Industrial Metrology Product Development: Best Practices and Success Factors

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Industrial Metrology Product Development: Best Practices and Success Factors

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Abstract

Innovation is extremely important for companies to gain and sustain competitive advantage in the modern business environment. Nowadays ability to adapt and evolve is crucial for any company willing to survive. The key to effective adaption and evolvement is innovation. New products are commonly seen as an output of innovation whereas new product development process is considered to be a sub-process of innovation.

The thesis focuses on development of a new product in the company the author has been working for. It aims at assessing the methods that the company is employing to develop new products. The goal is to determine the flaws in the new product development process of the company and the negative effects on performance and output the flaws have.

The thesis describes the generic new product development process, a certain form of which is used by majority of the companies involved in new product development. It contains a narrative literature review of articles documenting research in the field of best practices of new product development. It also reviews studies of critical factors of new product success, which separate the best performing companies from the others.

The thesis uses the best practice research and success factors studies as a reference point to assess the methods and evaluate the process that the company used to develop the product the thesis is focused on. The thesis also describes the market and the competition that the company is facing. In the end it gives a number of recommendations. The company can use the results as guidelines for improvement.

Keywords: new product development, best practices, success factors.
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1 Introduction

It is extremely important for a company to be innovative in the rapidly changing modern business environment, as [1]: markets evolve, customer demands increase. Globalization and international trade development intensify competition by bringing new opportunities as well as new competitors [2]. As the rate of technological advancement increases, older technologies become obsolete at a higher rate. [3,4] Thus, product lifecycles become shorter [4]. Shifting markets and intensifying competition force companies to adapt and renew in order to survive. The ability of a company to adapt and evolve determines its survival [5].

Companies have to admit that success factors of the past no longer fully apply to the uncertainties of the future because conventional wisdoms no longer work. Business models and even day-to-day definitions of business have to be called in question in order not to miss emerging opportunities [6]. More specifically, companies are forced to evolve their management processes in order to remain effective and profitable in the future [3]. The key to effective adaption and renewal is company innovation. Innovation allows companies to recognize existing opportunities and anticipate ones that may emerge in the future. It also helps to leverage emerging market trends and to establish a favorable position relative to their competitors [7].

Despite the common belief that change should initiate at the very top levels of a company, innovation should be encouraged throughout a company’s entire structure. According to Hamel [6], building companies with “radical and systematic innovation” is “the most important business issue of our time”. It is crucial to encourage innovation and challenge systematic hostility towards it—especially in organizations built for perpetuation—by questioning the set of beliefs that resist new methods and variance from the standard.

Innovation can occur in many different areas within companies. These areas may include marketing, sales or operations. [2]. This thesis is focused on new products, which are commonly viewed as the output of innovation, whereas new product development process is often considered being a sub-process of innovation [5]. In order to be able to introduce a product into the market, a company has to first innovate.

With the current market climate, product innovation is crucial to the survival and prosperity of every company [4]. It is also the key to sustaining favorable market position and ensuring future growth [1]. A considerable amount of product sales—27.5% according to America Productivity and Quality Control (APQC)—accounts for products that have been launched during the past three years [4].

New product development is a very challenging and exceedingly difficult process [1]. Many new products fail at a rate of about 41% despite improvement of the new product
development process over the years. New product failure rate has been persistent over the past several decades [3,8]. Therefore, the following questions still remain: In this new globalized context of company success, what separates winners from losers? What are the critical elements of this success? What practical steps may companies take to develop a successful product? The thesis aims at answering these questions in the context of a new product development process undertaken at the company the author has been working for developing the product.

1.1 Background

This project was carried out at A.M.S. Accuracy Management Services Ltd. (AMS), a privately owned company located in Oulu, Finland. The company was established in 1995 and has its roots in providing services for shipbuilding and paper machine building industries. Currently the company specializes in dimensional analysis, alignment control and industrial metrology product development for large-scale assembly and inspection in cooperation with its partner, Leica Geosystems AG, a member of Hexagon Metrology Group [9]. The main product of the company is DCP Solutions, which it develops and provides training for.

DCP Solutions are comprised of DCP05, DCP15, DCP100 and DCP Pocket and Project. DCP05 is dimensional control software running onboard the TPS-series of total stations produced by Leica Geosystems AG. Currently, it is also distributed as part of the firmware software of Leica TDRA6000 laser station, which is a high accuracy total station designed specifically for making measurements on extremely large structures [10].

DCP05 provides users with a tool to control Leica total stations, perform station orientation, measure points, compare actual measured values with pre-loaded design values and display deviations. It also has limited analysis functionality. Measurements made by DCP05 are handled by DCP15 software, which is used to generate reports from the measurement data. DCP05 can either be used as stand-alone measurement software or in conjunction with DCP100.

DCP100 is a complete solution to manage manufacturing accuracy of large-scale assembly process. The solution is comprised of a modeler, analyzer and simulator. CAD design of the structure being analyzed is imported into the modeler, which generates a list of vital points in the structure to be measured. The list is loaded into DCP05 and the specified points are measured on the actual structure. Measured points are loaded into the analyzer, which analyzes deviations of actual point coordinates from designed values and visualizes the results on a three-dimensional model. Graphical and numerical reports can be generated based on the analysis performed. The simulator is used to simulate the joining of two structures based on measurement data and to calculate the optimal position of the structure being attached [11].
This thesis focuses on the development process of DCP Pocket and Project, the recent addition to DCP Solutions for Leica TDRA6000 laser station [12], which the author has been part of. It first evaluates this product’s position among both competing products and other products the company develops, following its development process from target to final specifications. It then evaluates the company’s process to develop new products, considers the challenges encountered and makes recommendations for improvement.

1.1.1 Problem Statement

The current solution is problematic because DCP05 has been on the market for well over a decade. It was first introduced in 1995 under the DCP10 name, alongside DCP20 visualization and reporting software and the DCP30 structure joining simulator.

Figure 1: Leica TDM5000 being used with DCP10.

DCP10 was developed to run on Husky FS/2 rugged handheld computers with a magnesium alloy case featuring backlit graphical LCD display that can fit eight lines of forty characters each, and an 8086 processor running the MS-DOS 3.30 operating system [13]. It was used with TDM5000 industrial total stations, and communicates via serial cable connection. As seen in Figure 1, the handheld computer and software was typically attached to the tripod that the instrument was mounted on, reducing its users’ mobility. Under this system, the operator was forced to constantly move back to the instrument during the measurement session or another person was required to aim the instrument at the points being measured.
In 1999, this software was ported to controllers embedded into total stations (see Figure 2) and released as DCP05. However, it has only been updated incrementally ever since, without any substantial or radical changes. Any development efforts focus on improving existing implementations and fixing bugs.

![Image of DCP05 running on Leica TC1800L total station controller](image)

**Figure 2: DCP05 running on Leica TC1800L total station controller.**

Hardware manufacturers have, on the other hand, evolved total stations with the advent of new technology. They have made significant changes to total station controllers as well. For example, the Leica TDRA6000, which developers ported DCP05 to (see Figure 3) features color touch-enabled displays with stylus input [10]. Software developers targeting total stations were given a more powerful platform to design user interfaces and interaction between the user and the instrument.
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Figure 3: DCP05 running in Leica TDRA6000 controller emulator.

Nevertheless, there is limited support of the latest total station controller features because it is still based on the old DCP05 codebase. For example, with the instrument running DCP05, user interaction is limited to text-based interface with low usability. The interface is not intuitive, hard to learn and takes a lot of training to master. The measurement flow is not as efficient as it could be.

Furthermore, despite the instrument’s operational range of several hundred meters operators were virtually chained to the instrument. In order to perform measurements and see the results, operators had to use the software running on the instrument. A second person was required to make the measurement process fast and efficient. Wireless controllers already existed, but were mainly used in land surveying applications.

DCP05’s lack of evolution created a need for a more efficient and streamlined measurement process. Operators needed a new mobile solution that would allow them to operate total stations from remote and perform large-scale assembly. The company had to come up with a new product in order to satisfy emerging customers needs, keep up with the advances of technology.

1.1.2 Proposed Solution

The company realized that it had to innovate in order to sustain its competitive advantage in the market of large-scale assembly solutions. It was essential to design a new generation product in order to provide customers with additional value compared to the old product. As a result, a new development effort used the drawbacks of the old solution as starting points for the new one.
A product concept is an approximate description of the way a product may benefit customers by satisfying their needs [14]. It can be viewed as a fusion of form, technology and need/benefit (see Figure 4). Crawford and Di Benedetto [1] explain that these dimensions connect because “technology permits us to develop a form that provides the benefits”.

The concept of the new product AMS started to develop was largely based on the existing solution. Its initially planned features were the same as the ones of DCP05: total station orientation, point measurement and calculation of deviations of the actual measured values from the design values of the structure being measured.

Initially, developers wanted the new product to satisfy the same basic customer needs as the ones of DCP05. These needs were well known to the company due to many years of experience designing large-scale assembly solutions and working closely with its lead users. The new generation product also relied on the same measurement technology provided by industrial total stations.

![Figure 4: New product concept dimensions.](image)

Innovation may be introduced in conjunction with any of these dimensions of technology, need and form. A company might be aware of a customer need and find technology to satisfy it in a certain form. It might also have existing technology and find a customer need to satisfy with a certain form of available technology. Alternately, a company might envision a form, find technology to create the form and then introduce it to customers to see if they benefit from it.
In the case of AMS, there existed a need to remotely operate total stations and make measurements with handheld portable devices connected to the instrument, utilizing a wireless connection. The company chose the Leica TDRA6000 laser station, which provides precise coordinate measurements in three-dimensional space. Leica AT401 laser tracker support has been added later.

This station provides high precision measurements over a very long range, making it a perfect fit for large-scale assembly industries such as shipbuilding. It is also equipped with Bluetooth wireless interface, which makes the implementation of a wireless solution technically possible. The Leica AT401 laser tracker also features a Wi-Fi interface, which extends the working range of the mobile solution significantly.

In the presence of need and technology, AMS had to come up with a form. The company approached the problem by setting a goal of designing a highly functional and usable graphical user interface, running on a rugged mobile handheld device.

![Getac PS236 rugged handheld computer](image)

Figure 5: Getac PS236 rugged handheld computer.

The Leica DX10 rugged handheld computer system was initially chosen to be the platform for the new product. However, it was soon replaced by the superior IP67 certified Getac PS236 handheld computer, pictured in Figure 5. This device features color touch-enabled screen with VGA resolution and a Marvell PXA310 processor running the Windows Mobile operating system [15].
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The IP67 certified Getac PS236 handheld computer provided developers with a modern computing platform. Its rugged hardware was suitable for field use of the product. The modern operating system provided the means to easily develop sophisticated graphical user interfaces. It also increased the development process efficiency due to availability of convenient development tools. Furthermore, Visual Editor simplified the graphical user interface development and enabled rapid prototyping.

Nevertheless, the project suffered budget overruns and was introduced later to the market than initially planned. The product also failed to meet its initial target specifications. This thesis is going to investigate the cause of these shortcomings through a study of the company’s development process for this new product.

1.2 Methodology

The author carried out the research in the area of new product development, an applied and practical field, which requires problem-solving solutions. The company’s challenge of new product development may be defined and solved through a constructive research approach. The approach aims to solve the problem by evaluating the existing methods currently used to develop the product, improving the methods employed by the company and adding to its body of knowledge.

In order to identify what went wrong, it is first essential to know what is right in order to have a reference point for comparison. The author performed literature review identifying the practices that differentiate the best performing companies from the worst ones establishes this reference point. The best practices of new product development are reviewed and critical factors of success are investigated. In order to assess company’s new product development process, a set of questions is also derived. A series of interviews are conducted using the questions. As a result, the author reviews currently employed practices of the company and compares them to the best industry practices and success factors using the set of questions, evaluates the drawbacks of the practices and proposes improvements.

1.3 State-of-the-Art

In industrial metrology applications, there are several technologies available to collect measurement data. Single point measurement devices measure coordinates of single points. Points are either measured mechanically by contact-based probing with articulated arms, or optically by total stations or laser trackers with reflectors positioned at measured points. Another approach is to use high-density non-contact digitizing with 3D scanners based on various techniques: triangulation-based laser scanners, structured light scanners, computer tomography, time-of-flight scanners and stereo vision digitizers [16]. The approach used in large-scale assembly industries is single point measurement of
assembled structures using optical measurement devices, such as industrial total stations or laser trackers.

There are many companies on the market producing industrial total stations: Hilti [17], geo-FENNEL [18], Topcon [19], Trimble [20] and Sokkia [21]. Most of the stations lack the accuracy needed for large-scale assembly, since they are designed for surveying, geodesy and construction applications. The Leica TDRA6000 [10] laser station and especially Leica AT401 [22] laser tracker targeted by DCP Pocket provide ultimate accuracy over the range of tens of meters.

Leica AT401 features angular accuracy of ±15 μm + 6 μm/m and distance accuracy of ±10 μm. Accuracy values are expressed in Maximum Permissible Error (MPE), which means that all measurement errors are guaranteed to be below the specified values. Typical accuracies of angular and distance measurements are stated to be half of the specified MPE i.e. ±7.5 μm + 3 μm/m and ±5 μm correspondingly. The tracker is claimed to be the most accurate on the market with the lowest MPE values [23]. Such high accuracy allows it to be used in demanding industrial metrology applications and large-scale assembly.
2 New Product Development

Every company has a new development process in one way or another. Some have a well-defined process that they strictly follow, while others have a hard time even describing theirs [14]. Research has shown that about 65 to 75 percent of firms use some kind of phased adaptable new product development process. Only 47 percent of the companies have clearly defined evaluation criteria after each phase. At least 40 percent of the companies have a person responsible for management of the phased new product development process [3].

2.1 Generic Process

A generic new product development process typically consists of a number of phases (see Figure 6) [1,14]. The phases are usually separated by evaluation points resulting in ‘go’ or ‘kill’ decisions, which permit or prevent the product development to proceed. Using a process to develop new products manages down the amount of risk and uncertainty, as the company passes from idea generation to product launch [1].

![Figure 6: Generic new product development process.](image)

The generic development process described is merely a guideline and varies a lot in practice [2]. It might differ significantly for incremental new products and breakthrough products [1].

2.1.1 Planning

The planning phase precedes every new product development effort. During this phase, all necessary planning and predevelopment work happens. The phase starts with opportunity identification [1]. A company identifies the opportunities it might want to pursue by explicitly considering business and technological opportunities [14].

Identified opportunities are assessed against business strategies, technology developments and market objectives. Selected opportunities get allocated resources, and project timing is outlined. The company’s product mission statement is eventually formulated, which specifies the target market, business goals, key assumptions and constraints [14,24].
Opportunity identification can be thought of as an opportunity funnel. It takes multiple inputs across the enterprise—such as marketing and sales, research and development, current development teams, manufacturing and operations, potential customers and other third parties like suppliers, investors and partners—and it brings them together [14].

Opportunity identification may happen passively, but a proactive approach is recommended. Opportunities may arise through frustration with current products, innovation by lead users, changing trends, demographics and technology. In order to be able to capture them, competitors’ products have to be studied, emerging technologies should be tracked, lead users interviewed, suggestions systematically gathered and the use of current products documented [14].

An actively managed opportunity funnel can collect vast amounts of new product ideas. The next task is to select the most promising product opportunities to pursue [14]. By this point, it is essential to have a sound business strategy in order to make the right decisions, achieve focus and allocate resources efficiently. Portfolio management methods are used to align the pursued opportunities with the overall business strategy and allocate necessary resources [25].

Establishing a product vision and defining its mission statement completes the planning phase. The mission statement should contain a brief description of the product, key business goals, target markets, assumptions and constraints to guide the development and stakeholders in the project [14].

### 2.1.2 Concept Development

After identifying opportunities and selecting the project to be pursued, the process enters concept development phase [14]. During this phase, developers identify customer needs and establish a concrete idea by proposing solutions that would satisfy these needs [1]. This phase is also called “the fuzzy front-end” of product development, which can be a formal process on its own [24].

The process starts with an identification of customer needs—the ways customers describe the benefit fulfilled by the product using their own words. Customer needs should be distinguished from solutions; they describe what the product has to do, not how it will be done [26,14]. In order to identify these needs, product developers gather raw data from customers. Various methods can be used to gather raw data, such as interviews, focus groups and ethnographic observations of customers performing tasks involving the intended product use. Developers may also administer written surveys to supply raw data [14]. Additionally, lead users provide valuable feedback and even innovative solutions [27].

Raw data is then interpreted in terms of customer needs, which are expressed as an attribute of the product being developed. The developer group interprets needs
according to similarities and organizes them into a hierarchy. In order to be able to make trade-offs correctly and allocate resources appropriately the team has to rank the needs and define their relative importance [14].

Customer needs specify what the product has to do using the language of the customer. They give insights into what the customers envision in a product, but provide little guidance about how the product should be designed and developed. Product specifications are aimed at providing developers with precise descriptions of what the product has to do. In technology-intensive products specifications are established at least two times [14].

Target specifications are established first. They represent what the development team hopes and aspires to develop. These specifications are revisited later in the process after the team selects a product concept. After resolving trade-offs among desirable characteristics, developers set the final product specifications. In order to set these specifications, they must prepare a list of metrics. Metrics are based on customer needs, ideally reflecting the degree to which the product is going to satisfy them [14].

Competitive products have to be benchmarked to get a clear idea where the product stands in terms of competition, which has a direct impact on its success. Developers use various sources to gather information about competitors’ products. Then, they compare their own product to competing ones making positioning decisions, which influence the characteristics of the new product [14,28].

After the target specifications are refined and trade-offs are resolved, the development team sets final specifications. During this step, they rely on a technical model of the product, predicting its characteristics for certain design decisions. They also develop a cost model of the product in order to evaluate the cost [14].

After final specifications are set, the teams starts searching for solutions to satisfy customer needs. During this step, they generate, evaluate and select product concepts. Teams first define the problem, systematically searching both externally and internally for solutions [14]. Direct contact with customers and users as well as collaborations with other teams, organizations and institutions, often enhances this search [24]. Teams then rate the explored concepts using selection criteria, ranking them by rating scores and occasionally testing them with potential customers. They incorporate the best concepts into the product [14]. During this examination process, a concept might go through many iterations and changes before reaching maturity. [24]. The phase results in a detailed product definition [1].

### 2.1.3 Product Design

During the design phase, the product’s definition becomes tangible. This phase also includes the development of all necessary elements of the product’s marketization, such
as funding, distribution, promotion and technical service. Thus, marketing development happens in conjunction with technical development. [1].

Product design starts with its architectural design. Product architecture defines the way functional elements of a product are assigned to its physical building blocks [14]. Solid architecture is crucial to product performance because it reduces the cost of changing the product later and can improve the time to market [1]. Every product contains physical elements implementing product’s functions. These elements are linked to the concepts developed previously. Developers combine physical elements into major building blocks called chunks. Product architecture defines the way physical elements are organized into chunks and how these chunks interact [14].

In order to design product architecture, developers first create a schematic. The schematic shows the product components and their interconnectivity. Alternative schematics may also be developed and explored. After the product schematic is ready, chunks are defined by clustering their physical elements. Designers create a geometric layout of the chunks, sometimes considering several layouts at the same time. Finally, interfaces among chunks are identified and checked [14]. After product architecture is complete, details of the product are designed. The output of this step is a document describing the geometry of each part, production tooling, plans for fabrication and assembly and specifications of purchased parts [14].

2.1.4 Testing and Refinement

Once the product design phase is complete, a product moves into the testing and refinement phase. This phase is characterized by the creation and evaluation of multiple preproduction prototypes. Prototypes are tested in order to ensure that the product is going to work as designed and whether it satisfies key customer needs [14].

Prototypes may be either physical or analytical. Physical prototypes are tangible implementations of the product design. Analytical prototypes are nontangible implementations of the product, such as systems of equations, computer models and simulations. Prototypes are divided further into comprehensive prototypes, which implement most of the attributes of the product and are essentially complete, focused prototypes, examining only certain attributes and features [14].

Prototypes are also useful during the concept testing step as a way to communicate the concept to potential product users [14]. Developers rely on prototypes to test user experience and gather information of how well does a prototype satisfy customer needs. Prototype testing can be done iteratively throughout the whole product development process, starting with mock-ups and ending with prototypes that closely resemble the final product. Based on the acquired feedback, the product is thus tested and refined [1].
2.1.5 Launch

The new product development process is finalized with a product launch, which is sometimes also referred to as commercialization [1]. After its launch, a product becomes available to the masses and the company starts to recover the investment it made into the new product development. Product success is often determined within its first weeks in the marketplace, making launch management an essential part of the new product development process [29].

Prior to product launch, companies consider strategic givens that have already been defined and cannot be affected anymore and revisit their initial goals. They decide which markets to target, but this decision is segmented by its end-use or benefit sought. Many marketing campaigns are further segmented by geographic, demographic, behavioral and psychographic variables. This decision shapes product positioning, its brand name and packaging design [1].

In order to ensure a successful product launch, companies establish goals with measurable metrics. These goals are used to clarify the level of accountability of the launch team, which is selected to execute the launch. Then it is necessary to create an effective launch process consisting of actionable steps for execution grouped into three phases: launch plan, preshipment and postshipment phases [29].

A well-designed process enables the team to effectively resolve outstanding issues and make the remaining decisions in a systematic fashion. The launch team is lead by a launch manager, who deals with personnel issues, ensures communication inside the team and acts as a mediator between the team and the organization. Product launch is supported by sponsorship consisting of final decision-makers who have authority over resources [29].

2.2 Best Practices

The product development process and its impact on the success rate has long been a topical issue for researchers in the area of new product development [3]. A critical factor to product and company success could very well be the identification of a practice that would enable it to improve the new product development process in terms of efficiency and performance [30].

A practice that would enable companies to effectively turn promising product ideas into physical products, bring them to the market faster and at a lower cost would give them a competitive advantage. Companies place considerable resources into the development of processes, tools, techniques and methods to aid practitioners in gaining a competitive advantage. Some concepts have undergone rigorous research; while others are presented without any proof of efficiency improvement [3].
Much can be learned from the way new product development is implemented by studying the practices employed in best-performing companies [8]. An essential element of effective new product management is to investigate why some products succeed while others do not and why some companies are better at new product development than others [4].

Over the past several decades, researchers have benchmarked the effect on performance and efficiency of various new product development practices. A number of best practice studies have been published [3]. Cooper, Edgett and Kleinschmidt repeatedly address the issue of product success [31,32,33] and various factors that influence it, such as methods of portfolio management [25,34,35], resource allocation for different steps and phases [36] and project timeliness [37]. Gruner and Homburg [38] address the issue of interaction with customers during new product development and its effect on product success. Barczak and Khan [30] delineate a framework of seven dimensions to assist with the identification of best practices in new product development. Product Development and Management Association (PDMA) conducts studies on best new product development practices presenting results, recommendations and implications [3,8]. These studies summarize prior research as well as present outcomes of the research performed by PDMA itself.

Cooper [4] also summarizes numerous studies of new product development performance and best practices, discussing the circumstances and facts. He pinpoints the critical factors that influence the success of a new product development effort and separates winners from losers. He derives a recommended set of practices from the studies of successful products versus unsuccessful ones. He also presents a series of checklists of items to assess the performance of the company and the chances it has to succeed with its new product.

The research pointed out several emerging themes, such as the consistent success rate independent of industry and process improvement, usage of cross-functional teams and multiple practices, a strictly structured and followed development process, assignment of project managers and champions, non-financial rewards, development process performance assessment, sound strategy and a deep investigation of its users’ needs.

The new product development process evolves, but the overall success rate of new products remains consistently low. About one third of developed products that make it to the market are failing. The rate is essentially independent from industry type. Nevertheless, progress has been made in reducing new product development cycle times. Products without potential are now eliminated much earlier in the process, wasting fewer resources on unsuccessful projects [3].

A recent research by Barczak and Kahn [30] presents a framework to identify both best and poor practices of new product development. They base this framework on prior benchmarking studies, PDMA certification standards, a Delphi methodology involving
20 leading experts in the field of new product development and a survey involving over 300 practitioners.

The research defines seven dimensions of new product development process and presents tools to conduct an audit of existing practices of a company. According to the framework they present, new product development process can be portrayed across seven dimensions:

- Strategy
- Research
- Commercialization
- Process
- Project Climate
- Company Culture
- Metrics and Performance Measurement

2.2.1 New Product Strategy

Having a sound company-wide strategy as well as one for each project contributes to the new product development performance [4,30]. Many recommend identifying a new product strategy prior to starting a new product development effort, formulating a product strategy as early as possible [3]. This strategy defines both the focus and goals of new development efforts. It enables selection, identification and prioritization of development projects that fit the overall company objectives [30].

The goals of a new product development have to be clearly defined and communicated [4]. First, new product projects in a company’s portfolio should be aligned with its strategy. In order to ensure a balanced product portfolio, a management system needs to be in place. It should be able to prioritize key projects and efficiently distribute available resources using such a system [30]. Staying focused is the key to effective new product development strategy and enables developers to avoid such pitfalls as project scope creep or pursuing wrong opportunities [4].

Crawford and Di Benedetto [1] emphasize the importance of having a formalized company strategy through the creation of a product innovation charter (PIC). This document should provide guidance on the role of innovation throughout all levels of the organization and set the conditions under which the company is going to operate. A PIC may guide new product development effort and provide a much-needed focus and direction to concentrate on. It prevents companies from wasting resources in the pursuit of opportunities that are less likely to result in successful products. It also limits the number of considered opportunities to the ones that have the highest potential and fit the company best, in terms of its other products and its established market [1]. Thus, without focus, projects are more likely to suffer from scope creep and unstable product specifications, inevitably wasting time and resources [1,4].
2.2.2 Predevelopment Research

Market, customer and developmental research are essential to every new product development effort [4]. This should be thoroughly undertaken before product development work begins. Markets should be assessed to understand their size, potential, the status of competition and expected sales. Customers have to be studied in order to identify their needs. Lastly, the technical capability of the company to develop, design and deliver such a product should be evaluated [28].

Research activities consist of a number of steps that precede the actual product development. Such predevelopment work is crucial to creating a product with a high chance of success. In order to increase the likelihood of product success, it is vital to take the following steps first [4]:

- Initial screening
- Preliminary market assessment
- Preliminary technical assessment
- Detailed market study
- Business and financial analysis

Initial screening is the initial approval of the project. During initial approval companies decide whether it is worth to allocate the time and necessary resources for the proposed new product idea [28].

Preliminary market assessment follows the initial screening. It is the first brief study of the market with the aim of assessing its attractiveness and potential. Such an assessment evaluates the competition and estimates expected market penetration of the product being developed [28].

After the market assessment, the product developers appraise the proposed product idea. During this preliminary technical assessment, rough objectives are established; preliminary technical feasibility of the proposed new product idea is carried out and possible technical risks are evaluated [28].

During the detailed market study, more comprehensive research of the market is undertaken. The competitive environment is analyzed in more detail, determining direct and indirect competition, strengths and weaknesses of competitive products and their prices [28]. User needs are researched using various methods, such as voice of the customer, [26] in order to generate product specifications.

Market information, as well as customer research should be used to deeply understand current and unarticulated needs of potential customers, their reaction to the proposed product, benefits they get from it and their price sensitivity [30]. Deep understanding of user needs is essential to product success. They also recommend distinguishing between customer needs and product features, which are solutions for those needs, and the use of
explicit documents for both [3]. The research is finalized with a financial analysis and a business case for the product. It is necessary to justify a heavy investment into the development of the product by ensuring that it has a high chance of success [28]. Studies have shown that the technical side prevails in the worst performing companies [4]. Appropriate balance between the marketing or business aspects and technical research should be maintained.

Adequate resources should be provided for the research process within new product development in order to perform market research and analyze the results (28,4). Skipping steps in the research phase, or even omitting the phase completely, results in a higher chance of product failure [4].

Properly conducted predevelopment work provides better project definition, and thus speeds up all subsequent stages. Companies may justify spending time and resources in the predevelopment stage because it saves time and resources later in the process. Research encourages inevitable product design changes to occur earlier in the process. Making changes early in the process reduces the cost of implementation and helps to avoid costly redesigns [4].

2.2.3 Product Commercialization

In addition to the research phase, companies should invest in a proficient launch, marketization, after sales support and customer service for their new products. The quality of a product launch is associated with overall product profitability and should never be underestimated. Good products do not sell themselves; therefore a market launch plan is required and cannot be omitted. [4] Nevertheless, companies often fail to place enough emphasis on the up-front strategic planning. This lack of emphasis results in weak strategic planning, which is later apparent when the product reaches the market [1].

Effective market launch planning should be an integral part of the development process and as central as the physical product development. Planning the launch of the product must begin early in the development process and should not be left as an afterthought. Also, the launch should also be sufficiently resourced to be successful [4]. A standard protocol for planning product launch should exist within the company [30].

The best practice of a successful product launch is to have a cross-functional team that makes decisions concerning the manufacture, logistics, marketization and sales. Customer service and support should also be involved in the launch team. [30]. The launch team should be involved with the product throughout the whole development process [4].
2.2.4 Development Process Implementation

Many studies have shown that companies should also place a strong emphasis on the completeness, consistency and quality of execution of the product development process. The process should be followed rigorously without skipping steps. Existence of a rigorous process used by the development team is strongly tied to profitability and reduction in time-to-market of the product [4,3]. Research has shown that a disciplined structured and customer-centered product development process positively affects overall development effort performance [3].

The process has to be formal, well documented and commonly agreed upon. It should be visibly and tangibly supported by management and consistently followed by the development team. Nevertheless, many companies still do not implement a formal product development process, despite its well-proven effectiveness [3]. In recent years, an expectation of a formal process is the norm, but 31% of companies still do not use one [8].

After each phase of the development process, there should also be clear, pre-defined ‘go’ or ‘kill’ evaluation criteria. The process should be flexible and adaptable to meet the needs of individual projects. Projects should be systematically reviewed upon completion. A supporting infrastructure with appropriate hardware, software and technical support should be available to enable efficient new product process implementation [30].

In order to ensure proper process execution, some companies integrate process quality assurance into the process itself. They introduce checkpoints and metrics to ensure that every action in the process executes in a high-quality fashion [4]. However, using a single new product development practice extensively, or more often than others, does not contribute to a company’s success. Instead, companies should employ a number of practices simultaneously and effectively. [3].

2.2.5 Project Climate

Throughout this process, it is essential to keep in mind that product development is a team effort. The commitment of each team member and the ability of product development participants to effectively communicate with one another greatly influence the project outcome [4].

Best performing companies extensively use multidisciplinary cross-functional teams. Their members have various professional backgrounds, such as technical, sales, marketing or operations. Teams should be clearly assigned for particular tasks. The assignment of cross-functional teams is considered to be crucial for a successful new product development. Furthermore, allowing teams to operate with significant autonomy
and letting them fully “own” the development process was found to lead to increased success of the developed product [3,4].

Most of the best performing companies enable collaboration between team members using a central information-sharing system. Such a system facilitates project information sharing. Multiple users may then work on the same documents concurrently across functional and location barriers [4].

It is a good practice to have a clearly identifiable project leader for each project that is undertaken. This leader should manage the project and be responsible for driving its development [30,4]. Project managers, which are by far the most widely used leaders of new product development, and product champions, increase the chances of development effort success [3]. It is also considered to be a pivotal best practice to make teams accountable for the outcomes of the development process. The members should be responsible for meeting the project goals in a timely manner as well as ensuring that the profit or revenue and time targets are met [4].

Team members should remain on the project from the very beginning to the very end, and not just act as participants in parts or phases of the development process. So should remain the team leader, holding responsibility for the entire new product development process, starting from the initial idea and ending with product launch. Making the team stay on the same project enhances team accountability. Furthermore, effective communication within the team is essential to team performance [4].

### 2.2.6 Company Culture

A positive company environment is also an important element in the effectiveness of new product development [4]. New product development efforts should be supported and rewarded by senior managers [30]. Entrepreneurialism and risk-taking should be encouraged within the development team [30,4]. Creativity should be supported at all levels of development [4].

Senior management may also increase the chances of product development effort to result in a successful product by providing necessary resources, encouragement and a united front for achievement. Empowering project teams and supporting team champions are linked with improved likelihood of product success. Therefore, new product development should be viewed as a long-term strategy that management is committed to. By always providing the necessary resources, managers may support the development of vision, objectives and strategies. Senior management should also participate in the new product development process by reviewing projects and making decisions whether to cease or continue development. [4].

Actively working with customers to develop new solutions is considered to be a good practice as well as using other multiple sources of ideas such as suppliers, customers and
An idea submission scheme is a way to capture these emerging ideas [4].

Team efforts—not individual ones—should always be emphasized. Success should be rewarded and recognized, while failure should not be punished [4]. According to several studies, the best performing companies do not use financial rewards or incentives to motivate people. The most common type of reward they use is a completion dinner for the development team at the expense of the company [3].

### 2.2.7 Metrics and Performance Measurement

Companies that lack adequate project evaluation and prioritization often suffer because they pursue more projects simultaneously than they can handle [4]. Whenever limited resources are available, pursuing too many projects results in a longer cycle time, poor execution quality and underperforming projects [25].

Without careful consideration of resource allocation, resources are wasted on poor projects that do not fit the company’s overall product strategy and do not have a high potential for success. At the same time, truly meritorious projects might not receive sufficient resources, and become overshadowed or diluted in the process [4]. In order to avoid carelessly wasting resources on the wrong projects, companies should utilize product portfolio management methods. Such methods enable executives to keep promising projects and abandon projects that are likely to fail, prioritize important projects and deprioritize unimportant ones and balance resource distribution [25,4]. Some companies have integrated funneling into their process in order to ensure that they only pursue the product development projects that have a high chance of success [4].

Best performing companies perform project evaluation using consistent criteria that are clear and well defined [4,8]. The evaluation process assesses each new product prior to being developed in terms of its alignment with the overall business strategy and its strategic importance to the business. They also assess the degree of product and competitive advantage for the project, such as differentiation, unique benefit and compelling value proposition, market attractiveness, technical feasibility, leverage of company’s core competencies and financial prospects. Projects that are unlikely to succeed should be killed as early as possible. Best practice studies show that several people should be conducting a project evaluation using defined metrics [30].

New product development projects should be evaluated throughout the whole course of the development process. It is crucial to have ‘go’ or ‘kill’ decision points in between each phase in order to prevent wasting resources on projects that are most likely not going to succeed. Having such decision points is strongly linked with the business’s overall profitability [28].

In addition to evaluation of project outcome it is also crucial to evaluate the process used throughout the project. The best performing companies measure overall product
development process performance by assessing it against objectives, expecting more of the process [3]. These include establishing a formal, well-defined, commonly agreed upon and consistently followed process, followed by thorough predevelopment research of markets, customers and technical feasibility. The product must then be given effective commercialization with a well-planned and properly executed launch. Development should comprise of dedicated cross-functional teams and an identifiable leader who remain on the project from beginning to end. These operate in a positive climate and unobstructed communication. Senior management should provide support and entrepreneurialism encouragement, and lastly produce a consistent and well-defined project evaluation.

2.3 Critical Factors of Success

Based on a number of new product development processes, benchmark studies compare the best performing company practices to those of all others. Best practice research may also be conducted within various companies to identify why some new products succeed while others fail [8,3,30,4]. From the previous best practices, Cooper derives [28,4] a set of critical factors for successful new product development. These factors are critical elements of a successful new product development process:

- Developing a unique superior product
- Maintaining strong market orientation and customer understanding
- Sharp and stable project and product definition
- Orienting products for international markets
- Being fast but not at the expense of quality
- Leveraging core competences
- Targeting attractive markets
- Employing effective portfolio management
- Availability of the necessary resources

These factors do not guarantee a successful outcome of a new product development effort. Nevertheless, numerous empirical studies have shown that these factors increase new product chances to succeed and separate the best performing companies from the rest.

2.3.1 Developing a Unique and Superior Product

Having a unique superior and differentiated product is a factor of uttermost importance in new product development. Such a product delivers unique benefits and superior value to its customers. According to Cooper [4], differentiated and superior products are the key to success. Multiple studies have shown that unlike unique products reactive products fail to produce large profits.
A superior and unique product is a product that provides good value for money for the customer, reduces customer total cost and features high price/performance ratio. Such a product provides excellent product quality. It may also be considered superior for meeting user needs, or it may have unique features to solve customer problems that are not available in competitive products [4,7]. However, if a product is unique, it does not necessarily mean that it is also differentiated. Differentiation depends on customer perception of the product value. Value itself is created using two mechanisms: by lowering customer cost and by raising customer performance. When the source of value in the product is perceived and measured, or in the case of measuring difficulties, extensively signaled, the product is perceived as differentiated by the customer. If companies fail to understand the mechanisms behind a customer’s value perception, or if they ignore the need to signal a product value, even a superior and unique product might end up non-differentiated or too differentiated: higher than customers would need [7].

A checklist of items may be used in order to assess the odds of a product’s success. During the project screening, this list of items should have the topmost priority [4]:

- Addresses the main product benefits that are important to customers.
- Offers customers new and unique benefits.
- Has a compelling value proposition.
- Superior to competing products at meeting customer needs.
- Superior quality compared to competitors.

Competitive advantage can also be gained by using other factors such as brand equity, company reputation, superior marketing communications, sales force, distribution channels, technical support and product availability. These factors have a positive effect on the product success, but have a considerably smaller effect than the product advantage. These factors alone cannot make a successful product from a weak one [4].

### 2.3.2 Strong Market Orientation and Customer Focus

In order to develop a successful product, a company has to thoroughly understand its customers’ needs and desires, the nature of the market it is targeting as well competitive situation in it. Strong market orientation is achieved by undertaking a necessary assessment of the market as part of the predevelopment work. By involving customers in the development process, a company may achieve customer focus. Strong market orientation and customer focus improve the chances of the developed product to succeed and increase profitability rates [4].

It is commonly believed that spending extra time on market analysis and research results in longer product development time. In fact, thorough research and analysis lead to reduced time-to-market because they keep development on schedule. Improved time efficiency pays off by increasing product success rates. Therefore, detailed market and
customer studies should not be omitted. They should be thoroughly performed and given sufficient time and resources [4].

The new product development process should exhibit market and customer orientation throughout all of its phases. During the idea generation phase, developers should thoroughly study user needs. They should also conduct focus groups, or voice-of-the-customer [26] research to understand the problems customers are facing, as well as their unarticulated needs and desires [4].

During this phase of customer understanding, competition should also be explored. Developers perform competitive benchmarking by studying the products competitors have to offer, determining their strengths and weaknesses and then identifying their competitive strategies [4]. Understanding of competitive products is critical for a company to successfully position its products on the market. It can also be a rich source of ideas during the product design phase [14].

Market, customer and competition research should commence early in the new product development process. It should not be an afterthought or an after-the-fact check. Its outcomes should serve both as an input for the product design process during the development phase and as a guide to the development team [4].

In order to achieve customer orientation, a company has to involve customers in the development phase [4]. Interacting with customers during the process of new product development has a positive impact on the developed product success [38]. Customers should continuously provide inputs to the development process via an iterative development process. Techniques such as concept tests, rapid-prototype-and-test, customer trials and test marketing should be used to efficiently co-develop the product with customers. Such an approach would verify the development team’s assumptions about target users of the product. It would also increase the chances of the product’s success by minimizing speculation and allowing the development team to receive feedback early enough in the process. Even technology-driven products can benefit from customer involvement in the development process. Building customer and market inputs into the process increases the potential of every developed product to succeed [4].

Despite the proven positive effect of customer involvement, research has shown that not every customer is suitable for involvement in the development process. A study conducted by Gruner and Homburg [38] shows that certain characteristics exhibited by involved customers have a significant effect on the new product’s success. The impact of customer involvement differs between financially attractive customers, technically attractive customers, close customers and lead users. While interaction with lead users as well as close and financially attractive customers may result in valuable cooperation, involving technically attractive customers has a negative impact on the development process performance. Thus, it is recommended to involve lead users, close and financially attractive customers in the new product development process. Customer
involvement during the initial stages of the process was found to be the most beneficial. [38].

### 2.3.3 Sharp and Stable Project and Product Definition

Another important success factor of new product development effort is having sharp, early, and stable definition of the development project and the product being developed [4]. Constantly changing basic project definitions results in project scope creep. This refers to the uncontrollable changes or an increase of the project’s scope that occurs whenever features or functions are added to the product. Most additions or changes are minimal in part, but may accumulate over time and have a substantial impact [39]. Additions to product definition result in moving development goal. When the goal is constantly moving, it takes forever for the team to reach it [4].

Scope creep is the worst time-waster of any new product development effort [4]. It is also a common reason for project failures [39]. One more major time-waster connected to scope creep is unstable product definition, which occurs when product requirements and specifications change throughout the development stage, causing team members to chase elusive development targets.

To a certain degree, every project suffers from scope creep [39]. Inevitable design evolution occurs during the lifetime of every project [4]. There is no way to avoid this; therefore it has to be managed [39]. Ensuring that most of the changes occur early in the development process rather than later can minimize the effect of scope creep on product development. The price of early occurring changes is significantly lower than the price of changes occurring later in the process. Furthermore, having a properly defined project before the actual development begins saves a lot of time during the product development phase [4].

In order to minimize chasing a moving target sharp, early, stable and fact-based product definition has to be secured. Solid product definition secures the scope of the project. Product definition is the outcome of the predevelopment work phase, in which ideas are evaluated, the market is assessed, technical feasibility is studied and a business case is built. Therefore, companies should never ignore predevelopment work and do it thoroughly [4].

The definition should include the scope of the project, target market, its intended users, a product concept with a list of benefits and the product strategy, including the target price and a list of features, attributes, requirements and specifications. Ensuring a clear and consistent definition of these aspects of the new product increases its chances to succeed significantly. Such a definition can serve as a communication tool and guide for the team members. It also defines clear objectives for the development team [4].

Crawford and Di Benedetto [1] advocate a product innovation charter to provide a clear focus for new product development process and help minimize these costly and time-
consuming problems. It forms a mission statement adapted to new product development activities. The charter defines the product background, a focus on particular markets and technology dimensions, goals and objectives, with evaluation measurements and guidelines.

2.3.4 Product Orientation at International Markets

Studies of product development show that products targeting global markets and the ones exported to its nearest neighbors are performing considerably better than the products designed exclusively for domestic markets. They also show that international products do better in domestic markets as well [28].

The strategy of designing a product, using the requirements of the domestic market and eventually exporting slightly modified versions, is comfortable but shortsighted. It can only lead to a poor long-term outcome due to the increased globalization of markets. In order for products to perform well in both domestic and international markets, they have to meet international requirements as well as domestic ones. In order to do so, companies have to employ a transnational new product process. In the transnational process, new product ideas are solicited from many countries and a global portfolio management is used to prioritize projects. Global decision-making groups are established to screen the ideas and jointly fund projects. International teams execute the projects, while market studies are performed in various countries [28].

2.3.5 High Speed and Quality

The ability of a company to design and deliver a product faster than others yields a strong competitive advantage [4]. Time is especially crucial for companies developing high-technology products, due to rapidly changing markets and evolving underlying technology [40]. Speed in developing new products reduces the probability of a changed market or competitive situation by the time the product is brought to the market [4]. It is easier to predict what the state of the market, technology and competition is going to be in the nearest future. Accuracy of such forecasts further ahead in time is much lower [40].

A shorter product development cycle enables a company to incorporate more advanced technology into its products compared to slow competitors. Being fast allows the company to get ahead and stay ahead. Sustaining the advantage can eventually drive the competitors out of the market [40]. A shorter development cycle also brings quicker realization of profits [4]. Being the first company on the market has multiple advantages. First-to-market products have a chance of capturing additional market share by simply preceding the existence of competition. This affords an advantageous temporary monopoly [40].
Being first on the market also enables companies to get earlier experience with customers, technology and channels of distribution. Such an experience can be used to refine the product and stay ahead of competition. The first product on the market may also influence the definition of standards by informally becoming the de facto standard. A standards group may use the first product of its type as a reference defining standards. It does not necessarily give the company control of the standards, but certainly gives it an advantage [40].

In order to reduce the product development cycle, Cooper [4] recommends thoroughly conducting the predevelopment work and establishing a stable product and project definitions. This saves time during the actual development phase and helps the company to avoid product scope creep. Cross-functional teams are considered to be essential to new product development. In addition, parallel task completion saves processing time. It may be combined with a spiral development process in a series of build-and-test spirals, with constant evaluations based on customer feedback. Focusing the new product development, prioritizing only the essential projects and assigning resources to the ones that truly deserve them results in higher quality and time improvements [4].

2.3.6 Leveraging Core Competences

Every company possesses a set of core competences. These competences are in-house technical skills, such as engineering and manufacturing, existing customers and established distribution channels, sales force and customer service resources, knowledge and market intelligence skills [28]. Ability to leverage existing in-house resources, experience, competencies and capabilities has a positive effect on new product project success. Projects lacking product synergy tend to result in the poor development of new products. Though it improves the likelihood of the developed product turning out to be successful, synergy is not necessarily essential. If other compelling reasons to start the project exist, a development team might as well disregard it [4].

Developing products using technical skills and resources available in-house is typically less risky and less expensive than seeking these outside the company. Targeting familiar customers has the benefit of being able to take advantage of established distribution channels and the existing sales force, which is less expensive, less risky and less time-consuming [28].

Familiarity is a concept parallel to synergy. A company might engage in new product development by targeting an unfamiliar product category, such as new customers with unfamiliar needs to be met by the product using unfamiliar technology. Such a product would require a new sales force and distribution channels. It might be necessary to produce it using an unfamiliar manufacturing process. Unfamiliar projects usually result in a lower success rate [4]. Both synergy and familiarity should be considered when a new product project is being evaluated and prioritized during initial screening. Every new product idea should be assessed against technological competence and marketing
capabilities of the company [28]. Thus, whenever companies venture into unfamiliar markets, they should do so with extra caution [4].

### 2.3.7 Targeting Attractive Markets

The attractiveness of the market that the new product is targeting is an important factor because the more attractive a market is, the higher the tendency of success [4]. Attractiveness of a market is a function of its structural attractiveness, its size, growth and match between company capabilities and the needs of the market. Structural attractiveness is a function of five competitive forces at the market segment level: the existing rivalry between competitors, customer power, supplier power, the threat of new entrants and that of potential substitutes. Size and growth are important issues to consider on their own because they affect structural attractiveness by influencing the interest of large companies and new entrants to enter the market [7].

Market attractiveness should be the first issue for a company to consider when deciding where to compete [7]. The company should also consider the market size and growth rate, evaluate customer needs and whether a strong need exists and estimate how important the purchase would be for a customer. The intensity and basis of competition should be studied as well in order to develop a successful competitive strategy if the company decides to enter the market with its product [28].

### 2.3.8 Employing Effective Portfolio Management

Portfolio management aims to prevent spending scarce resources on too many projects while none of the projects get sufficient resources. It facilitates the company’s selection of new product development projects, focusing resources and using them more efficiently. Portfolio management ensures that the new potential products are balanced with existing products offered by the company and fit its overall business strategy [1].

Portfolio management is considered to be one of the most important senior management functions. Being able to pick the right set of development projects among various new product ideas is critical to a company’s prosperity and even survival. Portfolio management is the manifestation of the business strategy of a company [34]. Despite its importance, portfolio management is typically poorly handled. If a company is deficient in its portfolio management, negative consequences are to be expected. Missing strategic criteria result in projects misaligned with its business strategy. Such misalignment leads to unimportant projects ending up in the portfolio. Deficient go/kill criteria result in mediocre projects being pursued, while good projects are starving for resources [34,28].

Lack of focus results in too many projects being pursued at once and resources being thinly spread. Lack of appropriate resource allocation and project prioritization leads to increased time-to-market, poor quality and decrease in new product success rate. Deficient selection methods results in projects being selected based on politics, opinion
and emotion instead of facts and objective criteria. This results in product portfolio being misaligned with company’s strategy [34,28].

In order to learn about the importance of portfolio management, the types and details of portfolio management methods being used, various method trends and what distinguishes the best performing companies from the rest, Cooper, Edgett and Kleinschmidt [34] performed an exploratory study of 30 companies, using in-depth personal interviews and 205 questionnaires.

The study reveals that financial methods dominate portfolio management and project selection approaches. Such approaches use different profitability and return metrics to rate, rank and prioritize projects [34]. The metrics include net present value (NPV), internal rate of return (IRR) and expected commercial value (ECV). [34,25].

The second most popular portfolio management approach uses a business strategy as the basis for project selection and resource allocation. Projects are grouped into different envelopes or buckets across various dimensions of business goals, vision and strategy and rank-ordered until spending limit is reached for each bucket. Management may rank projects according to a financial index or a scoring model [34]. Strategic considerations dominate the decision of whether to pursue the project or not [25].

Bubble diagrams or portfolio maps are similar to the original portfolio models, except that axes rely on different metrics and projects instead of plotting business units [34]. Various parameters—such as reward versus probability-of-success or reward versus project-attractiveness—are plotted against each other creating a map [25]. Projects are then plotted as bubbles of a size that corresponds with the resources required. They are then categorized based on their quadrant [34,25].

Projects are rated on a number of questions or criteria. The yielded score is used to rank and select projects. Questions can either be simple or weighted according to their importance [34]. Questions, or items used often capture factors that positively affect product chances to succeed such as product advantage, market attractiveness, synergy or familiarity [25]. Sometimes, projects are evaluated based on a set of checklists that consist of a number of polar questions. In order to proceed, a project must achieve a certain number of ‘yes’ responses. The number of positive responses is used for prioritization or making ‘go’ or ‘kill’ decisions [34].

The study also reports on the practices used by best performing companies. In order to evaluate portfolio performance, six important metrics have been constructed: alignment with business objectives, very high-value projects in the portfolio, projects completed in a timely manner, a good balance of project types and an optimal number of projects. The top performers are reported to have achieved dramatically higher score across all six metrics. They especially excel in portfolio balance and at having the right number of projects. Best performing companies view portfolio management as significant regardless of functional area. They have an explicit portfolio management process that is supported
by management. The process is consistently utilized and has clear rules and procedures to be applied to all projects, which are treated as a portfolio [34].

Despite their overall popularity, best performing companies rely much less on financial models. Business strategy methods dominate their portfolio management and resource allocation. They also acknowledge that a single method does not provide correct results, therefore multiple methods are used [34].

### 2.3.9 Availability of Necessary Resources

Many new product development projects suffer from a lack of resource commitment. They are underfinanced and too little time is allocated for their completion. The result of lack of resources is usually foreseeable. Such projects often result in poorly implemented products or failure [28].

Many studies identify a lack of a market orientation and an inadequate market analysis as the key causes of product failure. Nevertheless, studies fail to determine the reasons behind marketing activity deficiency. They rarely address the question of resource allocation and the link to new product success and failure. Studies perform rough splits of innovation expenses across major stages of the new product process as well as a breakdown of total company expenditures. However, such studies do not provide sufficient detail to make meaningful conclusions about typical expenditures on various steps and activities of the new product process. Thus, differences in the patterns of expenditures may not be determined. Cooper and Kleinschmidt [36] address this issue by interviewing the management in 125 industrial companies on resource allocation.

The study reveals that companies use new product processes dominated by technical activities. Despite housing many critical and decisive activities central to new product processes, the front-end phase typically receives little attention and fewer resources. However, more successful projects are characterized by substantially heavier spending on the front-end process. During the mid-project steps, the difference in spending is not so great, but successful projects still receive higher funding. The postdevelopment stage exhibits higher spending on successful projects but higher manpower expenditures on failed ones. One possible explanation is that as projects started to be recognized as failures, companies reduced funding without killing them entirely. Therefore, they continued to allocate manpower with limited resources [36].

Overall, companies allocate more resources, both in terms of funds and manpower, on projects with successful outcomes, but the highest the difference in spending is observed during predevelopment activities. This finding is supported by the fact that in successful products twice as much resources were spent on the front-end phase—both in terms of funds and manpower—than in failed ones. The amount of time and money spent on the front-end activities of the new product process are strongly connected to a product’s success [36].
Since marketing activities play a relatively minor role in the new product development process, this research implies that a strong market orientation is missing. In order to establish one, companies should perform an adequate market analysis. Such an analysis requires sufficient funds being spent on the predevelopment phase of the process [36]. Therefore, in order to increase new products’ chances to succeed, sufficient resources have to be allocated for the project. The resources have to be available early enough in the project in order to ensure that the predevelopment work is conducted thoroughly. Proper market research results in strong market orientation, which decreases the likelihood of new product failure [4].

2.4 Forces of Competition

Success or failure of a new product largely depends on the attractiveness of its target market. Products targeting attractive markets are more successful [28]. Analyzing the attractiveness of a market is an essential step in deciding in which market to compete, since different markets differ widely in their attractiveness [7].

Attractiveness of a market depends on its size and growth rate, strengths of the competition forces and how capable a company is at meeting the market demands. Size affects how attractive the market is to large competitors. A company might gain and sustain competitive advantage in a small market because large companies are not interested in it. High growth rate can attract new competitors to the market [7].

Managers often define competition too narrowly without considering all the possible implications. It is commonly seen as a rivalry, occurring only between existing opponents that threaten each other directly by competing in a certain industry. In practice, competition goes far beyond the established rivals of the industry [41].

The thesis will first introduce Porter’s [7] five forces of competition from external sources (see Figure 7). These determine industrial profitability by influencing prices, costs and required investment to enter the industry. The competition forces are: rivalry among existing competitors, bargaining power of suppliers, bargaining power of customers, threat of new entrants and substitute products. Market attractiveness is a function of the strength of these five competitive forces affecting the market [7].

In order to evaluate the effect of these competitive forces on industry profitability, the underlying structure of the industry has to be analyzed in terms of these forces. It is the industry structure that drives the competition, not the company maturity, whether the company provides products or services, the level of technology it utilizes and the level of regulation it faces. Analysis of industry structure provides a company with a framework to anticipate and influence competition [42].
Figure 7: Five forces of competition that determine industry profitability.

The strength of each force is a function of industry structure, which is different among industries [7] but these forces driving competition are essentially the same regardless of the industry [42]. These forces should be considered before a company makes an attempt to enter a particular market with a new product.

2.4.1 Existing Rivals

Existing rivals in the industry undermine profit potential of each other. Profit potential is affected by the basis and the intensity of competition. Price is the most destructive competition basis and usually happens when products are weakly differentiated, in case of low switching costs, high fixed costs, overcapacity and whenever the product is perishable. The intensity depends on the number and size of competitors, industry growth rate, exit barriers and commitment to business [43].

2.4.2 Power of Suppliers

Suppliers may shape the competitive environment of an industry by raising prices, lowering quality and reducing availability of their products. The bargaining power of suppliers depends on supplier concentration in comparison to the industry it sells to, switching cost from one supplier to another the participants of the industry may face, suppliers' product differentiation and availability of its substitutes, ability of suppliers to integrate forward and enter buyer's market and how heavily suppliers depend on the industry in terms of volume or profit [43].
2.4.3 Power of Customers

Customers may shape the competitive environment of an industry by demanding a higher quality product at lower prices and by playing competitors against each other. Bargaining power of customers depends on purchase volumes, differentiation of industry's products, costs related to switching vendors, ability to integrate backward to start producing vendor's product and how price sensitive customers are. Price sensitivity in turn depends on the fraction of the customers' expenditures that the product represents, profits earned, dependency on the quality of the product and how the product affects their overall costs [43].

2.4.4 Threat of New Entrants

Profitable industries attract new entrants who are willing to gain market share. New entrants pose threats to companies already competing in the industry by introducing new capacity without an increase in customer demand. Barriers to entry deter new entrants from an industry [43].

One of the major barriers to entry is the economy of scale, or the low per-unit cost enjoyed by companies that produce large volumes of products. In industries where economy of scale is present companies are either forced to enter at a large scale or accept cost disadvantage. Economies of scale can be present in all the functional areas of a company [41].

Another significant new entrant barrier is product differentiation, which may be achieved through brand equity, customer loyalty, customer service, product differences or being the first product in the industry. New entrants are forced to make substantial investments in order to outperform existing products [41]. The network effect, or a customer's willingness to pay for a product, increases with the number of customers patronizing the company. This effect may be an additional barrier to entry [43].

Requirements to invest large financial resources in order to enter an industry—particularly if the investment is risky—may deter new entrants [41]. Another barrier to entry is the switching costs the buyer would have to face in order to switch suppliers. Such costs might include employee retraining, additional equipment cost, product redesign and testing, disruption or reconfiguration. [7,41].

Also, new entrants might be faced with the need to secure a distribution channel. If companies established in the industry have already secured the existing distribution channels, new entrants would have to persuade the distributors to accept their product as well [41]. Other incumbency advantages such as proprietary technology, access to raw materials, subsidies, favorable locations, government subsidies and cumulative experience are significant barriers to entry [43]. Government may bar entry via licensing policies, control of raw materials access, standards and regulations [41].
2.4.5 Threat of Substitute Products

Companies may also be threatened by substitute products that perform similar functions and offer similar benefits, but by different means. Substitutes set the ceiling that the company can charge for its products. There are nearly always substitutes available in industries [43]. Substitute threat is a function of the price/value ratio that the substitute product provides, cost of switching to the substitute and customer's propensity to switch. In addition to that the options of not using the product, using less of it, using recycled or reconditioned products and backward integrating often act as substitutes [7].

2.5 Competitive Strategy

Porter [41] defined competitive strategy as a way to find a favorable position for a company in the industry where it is best at defending itself against the forces of competition or can influence the forces and shape the industry in the company’s favor.

In order to address these forces, a company takes either defensive or offensive action. A company either positions itself so that its existing capabilities provide the best defense against forces or it may attempt to anticipate changes in underlying forces and respond appropriately before the changes are recognized by rivals. A company may also try to influence the forces via strategic moves, thereby improving its position [41].

The key to developing a successful strategy is to look deep into the forces of competition and identify their sources. Knowledge of the underlying sources of the competitive forces enables understanding of critical strengths and weaknesses of the company relative to competition [41].

A company might have numerous strengths and weaknesses, but only cost advantage and differentiation are considered to be significant because they impact the two basic sources of competition a firm may have. Cost advantage and differentiation arise from the industry structure and rely on the company’s ability to cope with competitive forces better than its rivals [7].

The basic sources of competitive advantage lead to three generic strategies: cost leadership, differentiation and focus. The focus strategy is divided in turn into cost focus or differentiation focus (see Figure 8). Cost leadership and differentiation strategies aim at a broad range of market segments while focus strategies are concentrated on a particular market segment [7].
Companies commonly use these strategies in order to outperform their competitors and achieve competitive advantage. However, in order to achieve either type of competitive advantage using corresponding competitive strategy, the specific steps vary widely from industry to industry [7]. The best strategy for each company is unique depending on the circumstances surrounding the company [41].

### 2.5.1 Cost Leadership

Cost leadership strategy is about becoming the low-cost producer in the industry. The sources of cost advantage vary depending on the industry structure. Companies may attain an advantage through economies of scale, proprietary technology or having privileged access to the raw materials, for example [7]. Cost leadership defends the company from all the five competitive forces because bargaining will erode profits until profits of the next most efficient competitors are eliminated. The least efficient competitors will suffer first [41].

Low cost producers sell standard, no-frills products and usually emphasize their cost advantage. However, it cannot ignore the bases of differentiation to make the product’s perception comparable and acceptable. Parity or proximity of differentiation must be achieved so that a company may gain above average performance in an industry. Parity allows direct translation of cost advantage into higher profits than competitors. Proximity ensures that the price discount does not offset the cost advantage [7].

One way to achieve cost advantage is by using low-cost design. Traditionally product cost is a consequence of product design, not a requirement. A company may achieve low-cost product design by setting targeted cost as a requirement of equal importance as other critical requirements [40].
A company may also achieve cost advantage through superior manufacturing and economies of scale. Economies of scale occur through high volume manufacturing, especially in conjunction with high fixed costs. A company may achieve superior manufacturing by using highly automated manufacturing instead of a labor-intensive process [40].

Superior supply may be a source of cost advantage. Supply chain consists of materials acquisition, manufacturing, inventory, order management, distribution, invoicing and warranty. These elements in the supply chain frequently become the source of cost advantage [40].

Product development is often one of the biggest cost elements in high-technology products. Since improved product development processes result in significant cost differences, products developed using superior processes may yield a company cost advantage [40].

The globalized product development process and global scale may be sources of cost advantage. The globalized development process results in the ability of a company to simultaneously offer a single product to the world market with the flexibility to manufacture it wherever it costs the least [40].

In order to be able to pursue a cost leadership strategy, a company has to have an understanding of the cost positions of competitors, which is essential in their assessment of their own position relative to their competitors. The systematic framework of cost analysis for making such assessments should not heavily rely on existing accounting systems because this would only interfere with the strategic cost analysis [7].

### 2.5.2 Differentiation

A company develops a differentiation strategy in order to become unique in its industry among the dimensions widely valued by the customers [7]. Ideally the product is differentiated along several of such dimensions [41]. Differentiation depends on the industry and may be based on the marketing approach, the product itself or its delivery system [7]. Differentiation insulates the company from the rivalry due to brand image and customer loyalty, resulting in low sensitivity to price [41].

If the extra cost incurred from its uniqueness is less than the price premium of the product, the company can achieve above-average performance in the industry. However, in order to do so, a company taking the differentiation approach cannot ignore its cost position and should aim at cost parity or proximity by reducing costs unrelated to differentiation [7].

Many companies limit themselves by only seeking a differentiation advantage either in the physical product itself or in the way it is marketed to customers. However,
differentiation can potentially arise in multiple areas, from the use of raw materials or product design to operations or maintenance [7].

Differentiation may be achieved through unique features of the product or even through the strength of a single feature. Products may be differentiated through ease of use, especially in consumer markets. Improved productivity through reduced labor requirements compared to competing products is a potential source of product differentiation [40].

A company may differentiate from others by protecting existing competitive investments, which is achieved by providing compatible upgrades to the existing systems customers own. Lower cost of product failure and total cost of ownership, high performance, superior design, brand name, convenience and providing complete solutions can all be sources of differentiation [40]. Differentiation analysis should be performed in order to identify possible sources of differentiation [7].

2.5.3 Focus

A focus strategy, the third generic competitive strategy, aims at a narrow competitive scope within an industry. A company that takes a focus approach first selects a segment or a group of an industry and then tailors its strategy to serve it at the exclusion of others. The company might not have an overall competitive advantage, but by optimizing its strategy to the target segment, it seeks a competitive advantage within that segment [7].

A focus strategy is subdivided into the cost focus strategy, which is when the company seeks cost advantage within its segment; and the differentiation cost strategy, which is when it seeks differentiation within its segment. Both strategies exploit differences between the target segment and the other segments of the industry. The differences might manifest in a form of unusual needs or different cost behavior. These differences may be exploited whenever broadly targeted competitors serve them poorly at the same time as they serve others [7].

2.6 Competitive Analysis

In order to be able to effectively address competition and deliver a superior product, a company has to undertake a competitive analysis. This includes an understanding of the competitor’s product, its strengths and weaknesses. An understanding of its customers provides insights into the business and its keys to success. Understanding its strategy and how the product fits into competitor’s portfolio gives clues into how competitors will respond to the product launch [28]. Thus, competition should be studied throughout the whole new product development process [14].
Understanding competitors and their products is facilitated through the use of competitive literature and advertising, trade publications, by acquiring the actual product, product road map based on recent product introductions. Trade shows are a good source of information about competitors. Own sales and service people might have information about competitive products [28].

A company may obtain opinions about competition from customers during a needs and wants study. Suppliers may reveal information about competition. Financial sources on the operations, such as annual report, might provide valuable information. Consulting firms specializing in competitive intelligence often have considerable experience and detailed information [28].
3 Product Development Effort

The company started a development effort once it identified an opportunity to develop a mobile industrial metrology solution for large-scale assembly and inspection. In addition, the last new product that the company developed started to become outdated and was failing to meet evolving customer needs. Therefore, the company was in dire need of a new product that would be up-to-date with modern technologies and would satisfy emerging customer needs. It was continuously seeking opportunities through cooperation with its lead users, key customers and partners. Such an interaction facilitated the assembly of a large body of knowledge related to industry inside the company. Feedback, frustrations, complaints, wishes and feature requests were constantly collected from the customers.

The opportunity emerged when a product manager from Leica Geosystems, a partner of AMS, expressed an interest in adding a mobile version of DCP05 to the product line of DCP Solutions. The company decided to start the development effort since the new product fit the product line and also aligned with the company’s strategy. Initially the goal was to implement the functionality of DCP05 on a handheld computer running Windows Mobile operating system. Confidence that the new platform would enable the developers to design an improved user interface with efficient user interaction was the premise to change the platform. A handheld device would also enable implementation of remote wireless communication with the measurement instrument.

After the management decided to turn the identified opportunity into a product it entered planning phase by allocating resources and assigning a core team to the project. The core team consisted of two engineers who are employees of AMS. One engineer has background in embedded software and industrial metrology application and another has background in systems design. The team also consisted of a project manager from AMS and two representatives of Leica Geosystems—a product manager and a technical person—who were responsible for software testing and approval and were a source of marketing information, feedback and overall consulting regarding the measurement instruments. Occasionally a person with background in metrology systems has been involved who was responsible for some of the algorithms inside the software. The team did not have a clearly defined mission statement and the product vision was not communicated to all the team members.

After the development team conceived the new product, it entered concept development phase by jointly establishing specifications of the new product to be developed. The team did not undertake a formal need identification process. Instead, it relied on its experience and assumptions about potential users. The new product was going to satisfy two major needs that according to the team the customers have: the ability to make measurements remotely with greater speed and efficiency, and to conveniently manage the measurement data. The team has not used any formal process to establish specifications. It largely
relied on the design of the old product therefore the initial specifications were essentially the same as the ones of DCP05 except the fact that the new implementation was targeting a different device running a different operating system:

- Configure measurement parameters
- Perform instrument orientation in space
  - Direct Orientation (measure plane, line and origin point)
  - Point Orientation (measure 3 points with known coordinates)
  - Move Station (measure 3 points, move instrument, measure again)
- Load lists of points to be measured
- Aim the instrument at the point to be measured
- Measure point and display measured values
- Display deviations of measured values from the design values
- Make calculations based on measured points
  - Circle fitting
  - Distance
  - Angle
- Special applications
  - Roller alignment
  - Shaft alignment
  - Line setting

The specifications the team initially established were in a form of a feature list and interface displays. Such specifications not only described what the product has to do, they also described the details of implementation. The feature lists, user interface mockups and the prototypes focused on the user interface as a means of communication among the team members throughout the whole process. The specifications have been evolving throughout the development process. New features have been continuously proposed and the scope of the project kept on going.

The team did not perform competitor benchmarking since there were no competitors in the niche the product was aimed at. The team did not use a formal design process either, but instead had a form of iterative and incremental software development process in place. The product has been developed in a series of repeated cycles. During each cycle, the teams planned, revisited requirements and analyzed and tested new features. Each cycle resulted in a prototype that was submitted to representatives of Leica Geosystems for testing evaluation. After receiving feedback, the team started a new development cycle. The iterations kept on occurring until the stakeholders—product manager from Leica Geosystems and upper management of AMS—were satisfied with the result. No prototypes have been developed throughout this phase. Unfinished implementations were used for evaluation purposes. After the implementation reached a state, which was considered to be complete enough by the stakeholders they made a decision to launch the product. Leica Geosystems was responsible for product launch and distribution to customers alongside the measurement instruments it designed and produced.
3.1 DCP Project and Pocket

The development effort undertaken by AMS resulted in the DCP Pocket, which is a mobile large volume metrology software suite running on a fully rugged handheld computer. It is accompanied by DCP Project software, which is a tool to perform analyses and prepare measurement jobs for the DCP Pocket. Together they provide a complete solution for truly large-scale assembly and inspection tasks [12].

The older generation DCP05 is now the low-end product in DCP product line, while the DCP Pocket is its high-end solution. The DCP15, which was previously used for results reporting, has become obsolete. It is replaced by the more advanced DCP Project, which targets the older DCP05 in addition to the DCP Pocket. DCP05 is currently the default software used with the Leica TDRA6000 laser station, and is bundled with every station sold [12].

Other than being a mobile solution, the key difference in the DCP05, the older generation product, is the job-based approach that the DCP Pocket takes by addressing measurement tasks. It also introduces the concept of measurement features used throughout the whole application, whereas the DCP05 operates with points only.

![Figure 9: Coordinate systems and features.](image)

The DCP05 has limited analysis functions and is capable of calculating distances, angles and circles using the measured points. However, every feature is stored in a separate file, making management of measured data a rather complicated process. In order to address that issue, the DCP Pocket stores all the objects used throughout the system in a single file in a hierarchical tree (see Figure 9).
In addition to basic points, the software uses the concept of measurement features to perform measurements and dimensional analysis. The concept of measurement features is a major improvement over DCP05, which operates with points only and has limited possibilities to calculate angles, circles and distances using points only. Measurement features of the new product may either be measured or constructed using other existing features. A point, for example, may either be measured or constructed by using two existing points that create a new point in the middle, two existing lines that create a point at their intersection or three existing planes. Other features can be either measured or constructed in a similar way giving operator greater possibilities compared to DCP05.

Similarly, a line may be constructed by using either two points or planes, or measured using two points. A plane is constructed using three points, or it may be measured using three points or more. A circle is constructed using three points, or it may be fitted into three or more measured points. Angles are measured with three points or constructed using three points, a plane and a line, two planes or two lines. Distance is measured or constructed with two points, a point and a plane or a point and a line.

Point feature is a basic building block for all of the software features. Every point in any feature may be used as a point to construct other features, or to perform distance or angle calculations. The ability to both construct features from points and points from features provides users with a broad variety of possibilities to analyze complex geometries.

The DCP Pocket may also control the dimensions of objects and precisely align them in three-dimensional space. Every point has nominal design values with the ability to set both positive and negative tolerances, as seen in Figure 10. Here, the DCP Pocket compares nominal values to actual values and displays deviations. It can also instantly align objects by displaying deviations in real-time.
DCP Project accompanies the DCP Pocket. DCP Project is a desktop software enabling the user to pre-configure measurement jobs to make measurements and to report the results afterwards. Job files are wirelessly synchronized with a computer running DCP Pocket via Bluetooth.

The combination of the DCP Pocket and Project provides users with substantial value by giving them a tool to perform dimensional analysis on the spot without needing to touch the instrument. Thus, the measurement process is more streamlined and essentially a one-man job.
3.1.1 Example 1: Object Measurement

One of the major customer needs that the product satisfies is the possibility to perform various measurements and analysis of geometrical features of physical objects. In order to demonstrate typical measurement workflow, the operator selects a bucket and measures its dimensions, such as its height and the radii of its top and bottom bases, as pictured in Figure 12. These values may be used later to calculate the volume of the bucket.

![Figure 12: Bucket dimensions to be measured.](image)

Figure 13, Figure 14 and Figure 15 show the steps taken by the instrument operator to measure the bucket dimensions.

![Figure 13: New job is created and circle feature is added.](image)
Only the object dimensions are the subjects of interest, therefore exact coordinates of measured points are not needed. For that reason, measurements are performed in a sensor coordinate system without instrument alignment. The origin of the sensor coordinate system is located in the center of the measurement instrument and all the points are measured relative to it. Leica Red-Ring Reflector (RRR) [44] is used to make the measurements. RRR is a corner cube made of three-sided glass prisms embedded in a steel sphere seen in Figure 15.

![Figure 14: Circle points being measured.](image)

Next, the operator creates a new job on the handheld device and establishes a connection to the instrument. The new circle feature is added to the job (see Figure 13). The circle feature will define the top base of the bucket.

![Figure 15: Points to be measured in order to define top and bottom circles.](image)

The operator sets the offsets of the tool, which are used to place the reflector. These offsets are subtracted from the measured coordinates during the feature calculation. Next, the operator measures points. It is necessary to measure at least three points to define a circle. Measured points of the top and the bottom of the bucket can be seen in Figure 15.
The software calculates circle feature is by fitting a circle into the measured points. As seen in Figure 14 the radius \( R_1 \) of the bottom of the bucket defined by points \( A_1, B_1 \) and \( C_1 \) is 95.66 millimeters. The radius \( R_2 \) top of the bucket defined by points \( A_2, B_2 \) and \( C_2 \) is measured in exactly the same way yielding the result of 141.24 millimeters. In order to calculate the height of the bucket, the operator adds a distance measurement to the job.

Bucket height can either be measured or constructed using existing features. Distance measurement may be constructed using two points, a point and a plane and a point and a line. Since the top and the bottom base circles are already defined, distance is constructed using centers of the circles. As seen in Figure 16, the measured distance is 241.56 millimeters.

\[
V = \frac{\pi h}{3} \left( r_1^2 + r_1r_2 + r_2^2 \right)
\]

**Figure 17:** Circular cone frustum volume equation.

The bucket’s volume may be calculated using the circular cone frustum equation in Figure 17, once the operator has obtained the height and the radii of the top and bottom of the bucket. The volume of the bucket calculated using these measured values is approximately 105.370 cm\(^3\) or around ten liters.
3.1.2 Example 2: Object Alignment

The product satisfies another major need, which is to build and inspect objects in three-dimensional space. Dimensional control is essential in industries such as shipbuilding and aircraft assembly, where large objects have to be aligned and assembled together with high precision.

In order to demonstrate this functionality, a bucket is moved from point A to point B with a precision of 2 millimeters. The center of the top base is used as a reference point (see Figure 18).

Figure 18: Bucket alignment in 3D-space.

Figure 19: 3-2-1 alignment procedure.
The object coordinate system relative to sensor coordinate system is first defined. In order to do so, the instrument has to be aligned. In this case, the operator uses a 3-2-1 alignment (see Figure 19), which requires a plane, a line and a point. Plane defines both the plane itself and the axes that lay on that plane. Line defines the direction of one of the axes, and point sets the origin of the coordinate system.

![Image]

**Figure 20**: Setting tolerances and nominal values for a point.

The operator may use the point set feature to store points of the object. In this case, both negative and positive tolerances are set to 2 millimeters. The set has only one point, which is the center of the top base of the bucket. The point has nominal values assigned, which define where the point should be according to the design.

![Image]

**Figure 21**: Bucket alignment in real time.

Now the operator may begin the bucket alignment process. Actual values of the reference point are displayed in real time and compared to the nominal ones. The device also displays deviations. Once these are within the tolerance limits, the bucket is
considered properly positioned. Displays of misaligned and aligned bucket coordinates are shown in Figure 21.

### 3.2 Development Challenges

Throughout its lifetime, the project suffered a substantial scope creep. The team started developing a mobile version of DCP05, but eventually ended up developing a different product entirely. They added new features after development iterations, and the project scope kept on growing. The development timeline also became longer. As the company was chasing a moving target, the team lost direction of the development.

Furthermore, the company did not directly involve users in the development of the product. The project was kept secret up until the product release. Leica Geosystems provided some feedback after every testing session, but the development team had to develop the product based on assumptions rather than facts about its potential users.

Since users were not involved, the team lacked proper sources of feedback throughout the course of development. User and field-testing were not possible; therefore the team only performed in-house tests. The objectives were to create a streamlined measurement process and usable user interface, but the developers lacked usability skills, knowledge of user interface design principles, awareness of good design practices and usability evaluation techniques.

The team also lacked a centralized collaboration platform. Since the team was scattered around the world, it mainly relied on emails for communication and for receiving the source code, feature list and the testing results report. A team member would take the latest file, modify it and then email an updated version of the file to everyone in the development team.

Nevertheless, despite growing project scope, lack of customer involvement, poor feedback sources and collaboration difficulties the team has encountered the development project was eventually finished. The product was released to the market in July 2012 one year later than initially planned. Even though the product was not a complete failure, after entering the market it failed to reach the expected sales volumes therefore it cannot be considered fully successful.

### 3.3 Competing Products

In order to get a clear idea where a product stands in terms of competition, a company has to study competitive products. This is necessary since their attributes strongly influence the potential success of a new product. A new product also has to be properly positioned in the market in order to minimize the effect of competition.
In the industry of industrial metrology, there are several software suites that provide users with ability to collect, analyze and report measurement data. These suites are PC-DMIS [45] and QUINDOS [46] by Hexagon Metrology, SpatialAnalyzer [47] by New River Kinematics, Metrolog XG [48] by Metrologic Group, PolyWorks [49] by InnovMetric and 3-DIM [50] by GLM Lasermeßtechnik.

Due to different positioning, most of these products are not seen as a direct threat to DCP Solutions. They target wider market segments and various users with different measurement needs. Most of these software packages are rather general industrial metrology applications aimed at various types of industries with one-fit-all approach, while DCP Solutions are narrowly focused on the segment of large-scale assembly and inspection. Moreover, these products require a desktop or a laptop PC to run whereas DCP Pocket is a mobile solution. There are no significant barriers to enter the market of mobile metrology solutions but the relatively small size of the market compared to more sophisticated solutions requiring a laptop makes the competitors uninterested in trying to compete in the niche.

However, one competitor targets the same market segment with the same customers. GLM Lasermeßtechnik has developed the 3-DIM, a solution for large-scale assembly applications, using Sokkia industrial total stations. The software package consists of software to visualize and prepare measurement projects, align structures and report the results.

The product includes a handheld device that is able to control the instrument wirelessly, facilitating a remote acquisition of measurements. In addition, the mobile software has analysis functionality, which performs measured structure analysis on the spot without having to upload the measured values to a computer running the PC software.

However, unlike the DCP Pocket with its feature-based approach to analysis, the 3-DIM is point-oriented software. It functions to measure points using an industrial total station and compares design values to the actual ones. Therefore, in terms of point measurement, it is comparable to the DCP Pocket. The 3-DIM, however, is deficient in terms of possible analyses. While the 3-DIM is able to perform basic calculations such as distances, angles, circles and line intersections, it lacks feature construction, all of which are supported by the DCP Pocket.

3.4 Competitive Advantage

AMS operates in the industry of industrial metrology. The company focuses its product development efforts on those aimed at satisfying the need of customers performing large-scale assembly. Its partner Leica Geosystems distributes the products worldwide along with the industrial total stations and laser trackers it produces.
The DCP05 is primarily targeted at shipbuilding and paper machine industries, in which proper alignment of large structures is essential. DCP Pocket and Project has a much wider base of potential customers, including anyone with the need to perform portable measurements and analysis of a measured structure on a handheld device instead of a laptop.

In this particular industry, the bargaining power of customers is low. The purchase volumes are low since the product has a highly specialized niche. During the first year on the market about 100 licenses of the new product have been sold worldwide. DCP05 has shown similar volume of sales during the past years. The product is highly differentiated and targets needs of a very specific industry. In order to leave the primary competitor, customers would face the high switching cost of changing the vendor of the measurement equipment. The customers are price-sensitive. However, the software constitutes a small fraction of the price of the measurement equipment and other expenses related to it. The buyers’ ability and willingness to backward integrate is low.

The bargaining power of suppliers is low as well. The company uses only one supplier, which provides it with the rugged handheld devices that the software runs on. The supplier does not provide a differentiated product and many substitutes are available at a similar cost. Since most of the other devices available on the market run the same operating system, there are no switching costs. Forward-integration is not a threat, since such a highly specialized industry is outside the interest of a handheld device producer. Due to its low portion, of sales, the supplier does not depend on its industry. Nevertheless, it is well compensated by the other factors.

Threat of new entrants into the industry is rather low due to high barriers to entry. AMS relies on Leica Geosystems to distribute its product alongside the industrial total stations that Leica produces and sells. Due to an exclusive agreement, such a distribution channel would be inaccessible for other companies. The cumulative experience required to design products for such an industry is relatively high. Customers would also face switching costs to retrain employees and build up new procedures.

The threat of substitutes does exist. The main substitute the company is experiencing is the lack of any product purchase at all. Companies might continue using the measurement and alignment techniques it is currently using, often making the measurements and managing results manually by simply writing them down on a piece of paper. This occurs if the perceived value of the new product is not high enough to justify the switching cost, which is always present due to disruption and potential reconfiguration [7].

Existing rivalry in the industry is moderate. A number of industrial metrology software suites exist, but most of them are PC-based solutions requiring at least a laptop computer to operate the measurement instrument. A rival with a handheld solution exists, providing customers with similar benefits. The companies do not directly clash with each
other since AMS products are distributed with Leica total stations, while GLM products are distributed with Sokkia total stations.

The company adopted a focus strategy to address the five forces of competition. It chose a market position in which the strengths of these forces are the lowest. The company focuses on large-scale assembly applications, which has a rather small market with special customer needs. The market size is too small for big players, so it is outside of their area of interests. The customers in the segment have peculiar needs that the company is good at satisfying by providing a differentiated product.

### 3.5 Practices Assessment

In order to assess new product development practices at AMS and the environment that the products are developed in, the author conducted a survey inside the company. The aim of the survey was to benchmark the methods, techniques and processes the company is employing as well as the general attitude towards the importance of new products as part of the long-term strategy of the company. The author conducted the survey in the form of a series of interviews of the members of the team who were involved in the development of the new generation of DCP software. Upper management of the company was interviewed as well. The interview questions were taken from the audit developed by Barczak and Khan [30]. However, no scores were assigned to the answers. The author took qualitative approach to method evaluation comparing company’s practices to the best practices described previously.

The audit developed by Barczak and Khan [30] consists of a set of 100 questions to serve as a basis of current practice assessment. They recommend conducting the survey among employees of different backgrounds, representing a broad cross-section of company staff. Questions of the survey have three possible answers: ‘no’ with a score of -1, ‘partially true’ with the score of 0 and ‘yes’ with the score of 1. The survey results lies on a scale from -100 to 100, where a result on the negative end means non-existent new product development process and a result on the positive end means exceptionally technically perfect process. This audit allows the company to assess its current practices against the seven dimensions of new product development: strategy, research, commercialization, process, project climate, company culture and metrics and performance measurement. Such an audit may be used to identify the gaps between current practices and best practices, and enables a company to close those gaps.

AMS has a company-wide long-term strategy. They consider innovation and new product development to be essential to both their survival and in order to keep a favorable market position by retaining a competitive advantage. New product development constitutes a considerable part of the long-term strategy of the company. Potential opportunities that could be pursued are continuously identified. The company has new product development goals and focus. These goals and focus narrow down the opportunities they consider and balance the company product portfolio. They select and
prioritize the projects they pursue according to them. They also distribute resources in accordance with project priorities. All the undertaken development effort fits the overall company mission.

However, the company strategy and goals are not clearly defined and visible to all of its employees. These are considered to only be a concern of senior management; therefore it is not communicated throughout the company. The company does not have a formal strategic planning process or a formal portfolio management process to manage its products. All the decisions relative to strategy and product portfolio management are made informally.

The company studies the needs of current users and potential customers. It tests some concepts with potential users prior to implementation, but does not employ a formal process. Such studies are part of the product development process, though the company does not have a separate formal budget dedicated to research. Without any formal process in place, the company considers market size potential and their competitive situation prior to commencing the new product development effort. Thus, market research and marketplace study results do not undergo formal evaluation and are not readily accessible by development teams.

Commercialization dimension is irrelevant, therefore cannot be assessed. This is because the company is not directly involved in product launch and does not have a product launch plan or a product launch team. Company’s partner, Leica Geosystems, is responsible for new product launching and distribution.

AMS does not use a formal documented new product development process. Nevertheless, the company follows a certain development process, but it is not well defined. They evaluate new product development projects throughout the process, but the criteria are not specific. The ‘go’ or ‘kill’ criteria are neither clear nor pre-defined. The process that the company adheres to is flexible and varies from project to project according to its needs, size and risk. The employees understand the process used to a certain degree and the discipline is relatively well maintained. However, the process structure is not clearly visible to its employees. There are no endeavors of the senior management to structure the process and make it well defined. The management considers a formal process to be an attribute of large enterprises only.

A project manager is assigned to each project, and is responsible for tracking the development process. The company provides employees with a supporting infrastructure that is accessible to everyone. However, the team lacks convenient collaboration tools in the absence of which productivity might suffer.

The company features a climate conducive to new product development project work. The group responsible for new product development is identifiable and the members of the core team work on projects from beginning to end. The members assigned to the development team are carefully assigned. The group is dedicated to new product development work only. The leader of the group managing the development project is
clearly identifiable. The group cannot be considered cross-functional, due to a lack of members with different functional expertise.

AMS senior management considers new product development to be a high priority, thus they provide all necessary resources to facilitate it. The management encourages various sources of new ideas that could potentially arise from exterior sources. Furthermore, they encourage open innovation and risk-taking. Knowledge is commonly shared throughout the company. The company works with its customers to identify new product opportunities and develop new products to a certain degree. However, the customers are not directly involved in the product development process.

AMS does not formally assess the performance of its new product development efforts. The overall performance of development effort as well as performance of individual projects are somewhat assessed, but this is mostly achieved through informal evaluation. There are no specific metrics defined to facilitate project decision-making. There is no formal performance measurement effort in place tracking and storing performance data. Furthermore, there is no precedent of projects being killed before their completion.

Eventually the company managed to develop a unique superior product despite the budget overruns, the problems encountered along the course of the development process and the late product delivery to the market. This product was still unique upon its release to the market. The company highly differentiated the product from the rest of the products in the industry. Unlike the rest of the similar products, it runs on a handheld device and provides user with a tool to measure, analyze, inspect and control dimensions on the spot without the need of a desktop or a laptop computer.

The product focuses on a particular industry segment; satisfying peculiar needs of its customers better than products and companies targeting wider segments and applications. It provides good value for money to the customer by increasing measurement process efficiency, simplifying management of measured data and providing advanced analysis functionality compared to the previous generation solution. The main benefits are important to users; however, the company did not place enough emphasis on signaling the product value to potential buyers.

The streamlined measurement process is attributed to an improved user interface and the possibility for a single operator to make measurements. Also, operators may now analyze complex geometries using features and feature construction, which can either be preconfigured or executed on the spot using a handheld device. All of these changes reduce labor and training costs. Other solutions lack such an advantage because they involve a fully-fledged computer in the measurement process. The functionality is also superior to the only product competing in the same narrow segment of large-scale assembly solutions market.

The product has a certain degree of market and customer orientation. However, no formal market research or user studies were undertaken prior to the development effort start. Neither was the competition thoroughly studied. As a result, the development team
constantly changed the specifications, as they were initially unsure of what kind of product was needed. The company relied on its experience and assumptions about the potential users of the product. The company did not carry out thorough predevelopment work, which would have established sharp and stable specifications early in the process. The definition of the product changed constantly throughout the development process, resulting in substantial project scope creep.

Also, a number of expensive redesigns took place later in the project. The team initially developed a port of the older generation product to a new platform, but eventually ended up with a different product. They later added features that were not considered earlier in the process, increasing the development cost and lengthening the development timeline far beyond what was initially planned. Unstable product definition turned out to be a major time waster during the development process.

The development effort targeted global markets and the product was designed having them in mind. The company employed a transnational team and the development has been done with an international partner having international customers in mind. The product is on the domestic market as well but no adaptation or customization is made. The product was initially designed as a global product.

During the development process, the company leveraged existing competences and developed the product based on its team’s experience working for many years in the area of large-scale assembly. Even so, the company decided to adopt a new platform that was unfamiliar to the development team. The team also lacked any user interaction and usability skills, therefore the development of such a product turned out to be challenging.

The company considers the product’s target market to be attractive. The market size is small and the biggest competitors in the area of industrial metrology are not interested in entering it. However, the company satisfies a strong need for a tailored solution. The company managed to establish a favorable position in the market relative to its competition.

There is barely any existing rivalry with relatively low supplier and customer bargaining power. The threat of new entrants is low due to high barriers to entry. The company secured the distribution channels for its products that are not available for their competitors. It also has substantial experience of its market segment gathered over time.

The company does not have a portfolio management method in place. They select which products to pursue based on assumptions, intuition and experience, although the company typically does not pursue many development projects simultaneously and the overall number of products is rather small. Nevertheless, a strategy based portfolio management system is considered to be a success factor. Such a system would allow a company to select product ideas that are aligned with company’s strategy. The company does not have a formalized strategy that it communicates to everyone and it does formally evaluate the strategic fit of potential projects that it might pursue.
The company occasionally suffers from a lack of available resources, but this is not caused by poor workforce distribution. It is rather the size of the company itself and its technology-orientated nature, despite designing products that involve a substantial degree of user interaction. Inadequate resources are allocated to the predevelopment phase, in which crucial user studies and market research should be carried out. Lack of time and allocated resources result in insufficient market and user orientation and companies lose a sharp and stable project with product definition.

The company has managed to establish a favorable position in the market, which it targets with its product. The niche it occupies is outside of interest of other players due to being too small. Nevertheless, the niche is big enough for a small company like AMS of 2 to 5 employees involved in product development at different times and yearly brings around 200 000 € in profit. As a result of the favorable position somewhat deficient new product development practice and lack of a formal development process nevertheless result in a successfully commercialized new product.

In order to improve its process and reduce the risk of unaccounted-for project scope creep the company should focus more on the predevelopment work. The past experience of the company has shown that attempts to save time during the research phase results in expensive redesigns later during the new product development process. Expensive redesigns caused more time and resources wasted in the end than saved in the beginning. Therefore the company should invest into the predevelopment phase including market research, business analysis and early prototyping rather than immediately rush into product development. Predevelopment phase should result in sharp and stable product definition. Customers should be more involved in the development process in order to improve customer-orientation of the product. The process itself should be more formal and collaboration tools should be used more in order to improve communication between team members working from different locations.
4 Conclusions

Globalization introduces both new competition as well as new opportunities. Thus, in order to remain prosperous and ensure its survival, new product development is an essential long-term strategy for every company. This development effort helps combat the conditions of a changing business environment in which markets evolve, new customer needs emerge and customer demands increase. Moreover, a substantial part of every company’s revenue typically comes from newly developed products.

Many companies pursue this strategy as a means to cope with evolving markets and increasingly fierce competition. Tens of thousands of products are developed, marketed and released every year. The processes of new product development and the practices employed by the best performing companies have been researched for the last several decades.

Nevertheless, most companies’ new product development strategies still fall short. On average, roughly one third of new products tend to fail. However, research has shown that despite high failure rates, the overall new product development processes employed by companies have improved over time.

Studies of practices employed by best performing companies reveal that having a sound well-defined strategy communicated throughout the company contributes to the performance of new product development. The strategy should be defined at an early stage and adhered to throughout the whole development process. A strategy may provide focus and prevent the company from going off-track.

Predevelopment work is essential to new product success. The project should be thoroughly evaluated before development commences. Markets and users should be thoroughly resourced. Technical feasibility should be evaluated and a business case should be built. Performing thorough predevelopment work is crucial to the product success.

A disciplined and structured process positively affects the development performance. It has also been proven that having a complete, consistent and properly executed new product process highly influences time-to-market of the product and overall company profitability. All of the process steps should be followed with consistent effort at all phases. Doing any one single phase better does not contribute to product success.

In order not to waste scarce resources, companies should continuously evaluate projects and discontinue the ones with low odds of success. The process itself should be evaluated and adapted. Market launch should be considered an integral part of the development process and not as an afterthought. Strategic planning should be completed up-front and a launch plan should be in place.
A positive project climate and unobstructed communication positively impacts a team’s performance. Cross-functional teams prove to be the best at developing new products. Teams should have a certain degree of autonomy, have an identifiable team leader and stay on the project from the beginning to end. Collaboration tools enable teams to be more productive. Company culture should encourage creativity, entrepreneurialism and risk-taking behavior. Senior management support is essential to product success.

In order to succeed, a company has to develop a unique superior product with benefits important to customers. It should be superior at meeting customer needs and have superior quality compared to its competitors. Developing such a product is the most critical success factor. The developed product has to be market-oriented and customer-focused. It should also be oriented to an international market from the very beginning.

A sharp and stable project and product definition must be set early in the development process to guide the team and reduce the effects of potential scope creep. Being first to the market has a competitive advantage, but such a strategy should not be pursued at the expense of the product quality.

A company should leverage existing core competencies and develop products using existing capabilities. It should also target attractive markets in which the company may have a competitive advantage. It should not resort to entering unfamiliar markets in an attempt to keep the odds of success high.

Necessary resources should always be in place in order for the project to have a high chance of success, as underfunded projects tend to fail. In order to efficiently distribute available resources among the more promising projects, an effective portfolio management system should be utilized.

4.1 AMS Approach

When compared to the best performers, the practices AMS employs are far from being perfect. First of all, the company does not employ a formal product development process. Its informal process is not well defined, documented or consistently executed.

The company does not do proper predevelopment work. They do not thoroughly research markets and customers or properly elicit customer needs. The company cooperates with its main customers and lead users, but this cooperation does not have a structured form. Customers are not directly involved in the development process. Concept testing does not occur prior to development. The company develops concepts into a product feature and then tests it at a later stage. Such an approach results in expensive redesigns late in the process.

There is neither a formal evaluation nor a formalized strategy in place. Senior management has a strategy in mind but it is not communicated throughout the company.
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It does not utilize portfolio management, so decisions to pursue products are based on assumptions and intuition. The company is technology-oriented, so it pursues mainly the activities on the technical side rather than the marketing side. The development team is not cross-functional.

The recent product development effort suffered a substantial scope creep due to lack of sharp and stable project and product definition. The team did not perform substantial predevelopment work. The markets and users were not thoroughly researched and the project was not properly planned. The team rushed into its development and ended up chasing a moving target. New features kept emerging and project scope was growing. The initial budget and timeline estimations were inaccurate and as a result, the project suffered budget overruns and it was late to the market.

4.2 Recommendations

It is recommended for the company to take a more formal approach to all aspects of new product development. The company strategy should be well defined and communicated with all of its employment levels. In order to effectively select which projects to pursue, the company may employ a portfolio management system that would help them to effectively pursue projects aligned with its strategy and to allocate resources.

In order to avoid project scope creep, the company is recommended to emphasize predevelopment work even more. Customers and markets should be thoroughly researched and the developed product should be sharply defined. It is impossible to avoid the evolution of product specifications throughout its development, but the negative effects of scope creep may be minimized when the most possible information is available prior to the start of the development process.

In order to be able to better satisfy customer needs and produce usable products, the company should make customer and market-oriented products. Involving potential customers directly in the development process proves to have a positive effect on the product success. The company should take greater advantage of various prototyping techniques and thoroughly test various prototypes prior to making full implementations. In this way, most project changes, such as the introduction of new features, will emerge earlier in the process when the price of change is at its lowest.
5 References


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