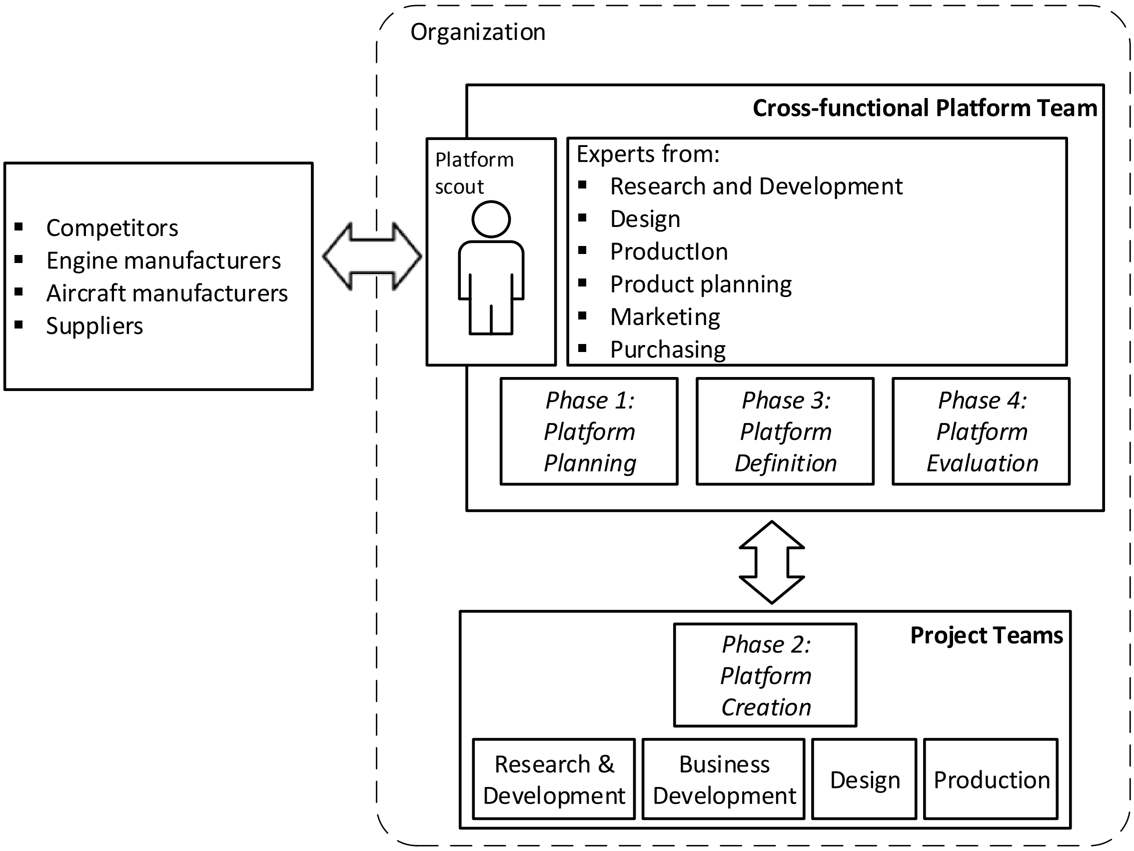

Figure 28. Constituents of the Platform Team and its interaction with other stakeholders of product and platform development

The platform scout has been described here as an agent carrying out the functions of a) proactively seeking information outside the organization from customers, suppliers and competitors, b) proactively seeking information within the organization from functional departments and R&D.

Therefore, the value that the scout brings is to enable building a knowledge base which provides reusable knowledge intended to be used in the platform. This is particularly relevant in case of GKN Aero's platforms which are being currently developed to be based on reusable knowledge. Previous studies at GKN Aerospace have identified areas having high potential for reuse. Employees with competences and expertise; and knowledge from technology development are identified as areas with high potential for reuse. The proactive scouting for information within the organization by platform scouts and functional experts of the platform team capitalises on these identified areas of reuse. By proactively seeking information, the scout also leverages phases of product development that currently suffer from late surprises, thereby mitigating project risks. This is discussed in further detail in Section 5.2.4.

The platform team thus addresses the needs identified for:

a) Cross-functional collaboration in platform creation

b) Clear platform goals, timeline, deliverables and deadlines

c) Demarcation between product and platform development

d) Managing platform creation, use and evaluation within product development projects

e) Continuous platform scoping

f) A shift towards a mixed or top-down approach in product family design (through the platform scouts)

The platform team proposed here is motivated by the strong emphasis laid on the significance of cross-functional product development teams in implementing a platform strategy. Simpson cites an example of Sanofi Aventis, developer and manufacturer of vaccines who use a fully integrated approach, with their product platform team consisting of representatives from R&D, manufacturing, marketing, quality assurance, logistics, and even the legal department. He states that "Cross-functional teams have been used to great effect in other industries, including automotive and aerospace" (Simpson, 2006). Another example of successful implementation of a department responsible for platform development and management is the Group Tucks division at Volvo AB.

Finally, the platform team proposed here is a conceptual idea that lacks requisite grounding in empirical results beyond statements expressing the need for a dedicated team and cross-functional collaboration. Hence, a clear definition of its structure and position within GKN Aerospace's current organizational structure is challenging to formulate. However, a proposal is made for a potential platform team structure and its position within the organization. This proposal requires further investigation and evaluation for validity and applicability at GKN Aerospace and has been described in Section 5.2.1.

5.1.3 PCDE Phases

Four phases have been identified and defined as essential in platform development. These are Platform **P**lanning, Platform **C**reation, Platform **D**efinition and Platform **E**valuation.

The input, output, controlling mechanisms and prerequisites or controls for the PCDE process are shown in Figure 29 and the **PCDE** phases of Platform Development are illustrated in Figure 30.

As in Figure 30, the purpose of the PCDE phases is to create an improved, updated version (P_N) of the platform from an existing version (P_{N-1}). Prerequisite for the PCDE phases to be carried out are an explicitly defined, shared and communicated platform vision as well as top management drive. Platform Team carries out the planning, definition and evaluation phases.

It supports product and technology development teams which carry out the creation phase. Since the aim of the RBP framework and PCDE phases is to facilitate continuous creation and improvement of the platform, the actual use of the platform has not been explicitly included in the framework. Platform use as an input to Platform Evaluation is however discussed.

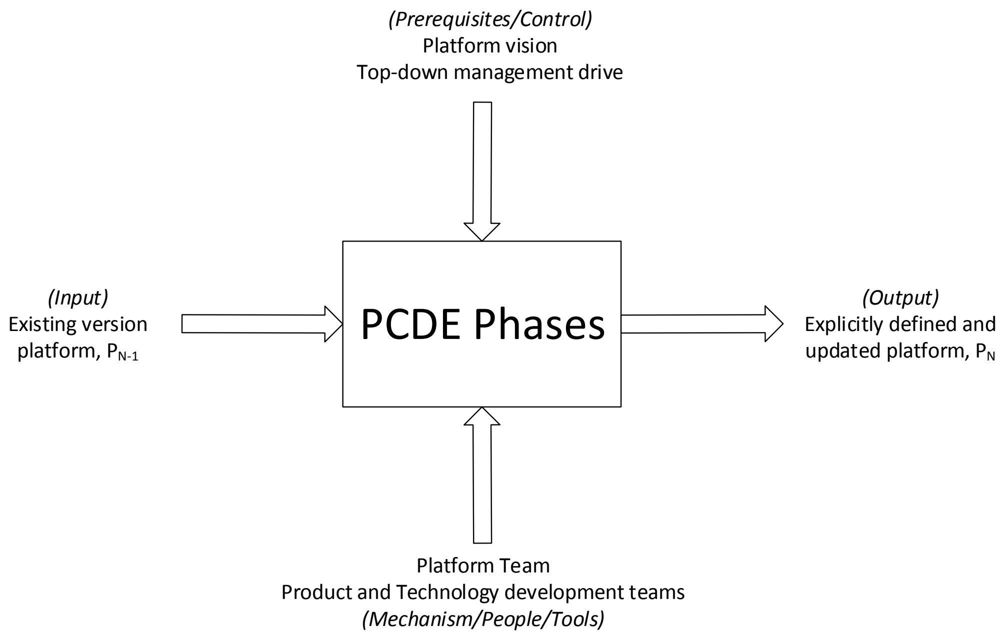

Figure 29 Input, output, prerequisite and people involved in the PCDE phases

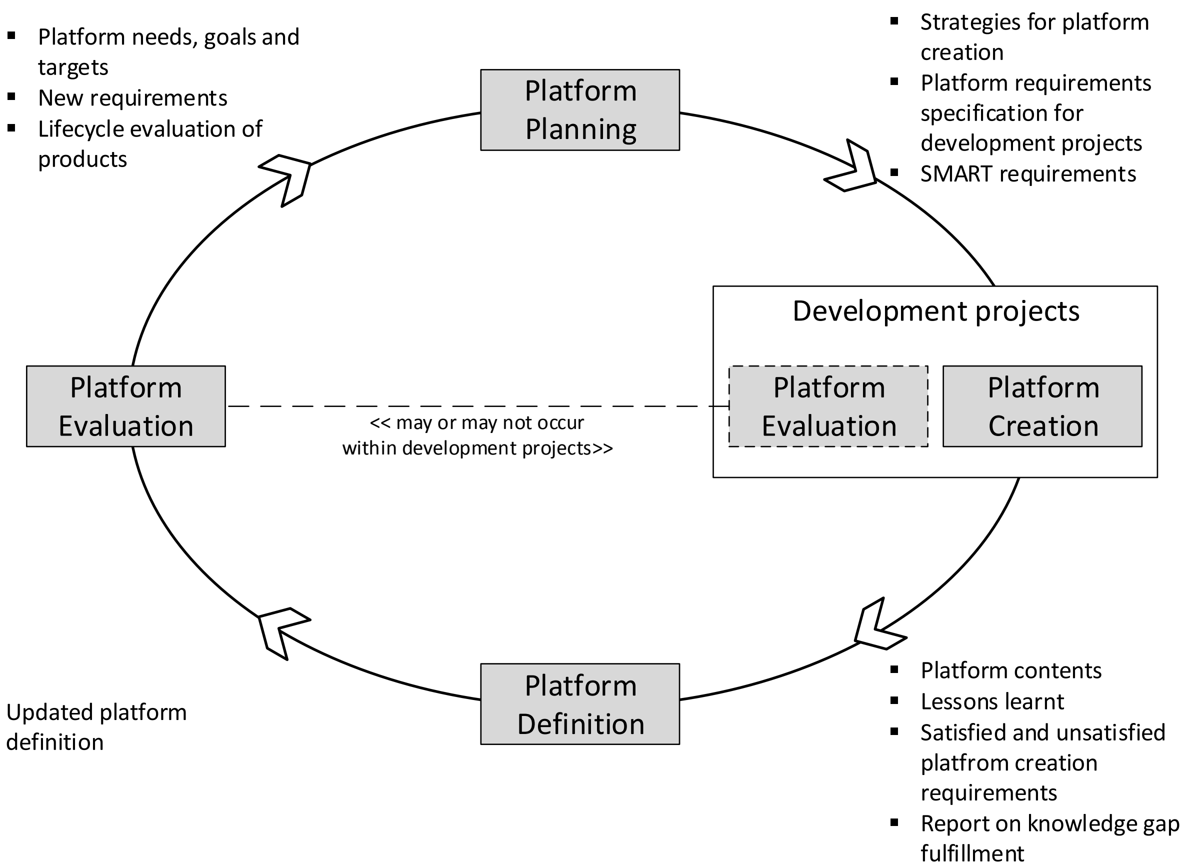

Figure 30 The PCDE phases of Platform Development

a) Platform Planning

The purpose of the Platform Planning phase is to use platform vision as a basis to formulate strategies for platform creation. Platform goals, needs and targets are an input to the platform planning process. The output is not only a strategy for creation but also a balanced platform requirements specification that is fed into development projects. For GKN Aerospace, platform needs and targets arise from technology, product and production development. Hence, all three components should be taken into account in platform planning.

As a consequence, the planning phase would require complex trade-offs to be made through cross-functional collaboration. Knowledge and experience held by functional experts is a key factor in making these trade-offs. During this phase, any resolution of potential conflicts can be done with the help of management or by referring back to the platform vision in which platform decisions must be anchored. The proactive top-down planning is supported by senior management and the knowledge required for this is continuously sought by the platform scouts.

A typical Systems Engineering process involves converting needs and wishes into specific, measurable, attainable, relevant and traceable requirements (International Council on Systems Engineering, 2006). Systems engineering approach could be used to convert goals, targets and needs laid out by top management into balanced platform requirements specification that is provided to each product and technology development project.

The requirements specification is forwarded to development projects where the current platform is used. As a part of this requirements specification, a platform team specifies knowledge gaps that they wish to be filled in each development project, which would help improve the current version of the platform. For instance, this could be the limits of a particular design parameter or a production parameter or the effect of these parameters under certain physical conditions.

b) Platform Creation

The outcome of Platform Planning phase feeds into a Platform Creation phase which takes place within product and technology development projects. In case of product development projects, requirements from engine manufacturers are received and these requirements are treated with highest priority. Product development projects use a current version of the platform and requirements for platform creation are also to be met within the project, but they receive a lower priority than customer requirements in project requirements specifications.

Due to these shifting priorities, the outcomes of development projects cannot directly become a part of the updated platform. Instead the outcomes are used in the next phase of Platform Definition to make decisions that help create an updated platform.

The platform team is present during major gate reviews and cross functional project meetings to simultaneously guide the use of a current platform as well as guide creation of an updated platform. At the completion of a product or technology development project and the Platform Creation phase, comprehensive documentation is handed over to the platform team which then carries out the Platform Definition process. This documentation includes lessons learnt, list of satisfied and unsatisfied platform creation requirements, a report on limits of the current platform and partially or completely filled knowledge gaps as requested by the platform team. The compilation of this documentation could occur as a continuous process within development projects with the platform team providing the necessary support and drive.

c) Platform Definition

Platform Definition phase concerns updating of the platform based on the outcomes of Platform Creation. The team receives the comprehensive documentation from development projects which serves as an input in this phase. Knowledge from the documentation is compiled across different projects taking precautions of adhering to existing secrecy issues within projects. Also during the Platform Definition phase the platform team uses operational level support of functional departments to create generic knowledge so as to surmount knowledge sharing barriers due to secrecy. The platform team, with help of platform scouts could also actively try to gain the confidence of engine manufacturers to have more open agreements and get requisite support for the organisation's platform and product development efforts.

Development projects simultaneously create and use knowledge. Knowledge that is created and used could either be a part of a current version of the platform or a knowledge repository that is not a part of the platform but is still deemed valuable for development. This knowledge repository could include capabilities, methods, design solutions, information on technologies, supplier base or quality requirements. Thus, the Platform Definition phase makes a distinction between knowledge creation for the platform and general knowledge creation (such as for continuous improvement) as shown in Figure 31.

This is done by studying the outcomes of Platform Creation in light of the platform vision defined by top management; strategies formulated during Platform Planning; and in context of the development projects they were a part of. Questions regarding their reusability, validity and generalizability are answered. Based on this learning, the platform team updates the platform with a new definition. This process of Platform Definition represents the bottom-up reactive approach in platform development. The team is also responsible for managing current and past versions of the platform, ensuring access throughout the organization and maintaining traceability within the platform contents. PDM tools are expected to provide support in these tasks. Experience from several development projects and knowledge from functional experts in the platform team could be used to create criteria based on which decisions can be made on whether a Platform Creation outcome should be included in the updated platform or the knowledge repository. The updated platform is then used within future development projects.

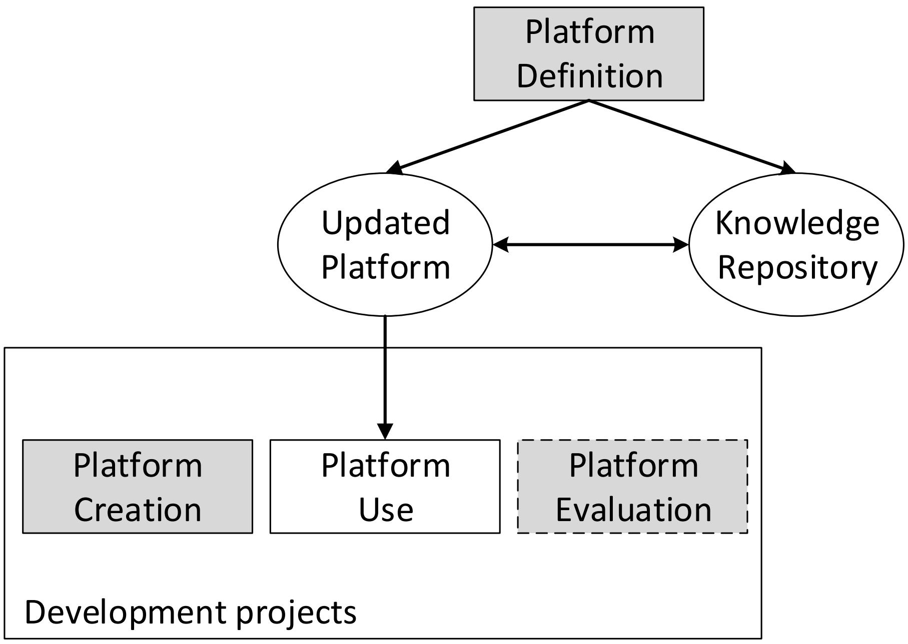

Figure 31. Output of Platform Definition phase and its use in product and technology development projects

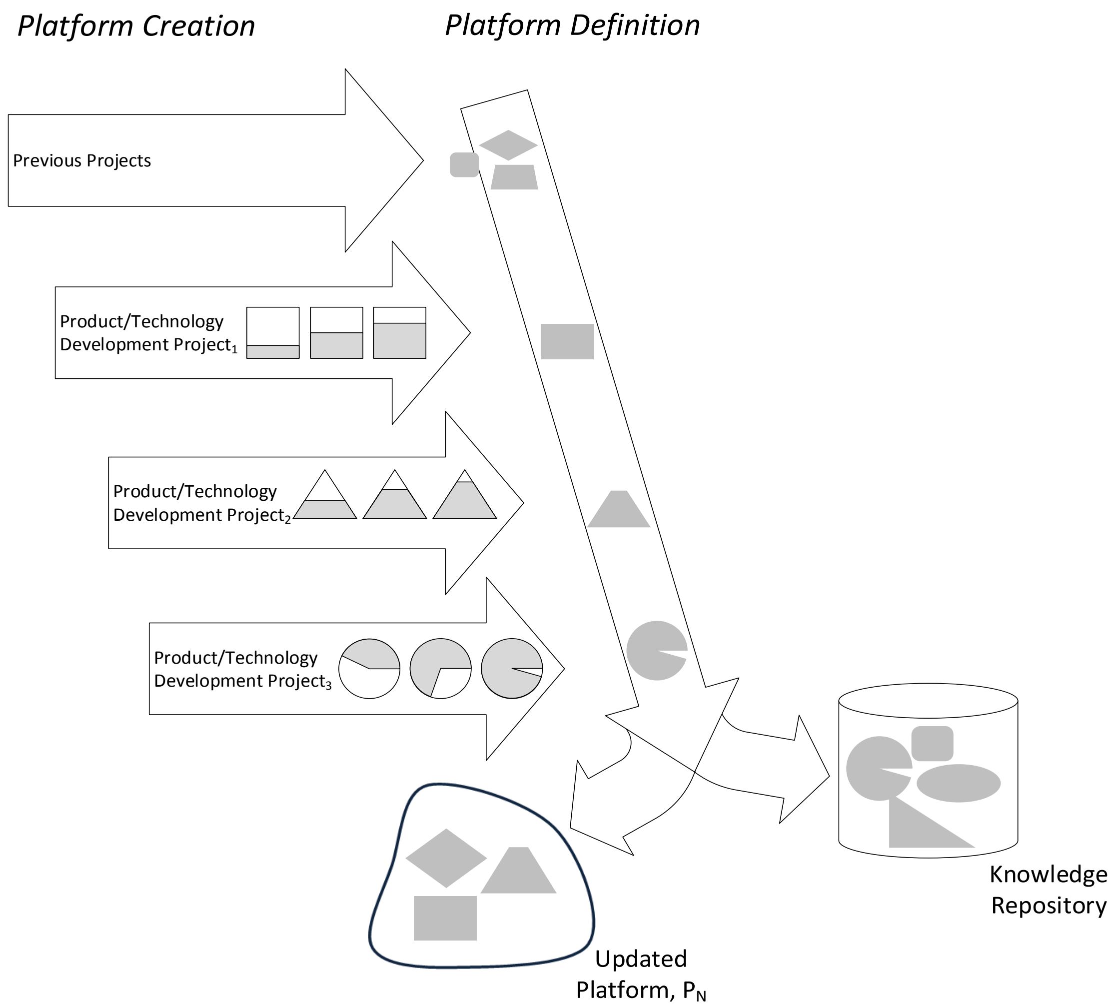

Figure 32 Difference between Platform Creation and Platform Definition phases

As seen on the left of Figure 32; development projects are based on a current platform and this is developed as best as possible as per the requirements from Platform Planning phase. The progressively filled geometric figures represent the fulfilment of requirements and filling of knowledge gaps. During Platform Definition phase the outcomes of creation are used to update the current platform. Here it is seen that an outcome of Platform Creation (the pie) was not included in the newly updated platform. It instead became a part of the knowledge repository. The decision of whether to include these outcomes in the platform or make it a part of the knowledge repository is made by the platform team, thereby alleviating this responsibility from the product and technology development teams who are faced with the requirement of securing project success. Further, the Definition phase allows the platform team to bring a functional perspective, expertise and information from within and outside the organization through its functional experts and scouts, in making educated decision on a platform definition.

d) Platform Evaluation

Platform Evaluation phase is the continuous evaluation of the updated platforms, done mainly through development projects. These projects could be the ones where new platform creation requirements are being studied such as those in platform creation phase or could be other development projects where there are no new platform creation requirements. It is through the latter that objective evaluation of the most updated version of platform's suitability can be determined. Operational level needs of users are documented as future platform needs and requirements. This is fed back to platform planning to refine the scope of the platform and its contents. Demonstrator projects can play a significant role in this phase to test the validity and applicability of the platform in new areas. The evaluation could also be triggered by sources outside the organisation such as a shift in the supplier base or emergence of a new or competing technology. Knowledge on field performance of developed products (such as engines that service aircrafts) is gathered to feed back to Platform Planning to evaluate if the requirements set by the platform have been too conservative, for instance.

Evaluation could also allow for unused knowledge from a current version of the platform to be forwarded to the knowledge repository, and already existing knowledge from the repository to be included in an updated platform. This has been shown in Figure 31, where the dashed line around Evaluation implies that the process may or may not occur within development projects.

5.1.4 Knowledge Management

Knowledge capture and reuse can be related to a number of initiatives within the organisation such as lean development, continuous improvement and platform development. Thus, knowledge capture and reuse throughout the lifecycle of the product could be governed by a dedicated body within the organisation. The platform team could work in close co-operation with this dedicated body and be responsible for knowledge management associated with platform initiatives specifically. In this way, the platform team can access knowledge throughout the product lifecycle and influence the entire lifecycle while maintaining a synergy with other knowledge related initiatives.

5.2 Managerial Implications

Managerial implications in adopting the RBP framework for GKN Aerospace are described below.

5.2.1 Setting up of a Platform Team

Here, a proposal is made for a potential platform team structure and its relative position within GKN Aerospace. This is shown in Figure 33. The team is composed of:

a) Director of Platform Management

b) A team of experts from various functional departments such as research and development, design, manufacturing, product planning and marketing

c) One or more platform scouts

d) One or more platform project managers

A platform steering committee is unlike a department or team and is hence represented by a dashed box. It is a small group of individuals who would meet on a monthly or quarterly basis to aid top management in the platform planning process. The main function of the steering committee is to assist top management in providing direction, control and guidance to the platform development efforts. This includes creation and communication of the platform vision that aligns with overall business goals and ensuring that platform development needs are represented and addressed. Thus, the steering committee would be present or represented when top management meets over agenda regarding the platform development. The steering committee could be initiated with a few members such as the Director of Platform Management, Head of Chief Engineers, Head of Business Development and Programs, Head of Finance etc. Other positions in the committee could be created as per needs and creating a provision for temporary members can also be considered. The intention would be for the steering committee to represent people within the organization in such a way that it would allow the creation of a holistic and balanced platform vision.

Director of Platform Management is similar to Head of Chief Engineering with respect to having a holistic view of different development programmes, engine product and engine service programmes. Director of Platform Management is accountable to top management for the readiness, execution and review of the platform within research, technology and product development projects. The Director of Platform Management also ensures that platform requirements are included in project pre-requisites.

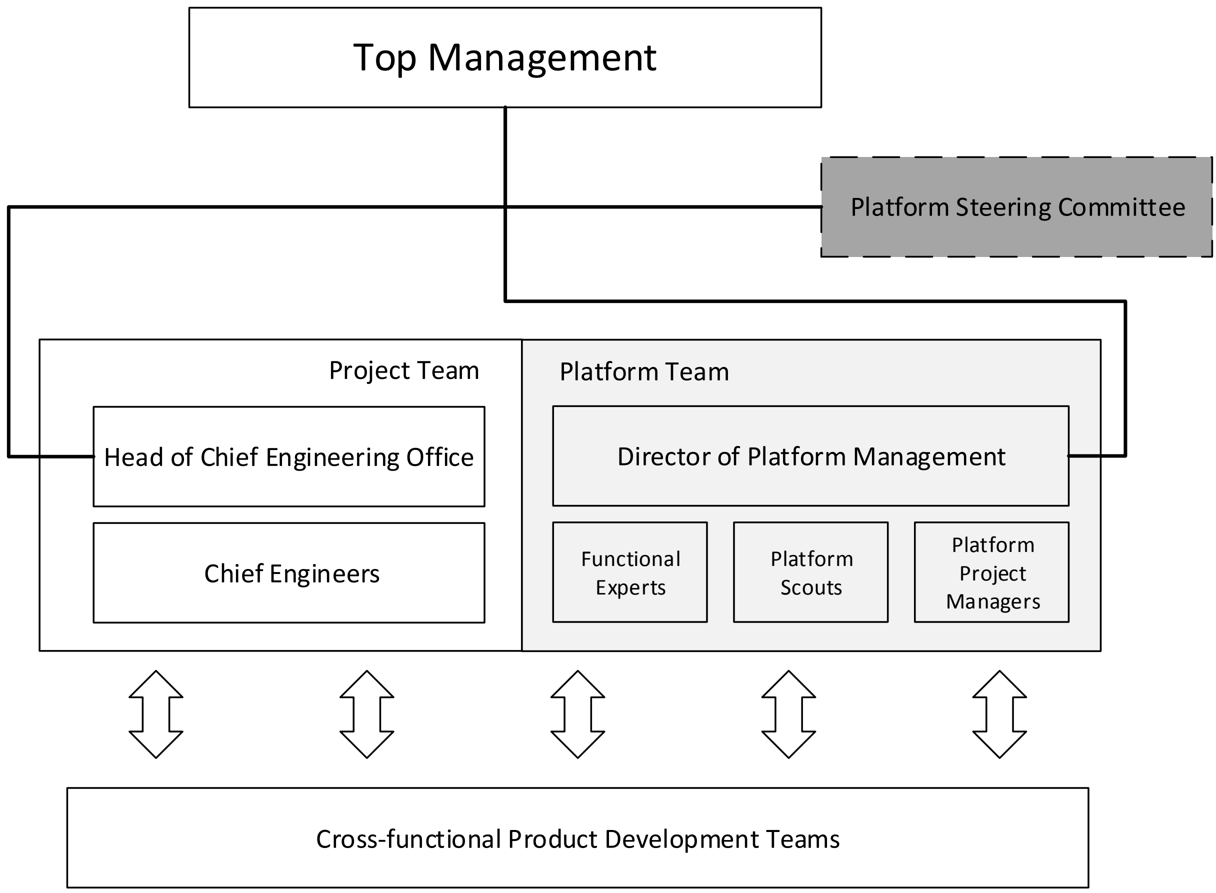

Figure 33. Proposal for the constituents and position of the platform team at GKN Aerospace

Director of Platform Management is supported by a team of Functional Experts from various functional departments, one or more Platform Scouts and one or more Platform Project Managers. Functional Experts are experienced and skilled representatives from functional departments and provide the Director of Platform Management, the Steering Committee and top management with requisite technical knowledge to support decision making at a higher level.

The role of platform scouts has been discussed in detail in Section 5.1.2. Platform Project Managers represent the platform team in product development projects to ensure that platform requirements are being met. Platform Project Manager could be responsible for platform sign-off at gate reviews to ensure the compliance of platform requirements that are included in project pre-requisites.

Some firms are experimenting with layered organizational models where platform teams are acting as a connecting layer between the slower science-related organizational layer of basic R&D and the fast-paced market-related product development layer, where designers are primarily concerned with tailoring and assembling products from already existing and proven technologies and components to respond quickly to changing customer demands. The suggested platform team structure aims at providing such a connection within the similar situation observed at GKN Aerospace.

5.2.2 Metrics for platform planning

The formation of a common organisation-wide platform vision could benefit from developing metrics to facilitate decision making at a higher level. A suggestion is quantifying the possible areas of reuse in monetary terms by drawing from experiences in technology and product development. This would also enable a cost-benefit analysis when planning platform investments.

5.2.3 Scope and Terminology

The RBP framework can be used for developing the proposed integrated platform, which is described in Section 2.1.8. The framework can help define the relations within the integrated platform and to define the scope of the platform at the lowest operational levels of abstraction. From the data collected it was found that, platform contents have themselves been referred to as the platform (for instance product families, generic production BOM, BOP, BOE, process families.) Thus, the usage of the term platform should be limited exclusively to the three components of the integrated platform and contents of each the platform should be referred to specifically. The establishment of terminology through progressive scoping down is also addressed by the RPB framework. More specifically, terminology and scope of current version of platforms is maintained and enforced through carrying out the Platform Definition phase.

5.2.4 Concurrent Engineering

The phases of detailed design, producibility and testing are areas where late surprises and much of the difficulties in projects exist. Leveraging of these phases has been identified as a key aspect in mitigating risks and enabling timely product delivery. The solution proposed, as seen in Figure 34 is to make platform specific information provided by the platform scout available to the platform team. This facilitates the platform team to prepare the platform for changes and trends in the market that have a bearing on the platform. On receiving broad intervals on platform specific requirements, the platform team checks the suitability of the platform in these intervals using KBE tools such as the Engineering Workbench currently being developed at GKN Aerospace. In this way concurrent engineering can be used for risk mitigation, knowledge reuse and cost reduction i.e., the three recurrent aspects of GKN platform vision found from the interviews.

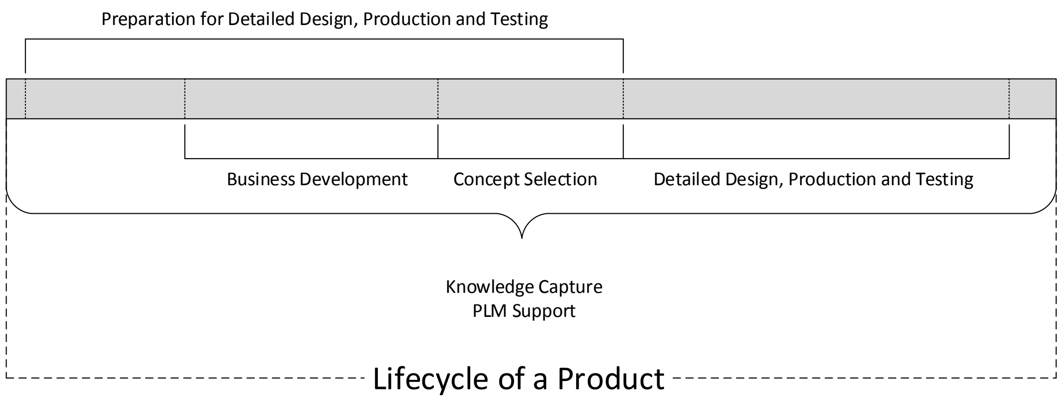

Figure 34. Role of Concurrent Engineering in leveraging detailed design, production and testing phases

This study confirms that a modular platform approach based on reuse of components is not suitable for GKN Aero's needs. Rather, the solution could be provided by configurable or scalable models. Even though, it was found in this study that there is scepticism on how far scalable and configurable approaches are feasible; the initiatives in developing KBE tools for multidisciplinary conceptual work have gained the confidence of engineers involved in detail design phase.

An objective of the platform team would be to use these tools on platform specific intervals provided by platform scouts. The expectation is for the KBE tools to propagate changes within the integrated platform and by doing so, determine the consequence of the new intervals for GKN Aerospace. Further, evaluation of new intervals could be carried out by experts in the platform team's branches within the functional departments. This facilitates preliminary detailed design and production testing. Concurrent engineering can be further supported by knowledge capture in a PLM environment.

Marketing and Product Planning would continue to function as before without major changes except cooperating with the platform team. Once contractual discussions with customers begin, individuals responsible for business development and product planning are equipped with knowledge of the platform's capabilities and can accordingly scope a project for successful completion. In this manner, major risks that previously emerged only during detailed design, would now be spread over a larger time span, and would be supported by the platform.

Finally, it is noted that the balance of top-down and bottom-up approaches in the RBP framework allows bi-directional influence of the platform on customers and vice versa. An outlook for the platform can be actively included in discussion for Risk-and-Revenue-Sharing Partnerships and Long-Term Agreements.

5.3 Summary

In summary, the value that adoption of the RBP framework brings to GKN Aerospace is summarized:

1) Planning phase of PCDE transforms platform needs and targets into strategies and SMART requirements. A Systems Engineering approach can provide support in this phase. Being carried out with drive and support from top management, it brings about the necessary organizational change in platform thinking.

2) It is in the Creation phase of PCDE that actual platform contents are created. This occurs simultaneously in product and technology development projects. Here a deviation from classical platform approaches is made, by using currently running product and technology development projects to develop an updated version of the platform. This would be a suitable approach for GKN Aerospace, as it contributes to making the currently adopted method more systematic, by introducing a clear vision, specific platform requirements and assigning a group responsible for managing the activity.

3) The value that the Platform Definition phase brings is that it separates the two processes: creation of platform contents and their objective evaluation across several projects in the organization. Creation of the platform contents is carried out by product and technology development teams. And it is the platform team (functional experts, platform project managers and platform scouts) that bring a functional perspective and expertise, project perspective and knowledge from within and outside the organization to create a balanced platform.

4) The value of the Evaluation phase is mainly in actively seeking and collecting new platform needs and targets that can be translated and fed into technology and product development projects. This phase is separated from Creation and Definition in order to ensure that this activity is not sub-prioritized, since creation occurs within product or technology development projects that are faced shifting priorities (from customer requirements, for instance)

Finally, the proposed framework addresses the current needs and challenges in platform-based product development. Here, ‘current needs and challenges’ must be emphasised as it is recognized that these continuously change, particularly in a platform development effort that is still in its nascent stages. Thus, the framework provides a bridge or transition from GKN Aerospace’s current approach to a more proactive, top-down approach while still preserving elements of a bottom-up, product-development based approach.

6 Discussion

This section presents a discussion on the strategies used to minimize validity threats in the study and reflections on generalizability of the conclusions. Here, empirical results, analysis and synthesis are referred to as outcomes of the study.

A workshop was conducted to evaluate the outcomes of the study. During the workshop, outcomes were presented to the interviewees and this was followed by an open discussion aimed at obtaining interviewees' evaluation of the outcomes. The topics discussed were:

a) What is the platform?

b) What is the purpose of the platform?

c) How is it defined?

d) What is the common language for platform development?

e) What is the current number of platforms present at GKN Aero?

f) What are best practices for platform development in similar industries?

g) Different views on the platform amongst colleagues

h) Different views on the platform within and across departments

From the discussion that took place amongst interviewees participating in the workshop, it was seen that that there is a lack of a common language for platform development. This is based on the fact that interviewees referred to different platforms (production platform, product platform, integrated platform) when using the word platform. Therefore, it was observed that the term platform was misunderstood in the discussion between interviewees, even though some of them were working together in the same project team. The discussion also confirmed the empirical finding that there is no shared or common understanding of the purpose of the platform, possibly arising from the lack of consistent usage of the term platform. This confirmed the presence of aspects that have been presented in the empirical results and analysis conducted in this study and served as a source for further input to the synthesis.

From the workshop, it was also found that the presentation of empirical results could benefit from incorporating rigorous traceability of different statements and views presented by interviewees. This was done by referencing all statements and views presented in the results to the interviewee who presented the view. Incorporation of traceability and quasi-statistics in stating results helped make a clearer distinction between empirical results and analysis of these results.

6.1 **Validity**

Validity refers to the accuracy and integrity of the conclusions and synthesis generated from a research. “A key concept for validity is the threat to validity; i.e., a way that one might be wrong. Validity then becomes a component in the research design which consists of the strategies adopted to rule out these threats” [(Maxwell, 2005), (Robson, 2002)]. Maxwell identifies two specific validity threats: bias and reactivity. Maxwell states that bias arises from the influence of researcher’s subjectivity, thereby allowing the selection of data that either fits into the researcher’s preconceptions or stands out to the researcher. Reactivity is defined as the influence of the researcher on the setting or individuals studied. Even though eliminating the actual influence is impossible, the goal in a qualitative study must be to understand and use it productively (Maxwell, 2005).

Accordingly, the following strategies were applied to minimise or eliminate threats to validity in the presented empirical results, analysis and synthesis.

6.1.1 Triangulation

Triangulation refers to the use of multiple sources to increase rigour of the research. In this study, triangulation has been taken into account in the following ways:

Data triangulation

Interviews were the primary source for data collection in the study. Triangulation on this data was provided by additional data obtained from company documentation and a workshop during which results, analysis and synthesis were discussed. Triangulation was also achieved by interviewing a variety of stakeholders involved in platform development in different capacities, and incorporating their feedback from the workshop. Further workshops and questionnaires could help eliminate any threat from researcher bias in the empirical results and outcomes of the study.

Theory triangulation

The scope of the literature review conducted was kept broad and literature was continuously updated to address new perspectives brought up during the study. Different perspectives were considered on platform approaches, definitions and strategies. Research areas that address other methods of increasing competitiveness in organisations were also incorporated such as product lifecycle management, knowledge management and organisational change. Literature specifically addressing platform perspectives for suppliers developing complex products and systems was difficult to find and could help further improve the theoretical base of the research.

6.1.2 Member checking

“Member checking involves returning to the respondents and presenting to them material such as transcripts, accounts and interpretation” (Robson, 2002). In addition to reducing the risk of researcher bias, Robson states that this demonstrates to the respondents that their contribution is regarded as valuable by the researchers. Transcripts were emailed to the interviewees to ensure that they had an opportunity to modify or suppress any of the material and were validated by interviewees.

6.1.3 Quasi-statistics

In reporting the results from interviews, an indication has been made whether an opinion was shared by only few respondents or a majority of them. Singular statements used in the study were declared as such. This was done to eliminate researcher bias as well as reactivity from empirical results and outcomes.

6.1.4 Researcher Biases

Audio recordings of interviews and the workshop, excerpts from documentation were maintained in addition to researcher's notes from the above. Each step in the analysis of the above data was documented starting from the raw data to the presented analysis and synthesis so as to prevent the development of researcher biases.

6.1.5 Respondent Biases

The researchers' interpretation and assumptions were withheld from the interviewees to prevent them from being influenced during the individual interviews. Any interaction required for setting up interviews and the workshop was taken up by the contact person at the company. This enabled keeping any formal or informal interaction between the researchers and respondents to a minimum outside the research setting.

The researchers' interpretations from the empirical results were however shared with the interviewees during the workshop to validate the empirical findings and receive feedback to refine the analysis. Therefore, input from the workshop was not used in the empirical results, but only in refining and providing recommendations.

6.1.6 Peer debriefing

Debriefing sessions were held and support was obtained from researchers who have been involved in current and previous studies on platform development at the company. Through these sessions feedback and input was obtained on methods adopted in the study, adaptation of data collection procedures for the context of the particular study and literature reviewed. These sessions also gave an opportunity for the researchers to provide an objective justification of the above mentioned aspects, and perspectives used in carrying out the study, to further ensure that researcher bias was minimized.

6.1.7 Negative and Discrepant information

The study was designed to elicit data pertaining to all perspectives and attitudes towards the platform. Consequently, the study was kept open to receiving data that was contradictory to assumptions made by researchers and other foundations laid by existing literature. These conflicting views were presented as such and were integrated in the analysis and synthesis, also adding to the internal generalizability of the outcomes of the study.

6.2 **Generalizability of outcomes**

Maxwell (2005) makes a distinction between internal and external generalizability. Internal generalizability refers to the generalizability of the conclusions within the setting studied, while external generalizability is beyond the setting. The border for this research setting has been established to differentiate between what is internal and external to GKN Aerospace.

6.2.1 Generalizability within GKN

To ensure that the empirical results are generalizable at GKN Aerospace, the interviewees were specifically selected to represent the majority of facets that are involved in platform development. GKN Aero's top management was not interviewed in this study, and if included in the interviews, could have helped confirm their role as described by the interviewees. The official documentation provided by the company is representative of the situation at the organisation. Inquiries were made to determine the extent of alignment in perspectives on the contents of the documentation.

Generalizability within GKN Aerospace could have been improved by conducting interviews with a larger sample of interviewees. An interviewee sample including more number of people from each discipline within the organization could have also improved the generalizability of this study. Generalizability could have been increased through larger participation in the workshop, by carrying out more number of workshops or longer duration for the workshop to create a more structured discussion as well as discuss specific topics in the outcomes of the study.

6.2.2 Generalizability outside GKN

In the current state of the project, generalizability of the outcomes outside GKN Aerospace, are at best limited to industries characterised by the dynamics and constraints as found at GKN Aerospace, with respect to their unique situation of platform development within product development projects, iterative platform development with simultaneous creation and use and their position as a supplier in the aerospace industry. The assumption can be made that suppliers for complex products and systems face a situation similar to GKN Aerospace. Also, the requirement-driven approach, incorporating both top-down and bottom-up measures to developing the platform, driven through product development could be applicable for other industries where the platform development requires adoption of mixed proactive and reactive strategies.

7 Conclusion

This section sums up the advances in knowledge that emerge from the thesis, revisits the research questions and outlines areas that could benefit from future work.

Platforms have been widely considered by both academia and industry as a solution to achieve competitiveness and growth for companies. Platform development is however not a straightforward process for companies as they face a myriad of options for platform approaches, definitions and strategies without specific guidelines for designing platform development to the unique needs of a company. Further, suppliers developing complex products and systems in industries like the aerospace industry find that reuse of physical parts is not a feasible option. Instead, technologies, assets, knowledge and other resources involved in developing the products are feasible to reuse. The identification of these reusable assets, their creation for the platform and their use in product development pose major challenges to suppliers who are not capable of taking a top-down proactive approach due to their position in the industry.

The Research Question 1 formulated for the study was:

What is the current status of platform development at GKN Aero with respect to platform vision; strategies for creation and use; relationship between platform development and product development; and tools used to support platform creation and use? What are the needs of people involved in platform development, with respect to the above aspects?

This research question is answered in Section 4 and the key findings are summarized in Section 4.5. The main contributions of the study and advances made have been revisited here. General outcomes and those specific to GKN Aerospace have been distinguished.

a) Results show that a commonly agreed and shared platform vision is lacking at the company. At a higher level there is agreement that the platform vision is to reuse technologies and knowledge, mitigate risks and reduce costs. However, at a lower level there are numerous aspects of the vision that could potentially conflict and compete with each other. The divergence at a lower level has been triggered by a lack of clarity on the term platform. Several initiatives at a lower level in the organisation have been treated under the umbrella term of platform, leading to potential conflicts or confusion.

b) Results show that there is a lack of adequate efforts from management to define a vision and its breakdown from a higher to lower level of abstraction. It was also found that this is necessary for resolving conflicts and for making the necessary compromises to formulate a balanced platform definition that caters to the company's unique needs. Results also show that these are crucial factors in designing a flexible platform.

c) Results as well as literature have shown that it is necessary to progressively scope down the platform concept starting from a platform approach, definition and strategy for creation and use, to a platform. Establishment of common terminology is an outcome of this scoping down process and is necessary for further platform development.

d) Results as well as literature have shown that a platform owner and structured cross-functional effort are required for achieving a company-wide impact and alignment in platform development efforts.

e) Results show an agreement on the current platform approach being more bottom-up than top-down, and a need to shift towards a more top-down approach. Description of the challenges in platform and product development (Section 4.1) also shows that the approach being adopted at the company is a mix of the proactive top-down and reactive bottom-up approaches.

f) Results show that at the company, capture of knowledge has been stated both as an aim in developing a platform as well as a prerequisite to the same. Analysis of these findings against literature shows that this delicate stance needs to be evaluated and a strategy for knowledge management needs to be developed.

g) It was found from the results that the company's current strategy is to iteratively create and use the platform through development projects. The current use of the platform is restricted to making estimates for the project completion time and cost; preparing a conceptual solution to meet overall requirements; and as guidelines for manufacturing and design.

h) From the perspective of literature, the current platform at the company merely forms portions of platform-based development even where literature maintains a wide scope in defining platforms. This confirms the gap found between literature and industry with respect to guidance available to companies on adopting platform approaches and formulating strategies. From this, better guidance from literature on platform planning is seen to be necessary.

i) From results on intended platform use and desired platform contents, it is seen that a wide variety of assets, capabilities, technologies and a large amount of corporate knowledge have been stated, creating a vast wish list for platform contents. At the same time, results as well as literature on platform strategies show that the particular set of assets and capabilities that the organisation wishes to share or reuse as platform contents needs to be defined.

j) Results show that at the company, PLM support for platforms has primarily been for accessibility and document control. There are efforts being undertaken for developing KBE tools facilitating multidisciplinary work during conceptual stages of product development.

k) It has been found from existing literature that KBE tools can provide significant support in a platform approach that is based on reuse of capabilities and development of assets rather than physical parts, especially when developing complex and customised products.

l) Literature shows that developing platforms and implementing platform-based development fundamentally brings about a change in the organisational culture. The roles and responsibilities of departments and individuals undergo significant changes. Careful efforts are needed to plan and implement the change. Results show that these aspects have also been identified as a need at the company.

Research Question 2 formulated for the study was:

What is a suitable framework for platform-based product development at GKN Aero?

This research question was answered in Section 4.5. The main contributions of the study and advances made have been revisited here.

a) The RBP (Requirement-driven, Balanced approach, Product development-based) framework for Platform Development has been proposed. It is requirement-driven and combines top-down and bottom-up approaches to developing platforms. By incorporating principles of a proactive approach identified as necessary at GKN Aerospace; and reactive approach, the framework provides a possibility to balance the two approaches. Finally, by allowing platform creation to be carried out in product and technology development projects, it allows for product development-based platform creation. The framework has been proposed to specifically address the challenges and needs identified in this study and is hence seen as s suitable framework for further evaluation and possible adoption.

b) The RBP framework consists of Top-Down Management Drive, setting up of a Platform Team and the PCDE (Platform **P**lanning, Platform **C**reation, Platform **D**efinition and Platform **E**valuation) phases of Platform Development.

c) Top management provides vision and purpose for platform development based on the overall corporate vision, long-term and short-term goals. Thus, it helps set a broad scope for subsequent scoping down of the platform. Top management sets up a platform team and provides it with resources, authority and responsibility for platform development. Finally, the platform development is driven by the top management as an organisation-wide effort.

d) A platform team consists of experts from various functional departments and a platform scout. It is in charge of the Platform Planning, Platform Definition and Platform Evaluation phases of platform development and manages the Platform Creation phase through its branches in the various functional departments. A platform scout is located at the interface between the organisation and its customers (could be OEMs), suppliers and competitors, gathering ranges on platform specific requirements from them. The scout also seeks information on platform specific requirements within the organization from various functional departments, R&D and even from the functional experts within the platform team.

e) Platform Planning is the phase during which platform strategies and platform requirements specification are created. These are formulated with the support of top management and represent the top-down aspects of the framework. Requirements for platform creation also include knowledge gaps for platform improvement.

f) Platform Creation takes place within product and technology development projects. In commercial projects, meeting product requirements generally takes highest priority. This influences the outcomes of development projects and outcomes themselves do not become part of an updated platform directly. Lessons learnt, list of satisfied and unsatisfied platform creation requirements; and a report on the current platform limits is passed on to the next phase.

g) Platform Definition phase concerns updating of the platform based on the outcomes of platform creation. Questions such as ‘can the platform limits be redefined, why were there deviations from the current platform in a development project, why were there any unsatisfied platform creation requirements, what outcomes are valid, generalizable and reusable?’ are answered. Results across different Platform Creation phases are studied and secrecy issues between projects are addressed before releasing a definition of an updated platform.

h) Platform Evaluation phase is the continuous evaluation of the updated platforms mainly in development projects where the there are no new platform creation requirements. This is to ensure that objectivity is maintained in evaluation. The operational level needs of the users are documented as future platform needs and requirements. Also, results from demonstrator projects, lifecycle evaluation of products are fed back to Platform Planning phase.

Managerial implications based on the above framework for the company are as follows:

1) Setting up a platform team comprised of: (a) Director of Platform Management who is responsible towards top management (b) a team of functional experts, platform scouts and platform project managers who report to the Director of Platform Management. Higher level platform decisions regarding vision formulation and renewal are made with help of company-wide representatives in a Platform Steering Committee.

2) Use of metrics to facilitate a cost-benefit analysis in making compromises and evaluating investments on the platform.

3) Simultaneous resolution of platform scope and terminology is recommended as broadening of one has led to broadening of the other.

4) Use of Concurrent Engineering facilitated by a proactive platform scout and KBE tools for spreading out high risk phases of detailed design, production planning, production and testing.

Finally, areas where future work can be carried out are outlined as follows:

1) Research into industries that face challenges similar to a supplier in the aerospace industry is recommended. The pharmaceutical industry is characterized by heavy investments in R&D and a high rate of product innovation to continuously diversify drug portfolios. The industry works in a highly regulated environment facing strict laws on certification, testing, safety, patents. Also, drug discovery and development face long lead times creating uncertainties in drug portfolio management (McGuire *et al.,* 2007). A literature review on methods adopted by the pharmaceutical industry to maximize of resource efficiency, reduce costs and ensure, timely delivery and efficacy of their solutions is recommended. This could provide new insights when analysing the unique challenges faced by suppliers in the aerospace industry.

2) Guidance for platform vision formulation for a sub-supplier in the complex, customised product industry needs further research. There is a need for methods and tools that support decision making, feasibility evaluation of developing and using platforms.

3) A more specific study to validate the outcomes of this study can be undertaken by increasing the sample size for individual interviewees and by including the top management in the sample. Use of confirmatory methods such as questionnaires for getting input from a very large sample is also highly recommended.

4) Further work to explore the RBP framework is a strongly recommended. A detailed study of the theoretical and practical consequences is required. Activities for the PCDE phases, interaction within the PCDE phases, their interaction with a platform, knowledge management system and PLM framework needs further research.

5) The suitability of the RBP framework to the integrated platform framework at GKN Aerospace needs further research. Further, their combined utility for GKN Aero requires exploration and subsequent confirmation through a demonstrator project.

6) Research on feasibility of forming a platform team and adopting concurrent engineering using platform scouts at GKN Aerospace could benefit from further inquiry.

7) Studies addressing generalizability of the RBP framework within similar industries and outside them is also recommended.

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Appendix A. Tables of Responses

Table 1. Table of Interviewees

Interviewee	Organizational Role	Organizational Division	Involvement in Platform Development
I1	Strategy and Technology Management	Core Technology	Research, Planning and Strategy
I2	Senior Company Specialist; Engineering Design	Research Centre	Research, coordinating research initiatives in platform development
I3	Production/Manufacturing; Process Engineering Research and Technology	Research Centre	Research, Setting framework for Production Platform
I4	Methods Development; Design Engineering Research and Technology	Research Centre	Methods development; influencing platform description
I5	Design Team Leader; Design Engineering Research and Technology	Research Centre	Platform Developer for Cold Structures
I6	Product Development Engineering; Chief Engineering Office	Chief Engineering Office	Owner of current platform; Offer current platform to customers
I7	Product Development Engineering; Chief Engineering Office	Chief Engineering Office	Platform responsibility for Cold Structures
I8	Design Engineer; Strength	Engineering Operations	Product Platform for Hot Structures
I9	Design Engineer; Aerothermodynamics	Engineering Operations	Capture Aerodynamic aspects in Platform
I10	Configuration Management; Robust Design and Configuration Management	Engineering Operations	Configuration management for product platforms
I11	Design Engineer; CAD Methods; Design and Integration	Engineering Operations	Product Platform for Hot Structures
I12	Director Design and Validation; Design and Engineering In-charge	Engineering Operations	Establishing Design Standards influencing Product Platform
I13	Senior Manufacturing Engineer; Manufacturing Engineering Department	Manufacturing Engineering and Methods	Production Platform for Hot Structures
I14	Senior Manufacturing Engineer; Manufacturing Engineering Department	Manufacturing Engineering and Methods	Production Platform for Cold Structures
I15	Director Product Planning; Strategy and Sales	Business Development and Programs	Use platform for building business case

Table 2. Vision for Platform

Interviewee	Vision for Platform
I1	▪ Everything proposed in platform literature - reducing lead time, customization, variety, new markets, more offer to customers, reducing cost, and having an efficient organization liked by upper management
I2	▪ Reduce risk, cost, achieve scalability, reuse technology and knowledge, efficiency, confidence, variety; Lacks clarity now; capture and reuse knowledge in KBE tools
I3	▪ Reuse of knowledge, equipment, stable production and development, ensure that there are no big risks, communication, knowledge capture framework
I4	▪ Reuse knowledge, obtain a common view (real main driver), narrow scope in new projects, structure for design space exploration, does not need to be specific; benefit is to plan future offers
I5	▪ Meet cost targets, find limits in manufacturing, robust methods, risk reduction, document value added in functionality and technology and include it in platform, obtain a common understanding, change propagation
I6	▪ Should be one single platform – product platform, balance between different requirements - product, customer, lead time, cost, manufacturability; a well-balanced platform, align everyone to work in one direction, be competitive, offer attractive products based on customer needs, predictably deliver solutions
I7	▪ Reduce lead time, cost, enhance market position, make sellable products
I8	▪ Collector of best product knowledge; guide for what and how to do; give information on what is the primary solution when entering new projects, reuse, reduce cost and create value for customer with high added value products with high technology, risk mitigation, guiding product development projects with all necessary knowledge, give information on how to connect different parts together
I9	▪ Combined and merged platform, need to know how the platform will be used, need answer to whether it is a starting point for new products or description of existing, vision should take care of trade-offs, platform should be specific at times and general other times, should be best solution with clear limits, features, opportunities, defined boundaries, pros, cons, description of components, indication of suitability for specific application
I10	▪ Reducing cost and lead time, risk management by validation of requirement fulfilment for certification
I11	▪ Balancing quality, production and lead time, translating to reduced cost
I12	▪ Vision for how platform should work and who will use it is getting aligned, but slowly
I13	▪ Design to fit industrial structure, make TEC for Dummies, include tips and tricks, capture project knowledge (Production Platform)
I14	▪ Many different platforms are needed, developed with customers, updated continuously. If it is one or few platforms then parts should be reused instead of design concepts, more predictable project timeline and more predictable costs; also reduce risk,
I15	▪ Minimizing programme risks, manufacture parts in same way, platform should be in one document, product and production should feedback to each other

Table 3. Platform Creation

Interviewee	Platform Creation
I1	▪ Platform has become a buzzword in creation ▪ Unsure of how procedure for developing Production Platform is used in creating a platform ▪ PowerPoint ideas have become documents which may become tools eventually ▪ There is weak cross-functional collaboration
I2	▪ Platform has become a buzzword which is good and bad ▪ Need to define vision for the platform and how it is to be used ▪ Lacks top senior view on platform ▪ Need for a high-level platform owner ▪ Been bit too much bottom-up, good initiatives at low level leads to competition or conflict ▪ Strategic marketing and business decision needed to align product, production and technology investments ▪ For long-term perspective, platform needs to be rich but flexible
I3	▪ Person in a strong position needs to be responsible for further platform development ▪ Strategy should be communicated by top management people should believe in its benefit ▪ Need to scope and balance what can be accomplished ▪ Have skilled engineers work on platform development ▪ Need better long-term product plans and how to produce ▪ Need more functional perspective on how product works to help decision making on technologies ▪ Need skills, experience and a mix of people, involvement of stakeholders ▪ Need to be fill gaps in Design Practise and Design Guidelines ▪ Platform creation should be part of daily project work
I4	▪ Beginning of creation is building an understanding of platform and its benefits, not platform itself ▪ Should be described well - contain knowledge from all disciplines ▪ Need a link between design systems, methods, product definition, practices and production ▪ Methods developed for early product development should be aligned with platform view ▪ Needs to be done at a company level, from top and bottom, indicated from a high level ▪ People need to prioritize it ▪ Needs to be a continuous process
I5	▪ Needs to be clear on where GKN intends to go with different products – be clear on what GKN intends to do ▪ Then work with that gap, for example - if it is cost, then work with supply chain ▪ Accessibility due to secrecy - benefit of sharing input from different OEMs, no platform requirements on projects as focus is to get product out

Interviewee	Platform Creation
I6	▪ Product support for parts developed 10-20 years ago need to be maintained - can never be only one platform ▪ When parts are manufactured in similar way they go into one type of platform ▪ Chief Engineers will feedback what is missing in platform to R&D - taking needs of OEM and transfer it to projects ▪ Must be able to affect short term decisions in conceptual phase to affect long term platform strategy ▪ Needs to be a flexible platform - detailed enough to get the benefit - coarse enough to not constantly redo platform. ▪ Parts of the platform have to be continuously developed. ▪ Can't create a recipe for exactly how to design a part.
I7	▪ Beneficial to have a clear definition of platform; better involvement of engineers working on current programmes in platform development. ▪ Need to go out and get input from OEMs ▪ Platform represents too much of what GKN has now and it needs to be more for use in customer dialogue and developed in similar fashion ▪ Design Practises are the knowledge bank, generic requirements from process to product should be represented in platform
I8	▪ Management should lay down the goals, vision and paths and engineering organization should provide experience for how to reach goals and vision. ▪ When an engineer is using platform should be like a recipe; should not give exact numbers for parameters like cost, but address the requirement and give guidelines
I9	▪ Contain information on entire chain from purchase to sale in platform in order to meet requirements - compromise between different things ▪ If there are quality requirements in platform then purchase will know what suppliers to choose. For ex: they lift parameters used in purchasing material into platform. ▪ Creation should be an agreed up on process, not someone saying what should to be done ▪ Have not read any instructions about the platform saying - this is the platform ▪ Clear instructions on creating platforms, so that new platform creation would be standardized ▪ People responsible for platforms sign off platforms so everyone knows its official ▪ Many solutions from current projects will go into platform; always expanding; Platform should include all aspects - material order to shipping to customer ▪ Important to create platform which gives common view that everyone is aware of

Interviewee	Platform Creation
I10	▪ Customer is an essential part of platform definition – there are contractual limitations on flowing technology to different customers - reason to have product families; ▪ Create a link between product requirements - verification/validation; link between manufacturing, technology and product platform; It is an iterative process ▪ Lack of transparency of platform and programme management; lack of awareness of programme, project, deadlines ▪ Need parameters in the platform so as to document valid product definition and data flow through organisation. ▪ Do not have resources needed - need to use intuition or guessing to proceed with platform ▪ Need a formal way of aligning platform work, need platform documentation group ▪ Management needs to set business plans, capabilities, requirements and expectation for the future without getting solution specific ▪ Need a single team for platform development. ▪ Requirements and deliverables from programme management on platforms
I11	▪ Need stable processes, System like configuration, specification or Design Practise system and methods ▪ Need a balance between making boundaries for the platform and allowing new ideas, it's important to allow new ideas and filter them through R&D ▪ No procedure followed to create product platform - good to document for future, but not really needed for creating
I12	▪ Need to understand how to document platform, when and who will use, and what is the platform ▪ Trying to differentiate and capture explicit knowledge selectively into the platform to keep it rich, but not overload with information
I13	▪ If all requirement aspects are known then balance between product and production will be good ▪ Cross functional approach was not useful without the top-down direction or influence in creation Production Platform – some contents, like immature technologies exist in the documentation that should not be there ▪ Need to decide how product and production platforms fit together
I14	▪ Both project and platform goals should be met; not formal enough platform requirement in project, Be unique vs reusing ▪ GKN not main contributor to engine and work with many customer - hence lack access to all info ▪ Projects missed within a particular engine manufacturer results in gap of knowledge ▪ Platform is being created in reverse ▪ Platform creation has to be natural part of project. ▪ The expectation: "develop platforms" has been flown down from management without any details on what a platform is and what the expectation is. ▪ Difficult to get access to the required people. ▪ Need lot of resources and engineering power to develop a platform. ▪ Existing procedures for creation work well for similar projects; difficult to use in new projects ▪ Because of dependencies between product and production, it should be developed together and all information should be linked even if it is split between two platforms

Interviewee	Platform Creation
I15	▪ Have not defined platform for different products; goal is to have an agreed platform for future programmes ▪ Need co-located technology development programmes with OEMs ▪ Platform should be signed off by different functional managers ▪ How to use platform requires clarity - need to have strategy for how to develop

Table 4. Perspectives on Knowledge Management

Interviewee	Perspectives on Knowledge Management
I2	▪ Knowledge management is a very wide area, platform can be part of it ▪ One way or the other, platforms are a way to represent
I3	▪ Lack systematic way of learning between projects (production perspective)
I4	▪ Platform systems and KM systems would be same thing - just different views on how to sort and describe things in different contexts ▪ Should be described well - contain knowledge from all disciplines
I5	▪ Currently, there are too strict standards on documenting limits knowledge capture ▪ Need a neutral ground for documenting and accessing knowledge ▪ Accessibility problems due to secrecy – lack benefit of sharing input from different OEMs
I6	▪ Experience from on-going programmes needs to be taken into account ▪ Collecting all of the knowledge is a problem because it is bounded by persons
I7	▪ Need to sit down and discuss good and bad from projects continuously over its lifetime, also with OEMs ▪ People leave after a project, so platform should collect knowledge over time and over different phases
I8	▪ Create guidelines by collection best knowledge
I9	▪ Platform creation started with securing knowledge from engineering in product department ▪ Have own in house codes, DP, excel sheets with parameters and product definition, own methods and tools
I10	▪ Cross knowledge is required ▪ Valuable to have logic and know what contents are there in platform ▪ Need common language so that author and user should be capable of expressing and understanding
I14	▪ Lack across project perspective ▪ Lack familiarity with documenting knowledge

Table 5. Platform Approach

Interviewee	Platform Approach
I1	▪ More bottom-up; Not long term and sound approach if pushed only by Research & Technology ▪ Weakness of approach is not asked engineering what they need in operational level work
I2	▪ Too much bottom-up ▪ Top-down incentives lacking definition ▪ Approach has been iterative (dream to document to PowerPoints to KBE tools)

Interviewee	Platform Approach
I3	▪ Started top-down, became more bottom-up ▪ BU has led current production platform to be a description of TEC variants ▪ Lacks flexibility
I4	▪ Both top-down and bottom-up ▪ Should encourage both
I5	▪ Both top-down and bottom-up ▪ Standardization across the 3 major customers
I6	▪ So far, more bottom-up than top-down ▪ Should be a mix of top-down and bottom-up ▪ Should be clear understanding of future offers
I7	▪ It has been bottom-up ▪ Need to come from the top (from product), define gaps and define production platform required to support the product
I8	▪ Currently more bottom-up, connect knowledge from different projects to make generic platform. ▪ Top-down could come next; unsure of what is a correct approach - first create a platform with existing knowledge ▪ Higher stake of customer and customer's customer make top-down difficult
I9	▪ Has been bottom up to manufacture components in a certain way to which platform adapts. ▪ Bottom-up is not sustainable for future as then there is nothing to offer the market ▪ Need to secure and achieve balance between the two
I10	▪ Fuzzy - bit of bottom-up is done. ▪ Need both top-down and bottom-up ▪ Understanding customer, lead time reduction need top-down ▪ Reusing solutions involves bottom-up approach ▪ Have a more modular approach to aerospace engine and make integration between the different engine components GKN is making
I11	▪ Bottom-up approach - standardizing different ways of doing things ▪ Wish it were more top-down – have not seen top-down initiative
I12	▪ Partly bottom-up by looking for standard things among a number of products ▪ Having a legacy or experience from several product development projects is important to know boundaries and then extrapolate (top-down in future)
I13	▪ Creation has been bottom-up; triggered from ensuring that product design fit the industrial structure
I14	▪ Big gain from bottom-up in production and top-down is unlikely ▪ Design solutions – top-down could be good
I15	▪ Currently more bottom-up ▪ Desire approach – balanced top-down and bottom-up

Table 6. Platform Use

Interviewee	Platform Use
I1	▪ Engineers use in discussion with customers - they have better awareness of design solutions, provide recommendations to customers etc. ▪ Lack of knowledge on how to use production documentation ▪ Special unit for platform development; having a platform will constrain the organization; less freedom for designers who start with platform instead of white paper

Interviewee	Platform Use
I2	▪ Can be used as support for developing engineering design systems, in early concept phase and understanding current portfolio ▪ Should be an executable model with defined relations ▪ Amount of information in platform depends on intended use, need to define intended use ▪ Used for making derivatives , marketing and bidding, ▪ Generic vs Specefic, should have version control, maturity level of constituent technologies, should identify where platform definition is insufficient, rules for configurations for product platform, identify restraints from production onto product pl. designer needs, range, validity, status, design rules, dependencies
I3	▪ Used for pre study and concept development to answer what are future needs and define the market position of GKN ▪ Input to conceptual and detailed design, design reviews, and BOP used by manufacturing ▪ Manufacturing document can be used as a checklist/handbook ▪ Limitations on (manufacturing) methods, materials, requirements on product functionality, requirements on conceptual design, sourcing, pre-production preparation, DfM requirements. ▪ State opportunities - not only current capabilities - esp. with production requirements from product design perspective
I4	▪ Already in use if OMS and DP system is part of the platform ▪ Technology, methods and TRL ▪ It's our DP system, it's everything from change management systems, to all our description instructions, in the production and so on, it's our methods ▪ description is how it fits together and how it's offered to the customer - could be a document, PowerPoint etc.
I5	▪ Need platform support in phases where bulk of engineering work and decisions occur, for example early concept phase ▪ Provide business intelligence with back of engineering knowhow. Next, is support for engineering. Finally, more details for repository. ▪ the design knowing what manufacturing can have, manufacturing knowing what they could expect ▪ TRL as platform content ▪ Need change in Platform thinking, way of working with platform as a solution, knowledge repository. Users, creators need to feel ownership ▪ People need to understand the benefit and importance, so people give and take from platform; feel like they own it
I6	▪ More similar products now than before; able to better predict lead time and cost ▪ DP missing in platform; in-service performance of product - as a feedback on whether practises are too/less conservative ▪ No foreseeable organisational change
I7	▪ Should bring in suppliers early on as a network; support decision making like manufacturing methods to be used ▪ Can be used to get volumes up and in turn better prices from suppliers ▪ CAD structure for visualisation ▪ Need to improve the way platform is visualized and communicated – currently it is mostly sitting with individuals – it will help make it more natural way of working and give information to customer

Interviewee	Platform Use
I8	▪ Everyone in the company: management to shop-floor should work with it - affects everyone in company ▪ Guideline giving limits, capabilities, opportunities; boundaries of design space, gaps in future technology ▪ providing flexibility and customised products; Will be used by people in new projects ▪ Easy to come in early in the project and talk about (product) requirements ▪ Intend to be used through IT system, CAD, PLM system, SAP etc. so all departments have access, with change propagation ▪ Unsure exactly who uses and how product platform is being used ▪ Should answer specific requirements but still be general, the specific technical requirements should be included ▪ Difficult to predict since it's not finalized, probably will need to change ▪ Don't know if platform will change the way of working.
I9	▪ reduce number of loops in iterations for manufacturability ▪ Design practises which are platform-type of requirements - used currently ▪ design requirements, boundaries for weight, geometry, producbility ▪ conceptual models that are starting point for all work ▪ smaller, less debated initial phase, simpler work, documentation done and other pre-sets
I10	▪ Naming conventions, strict product structure and framework for breakdown of product; common view of breakdown. Templated view of product; allows easier reuse ▪ Verification/Validation methods ▪ More company integrated, standardize how programmes and their documentation are expressed, ▪ Create awareness so as to involve day to day activities of all
I11	▪ Platform sets the box within which requirements are balanced, sets basic rules. ▪ To be used in early concept phase to select solutions - not in detailed work; if used in detailed work to choose manufacturing. processes/methods ▪ Off the shelf approved ideas that can be picked and used; ▪ No. of people working on drawings, modeling etc reduced from 15 to 6 from old to new TEC project; Had TEC "in my mind"; ▪ Platform restricts creative ideas in concept phases - ideas may not be necessary for similar projects but useful for new/diff projects
I12	▪ During concept phase, work with sets of design solutions than point solutions ▪ Engineers should know from platform if the set of requirements (Product cost-FR-Producibility) are within the knowledge boundaries - access to constraints ▪ Really need platform in conceptual and detailed design phase for NPD. Also in technology development to fills tech gaps; check if product fulfils functions in-service and loop back to development
I13	▪ Argue for Design for Producibility, starting point for manufacturing engineers ▪ support to argue for certain design solutions ▪ BOM,BOP,etc; more specific - facts, tips, tricks, reqts on product platform - limits and capabilities, collection of best part of all project ▪ Only mature processes/technologies
I14	▪ Have to pick up similar and predictable things, instead of final deisgns, we need the process of arriving at them, set up, expected process stability ▪ Production platform - has dos, donts, tips. BOM, BOP - hard to use as is in a new project, good to have documented. Could benefit from extended library of design interfaces - help in leading discussions with customers

Interviewee	Platform Use
I15	▪ Building business case and cost estimates ▪ Contain industrial processes, machining time, weldability, producibility. supply chain, design practices

Table 7. PLM

Interviewee	PLM
I1	▪ It should be more or less identical to product, same terminologies & structures ▪ Engineering workbench is close to platform idea ▪ Engineering will need support from IT tools to use platform
I2	▪ Implementation is an investment, pain or gain; PLM architecture that supports platform ▪ Platform Development can be System development; possibly UML ▪ next steps production, financial, sourcing, PLM systems
I3	▪ Requirements & limits could be implemented in PLM system; or these can be linked to DP system
I4	▪ Platform strategy will help set up a good PLM system ▪ tracking of data in projects, and lifecycle documentation, and relation between data
I5	▪ EWB is useful to understand design space & change propagation ▪ Integration with IT tools required
I6	▪ Ultimately platform should be a part of daily work process made available through CAD system, configuration control system etc. that shows information from all functions ▪ Generative TRS, verification process, templates etc. that have requirements integrated
I7	▪
I8	▪ Would be useful for designers to have platform in PLM system; if product platform is in a PLM system, would be great - would help designers to see different concepts ▪ KBE would make it easy to demonstrate platform - easy to eay change propagation ▪ Current KBE project aim - facilitate multidisciplinary work during early concept phase - this should be reflected in platform - want to shorten analysis time, do multiple loops on different concepts and see if platform is working for new project ▪ Platform is base for KBE tools ▪ Intend to be used through IT system, CAD, PLM system, SAP etc. so all departments have access, with change propagation”
I9	▪ Platform is a subset of PLM
I10	▪ Don't see alignment with platform - pain/gain - current PLM system moving ahead without long-term focus - moving from SAP to Teamceter without fully understanding why ▪ Currently - many systems requiring lot of system integration; each system creates diff culture and unnecessary friction in company - splits organization's vision ▪ Having one common PLM system will also help creating/using platform - have common info source
I11	▪ Platform should be supported by the "system" - all processes or ways to work with platform should be included in system

Interviewee	PLM
I12	▪ Useful for manufacturing to have access to designs(PDM)
I13	▪ Can be documents, integrated in DP or macro or part of PLM systems, but far from a configurator based on generic BOM
I14	▪ Far from having a generic BOM for TEC ▪ Will benefit from having an extended library of design interfaces (customer requirements)
I15	▪

Appendix B. Interview Guide

Hello,

As you may have been told, we are doing our Master thesis work on establishing requirements for the platforms here at GKN. We are also going model the organizational context in which the platforms are to be created and implemented. This interview is a part of our data collection. Through this interview we would like to understand the current situation at GKN Aerospace. We'll talk about - What is the scope and context of platform development? How platform will be used?

In order to ensure that we don't lose any important information from the interview and to make sure that we can go back and check, we would like to have an audio recording of the interview, if that is ok with you. We'll transcribe it in the next few days and send you a copy to verify as well.

The themes in this interview will cover the entire lifecycle of the platform from its initiation and creation to its implementation and maintenance. So we'll start with GKN's platform vision and the approach being adopted. We'll move on the platform creation process, its use, the support and organisation surrounding the platform focussing on requirements throughout. This is because; we are trying to understand the needs of people in different stages of the platform lifecycle. Although we have questions in the interview that address these requirements, you are welcome to give us input at any time during the interview on relevant needs and requirements for the platform in its different lifecycle phases.

For the purpose of this data collection, we would like to clarify the following terms:

- When we use the word *platforms* or *the platforms* we are collectively referring to the three platforms – product, manufacturing and technology platform which constitute GKN's integrated platform.

- We would also like to clarify the use of the term *platform development*. When we say platform development, we refer to the process of creating, implementing and maintaining platforms at GKN.

Introduction

1 a) What is your role at GKN?

1 b) How are you involved in creating and implementing platforms?

1 c) How is your everyday work related to platform development?

GKN Platform Vision and Approach

2 a) How did the idea of creating and implementing a platform at GKN come about?

2 b) What was the first major platform initiative? What was the first platform project?

2 c) What were the goals and outcomes of this project/initiative?

3 a) What is GKN's vision for the platform?

This could include:

-Reducing lead time and development costs

- Exploiting reuse within projects and across the organization

- Providing variety

- Reducing complexity

- Exploiting core capabilities (employee knowledge and skills, technology, managerial systems)

- Entering new markets

3 b) Implementing platforms could involve trade-offs such as variety vs. commonality.

What are these trade-offs in GKN's platform vision?

Given this, what are the most important drivers for a platform?

Platform Requirements

4. Given this vision and benefits in mind, what are the requirements for the platform?

Platform Creation:

5. In our literature review, we have come across two approaches to designing product families – top-down and bottom-up. [Simpson] In *a top-down approach*, a family of products is intentionally and strategically developed from a platform, whereas in a *bottom-up approach*, a group of existing products are consolidated and their components are standardized to enable higher economies of scale.

5 a) What type of approach would you say is used by GKN?

5 b) Who drives and supports platform initiatives at GKN? How are they driven and supported?

6. What is the procedure for creating platforms?

Is it as described in the documentation? Or is it different? Discuss the **fig 1** and **fig 11** (from GKN Platform documentation)

7. Can you identify the groups of people that create the platform?

They could be upper, middle management, etc. Are users involved? How do they drive platform creation?

8. Given the platform development process followed so far, what are the requirements for this process?

Platform Use:

9. What is the status of the individual platforms?

10 a) Can you identify the groups of people who will use the platform?

They could be engineers, designers, managers of divisions and departments etc.

10 b) How do they use the platform? What are the needs of these people while using the platform?

11. Who would be the users of the current platform documentation? How would they use it?

Support and Organisation surrounding the platform:

12. How does the platform alter the way employees work and the organisation works? What changes are foreseen in the everyday work of people who use or will use the platform?

13. Is there already an effort in facilitating these changes? What requirements can we have for the platform based on the changes needed?

14. What support can the platform receive from a PLM support by addressing product data, information, processes, tools, people etc. Are there any requirements for the platform when incorporating PLM support?

Related Initiatives:

15 a) What are the other on going connected projects relating to reuse?

15 b) How far have they come and what are the significant outcomes of these projects?

15 c) Are there any efforts to implement?

- *Lean product and production development*

- *Knowledge management*

Are there any requirements that the platform can take from these areas?

16 a) Are there any existing thoughts and plans for the platform's maintenance and renewal over time?

16 b) What are the requirements for the platform when thinking about platform maintenance and renewal in the future?