The Internet of Things; The Next Big Thing for New Product Development?

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More and more physical products have sensors embedded in them and are able to connect to the internet. This network of 'smart products' is known as the Internet of Things. These products create large amounts of data (smart product data) that can provide insight in the product's environment and use context. Although this data is expected to be of great value for businesses, it is not known how the input of this data affects the key success factors of product innovation in a business context. This research studies how the input of smart product data in the New Product Development process affects the key success factors of the process, namely (1) maximized fit with customer requirements, (2) minimized development cycle time and (3) controlled development costs. By means of a literature study, an expert study and an interview with PostNL, this study was able to identify how the input of smart product data affects the success factors of the New Product Development process. Both the literature ad experts agree that smart product data will help maximize the fit with customer requirements by providing extensive customer insight. In addition, the cycle time of the new Product Development process will most likely decrease, according to the literature and experts. However, opinions were more divided about the effect of the input of smart product data on cost control. This opens up questions for further research.

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1. INTRODUCTION

The ‘Internet of Things’ is a booming topic of discussion. It entails the idea of an extensive network of physical objects that contain sensors and are connected to the internet. Such sensing, connected objects - also called 'smart products' - are able to retrieve, store and share large amounts of data. Because of the sensing abilities of these smart products, this data can provide an insight in the product's environment and use context.

The concept has been around since the late 80’s, but it seems that the technology is finally ready to make it a reality. With the improvements in processing power, device miniaturization and network benefits of ubiquitous wireless connectivity, the Internet of Things is growing faster than ever before. (Porter & Heppelmann, 2014) It is expected that the amount of smart products will soon overtake the amount of connected individuals. Bauer et al. (2014) predicts that up to 30 billion objects will be connected by 2020. This rapid growth of smart products and their accompanying data flows will not leave businesses undisturbed. Businesses are already continuously challenged to keep up with technological advances. With the Internet of Things as the next wave in the development of the internet and a new source of large amounts of data, businesses face new opportunities as well as new challenges. (Porter & Heppelmann, 2014)

Although many have discussed these opportunities and challenges, none have discussed in detail their effect on the vehicle of innovation within businesses: the New Product Development process. It is not known what effect the various opportunities and challenges can have on the actual success factors of this process, namely (1) maximized fit with customer requirements, (2) minimized development cycle time and (3) controlled development costs. (M.A. Schilling, 2013)

Therefore, this research will study what effect the input of data retrieved from the Internet of Things has on the success factors of the New Product Development process.

1.1 Problem Definition

In order to structurally identify what effect the input of data retrieved from the Internet of Thing has on the success factors of the New Product Development process, the following question has been created:

- **How does the input of data retrieved from the Internet of Things affect the success factors of the New Product Development process?**

This research question will be answered with the help of a set of sub-questions. These subquestions are derived from the success factors mentioned in the previous section. They allow for a structured and detailed answer on the main question:

- *Does the input of data retrieved from the Internet of Things in the New Product Development process help maximize the fit with customer requirements?*
- *Does the input of data retrieved from the Internet of Things in the New Product Development process help minimize the development cycle time?*
- *Does the input of data retrieved from the Internet of Things in the New Product Development process help control development costs?*

1.2 Academic Relevance

Although many New Product Development theories appeared over the years, none of them related them to the rapidly growing digitization of the external environment of businesses. With the Internet of Things as the upcoming and possibly disrupting internet development, it is valuable to study how the availability of large amounts of data retrieved from the Internet of Things influence the success factors of the New Product Development process. Certainly, given that this data can provide environmental and contextual insight of products to businesses.

1.3 Business Relevance

Businesses continuously need to keep up-to-date with the latest technologies in order to stay competitive. The Internet of Things looms as a game-changing technology for many industries. However, without any specific research done, businesses cannot be sure how the Internet of Things affects the key success factors of their New Product Development process. This research will offer businesses an overview of the effects on these success factors. With this overview, businesses can prepare for the Internet of Things, knowing which success factors of the process will either benefit or be challenged by the Internet of Things. Wether it be customer insight, cycle time or cost control.

1.4 Method

This research will start off by providing a basic understanding of the Internet of Things in chapter 2. Chapter 3 will provide an understanding of the New Product Development process. The general process is explained alongside with a deeper insight in to the success factors. Chapter 4 consists of a literature study, an expert study and an interview with Aimée van Nunen, a business consultant for the IT Production department at PostNL.

Articles in the literature study originate mostly from consultancy firms and research departments from businesses and nonprofit organizations. This is due to the fact that the concept of the Internet of Things has only recently grown in popularity, despite the fact that it has been a concept since the 80’s. The literature study will point out the similarities and discrepancies between the positions of the articles on the sub-questions.

The expert study will consist of directors and managers of businesses that involve Internet of Things in their processes or offer Internet of Things solutions, professors that are involved in the Internet of Things and researchers that study the field of Internet of Things and Business. They will be asked to give their opinion and foresights on the effects of Internet of Things on the New Product Development process, based on their expertise and experience. Three questions are created that are based on the three success factors of the New Product Development process:

- *What effect do you expect the Internet of Things to have on the ability to match customer needs in the New Product Development process?*
- *What effect do you expect the Internet of Things to have on the speed of the New Product Development process?*
- *What effect do you expect the Internet of Things to have on the costs of the New Product Development process?*

Lastly, the interview with Aimée van Nunen will be in an informal format. The questions presented above will be used as guiding questions, alongside the question of how PostNL is currently implementing the Internet of Things for product development. This interview will function as a complementary insight to the expert study.

Once all results are discussed, they will be summarized in Chapter 5 and a conclusion will be made by identifying trends and discrepancies. Chapter 6 will first describe the limitations of this research and then elaborate on the research gaps in the found results. Suggestions for subjects for future research will be given alongside with suggestions for better research design.

2. INTERNET OF THINGS

The ‘Internet of Things’ is the agglomeration of physical objects that have a variety of sensors and are (inter-)connected through an internet protocol. Such a 'smart product’ is characterized by seamless ubiquitous sensing, data analytics and information representation with cloud computing as the unifying framework. (Gubbi & Buya, 2013)

Porter & Heppelmann (2014) state that it is the combination of physical components (hardware), smart components (sensors, software and data analytics) and connectivity (wired or wireless connection) that allows for continuous value improvement. The smart components enhance the capabilities of the physical product, whilst the connectivity components enhance the capability of the smart components. Connectivity gives smart product both the ability to exchange information between the product and its environment (whether that is its user, the manufacturer or other smart products) and the ability to offer functions that exist outside the physical device. Such functions exist in the product ‘cloud’. (Porter & Heppelmann, 2014)

An example is the increasingly popular idea of a 'smart watch'. Such a watch exists of the physical components of a traditional (digital) watch, but has built in sensors that can, for example, measure each movement that you make with he help of an accelerometer[1]. The data created by this sensor can be stored in the cloud trough an internet connection. With the help of data analytics, the amount of movements can be translated in to the amount of exercise. The user can now check their amount of exercise in a day on their phone, tablet, computer or other devices with access to the smart watch 'cloud' trough the internet. Users that are on an exercise schedule for example can now check if they have reached their exercise goals. It can even be taken one step further by letting the smart watch 'cloud' provide dietary suggestions based on the amount of exercise someone has had that day. Note that this integrated service would not have been possible without the smart components or connectivity components in the smart watch.

2.1 Big Data

Smart products retrieve large amounts of data through their sensory abilities and add this data to the digital environment through their connectivity. It is expected that by 2020 the Internet of Things will account for 10% of all digital content, which is estimated to be a total of 44 zettabytes (44 trillion gigabytes) by that time (Turner et al., 2014).

The data that the Internet of Things produces contributes to so called ‘Big Data’. Big Data is defined by data that is created in high volumes at a high velocity (real-time or nearly real-time) and in a variety of forms (e.g., text, images, sensor data). (McAfee, A. et. al, 2012) As Bauer, Patel & Veira (2014) reported, it is estimated that up to 30 billion products will be labeled as ‘smart’ by the end of 2020. This large amount of products will evidently create high volumes of data that will come in a diversity of forms (text, video, image, sound , etc.). Diwanji & Verma (2015) state that typical data retrieved from smart, connected objects contains information on the product's design, usage, operating environment, maintenance history, customer preferences and resource consumption.

Lastly, due to the connectivity of smart products, this data will generally be retrieved, stored and shared in real-time. With these characteristics it is safe to say, that the Internet of Things will contribute to the Big Data trend.

Many businesses have discovered the value of Big Data. Within the large amount of unstructured data lie valuable insights that can help businesses increase their competitiveness. (Manyika, 2011) One main condition however, is that businesses need to be able to handle such data. This is done through data analytics. Platforms like 'Hadoop' make is possible to aggregate and summarize data and visualize trends. It is up to the business to transform these trends into insights, and insights in to action. In the end, value can only be created trough concrete action. Rajpathak & Narsingpurka (2013) state: "The challenge for Big Data analysts is to develop techniques and algorithms that are intelligent enough to read and analyze this data to extract right information to aid in the product development process."

2.2 Scope

The data that can be retrieved from smart products will henceforth be called *smart product data*. Note that this smart product data can be sourced from products used by consumers as well as e.g. manufacturing equipment used during the New Product Development process. This means that data can be created inside and outside of the New Product Development process. This research will assume that smart product data is retrieved from external sources. That is, from smart products that are already in use by consumers. In case smart product data comes from an internal source (data retrieved during the process), this will be specified in the text.

3. NEW PRODUCT DEVELOPMENT

The New Product Development process is a vehicle of (product and service) innovation within businesses. Innovation in this context is defined as ‘the process of making changes to something established by introducing something new that adds value for the customer.’ (O’sullivan & Dooley, 2009) The New Product Development process is defined as the firm’s complete process of bringing a new product or service (hereafter referred to as ‘product’) to market. This can involve a physical product, but also a digital product (e.g. software and websites) or even an interactional product (e.g. services).

It is important to note here, that a new product can be interpreted in different ways. Booz, Allen & Hamilton (1982) have defined six types of interpretations of what a ‘new product’ can entail:

- New-to-the-world products
- New-to-the-firm products or new product lines.
- Additions to existing product lines.
- Improvements and revisions to existing products.
- Repositioning of an existing product (line).
- Cost reductions through design or process innovation.

The list proposed above can be interpreted as a continuum of radical innovations to incremental innovations (from top to bottom). Crawford (2008) states that the success of a new product is largely based on the value that is added to the customer. He adds that about 60% of newly developed products (over all categories) will be met with success (that is, with at least a break-even of costs and profits).

In addition, Crawford states that the failure rate for new-to-the-world products is naturally higher due to high levels of uncertainty throughout the development process. However, this product category does often reap higher profits than other categories if successful.

[1] An accelerometer is a sensor that measures changes in acceleration forces. By registering these changes, the sensor can sense if it is being tilted or moved with respect to a certain position. (Goodrich, 2013)

The New Product Development process is not set in stone. Many models have been created that vary in stages and terminology. Murthy et al. (2008) states that these variances can be explained by their context, such as the type, innovativeness and complexity of the products in question. However, the stages and interpretations of the terminology are often very similar. The BAH model created by Booz, Allen and Hamilton (1982) (hence the abbreviation 'BAH') and the stage-gate model created by Cooper (1990) will be used to illustrate this similarity. These two models are widely accepted in the New Product Development field.

The 7-step BAH model, functions as the base of many later models (figure 1, larger version in Appendix A.).

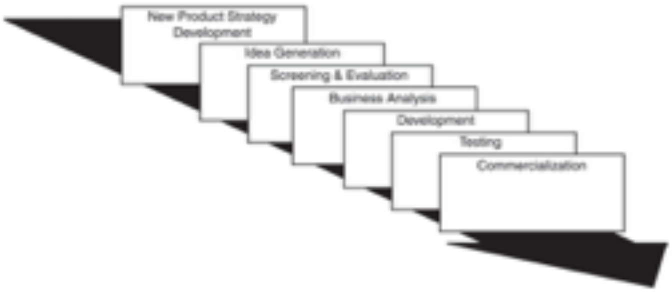

Figure 1. BAH model , source: Booz, Allen & Hamilton Inc. (1982)

The BAH model exists of seven stages, starting with *new product strategy development followed by idea generation, (idea) screening and evaluation, business analysis, development, testing* and *commercialization*.

In addition, Cooper's stage-gate model is seen as a major contribution in the New Product Development field (figure 2, larger version in Appendix B.).

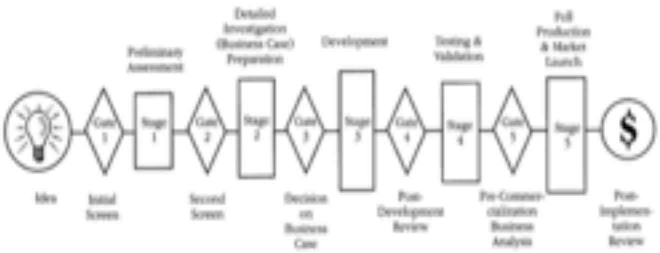

Figure 2. Stage-Gate model, source: Cooper (1990)

This model exists of five stages that are in their content very similar to the stages of the BAH model. Given that the process starts off with a new idea, the stages are: *preliminary assessment, business case, development, testing and validation* and *full production and launc*h. (Cooper, 1990) The added value in Cooper's model consist of the so called 'gates' between each stage. A gate functions as a go/no go decision after a certain stage. These decisions are based on predetermined deliverables and their criteria. These gates ensure that there are regular evaluative moments within the process that reduce uncertainty and risk in each consecutive stage.

Traditionally, the first stages (up until *business analysis* or *business case*) are less formal than their consecutive stages. This makes the front end of the New Product Development process typically chaotic, unstructured and unpredictable. The ideation phase is therefore often called the *fuzzy front end* of the New Product Development process. (Koen et. al., 2002)

Once uncertainty is reduced enough to create a clear project outline, the product will be developed trough prototyping, testing and validation activities, until a product design is reached that is ready for launch.

The last stages (*commercialization* and *full production and launch*) include all production, marketing, sales and distribution activities that are needed to bring the product to the customer.

3.1 Success factors

The speed, efficiency and effect of the new product process are believed to largely determine a firm's success (Schilling, 2013). Schilling translates this to three key success factors for the process: (1) maximized fit with customer requirements, (2) minimized development cycle time and (3) controlled development costs.

A new product or service will naturally be more successful if customer requirements and customer needs are met, even if these are not always known by the customer himself. Schilling (2013) identified several pitfalls for firms in trying to figure out these requirements and needs. Firstly, customer requirements and needs are not always known to the firm. In addition, firms might not always have a clear image of which of the known requirements are most valued by the customer. This can result in products that do not meet requirements enough or at all. Another pitfall is the overestimation of the customer willingness to pay for a certain feature, resulting is over-priced products. Lastly, firms can struggle with the difference of requirements by different customer groups. Firms must be cautious not to carelessly compromise between certain features when trying to meet the demand of both groups, as it might result in a product that does not appeal to either of those groups.

The second objective revolves around the speed with which a product is launched on the market. Early market entry could give a firm various advantages, such as building brand loyalty, gaining access to scarce resources and building customer switching costs. Short development cycle times also allows firms to quickly update and upgrade their products if needed. (Schilling, 2013)

However, firms must take care to only launch products that are validated. Bringing underdeveloped, or maldeveloped products to market just to be an early entrant could have a backlash on brand reputation and customer loyalty. (Dhebar, 1996) It also depends on the type of product if speeding to market is of high priority. Krubasik (1988) argues that products with high opportunity costs and low development risks should have a higher priority to decrease cycle time, but products with low opportunity costs and high development risks should prioritize making sure that the product is fully validated before launch.

As for controlling costs, development costs can run high if firms solely focus on quality and speed. Given that the development process involves a certain opportunity risk, firms must strive to keep costs in control. The development process costs must be recoupable, even if the product is well received by the market. (Schilling, 2013)

Crawford (2008) states that in a typical New Product Development process, costs increase with each consecutive stage. Costs and time (per activity) are typically lowest at the beginning of the process. Crawford points out that it is therefore the goal to decrease uncertainty with each stage, so that investments in the next stage are well-grounded and less risky. Investments (of finances and resources) increase as the process proceeds. As for the objective to match customer requirements, customer requirements are generally used as a major input at the beginning of the process, during the ideation stage.

3.2 Scope

The types of product innovations mentioned by Booz, Allen & Hamilton (1982) vary in their novelty. This links with the continuum of radical innovation to incremental innovation. Radical innovation is known to be hard to manage, due to the large amounts of uncertainty (Crawford, 2008). Given that the process around radical innovation is not fully understood yet, this research will focus on incremental product innovations. Although it is a continuum, the following types of product innovations are here considered to be incremental enough to be sufficiently managed with the New Product Development process described in the previous section, and see the most opportunities in combination with the Internet of Things :

- additions to existing product lines
- improvements and revisions to existing products
- repositioning of an existing product (line)
- cost reductions through design or process innovation.

Also, for the sake of this research the New Product Development process will be assumed in an abstracted form (figure 3). This is done because it makes it easier to refer to an estimated phase of the New Product Development process or illustrate changes in the process without implying specific effects to a certain stage[2]. After all, this research will study the effect of smart product data on the success factors of the process, and not its specific stages. The abstracted form will therefore safeguard this research from making statements about any specific effects on a model that may not be validated trough this research.

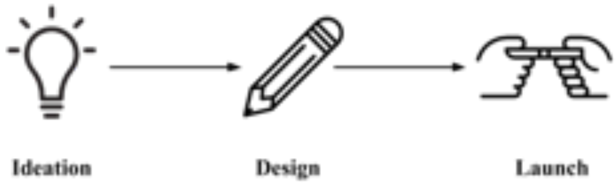

Figure 3. Abstracted version of the New Product Development process.

In the abstracted form, the New Product Development process is reduced to three stages: ideation, design and launch. Looking back at the two models explained at the beginning of this chapter, each of their stages can be fit in to one of the three phases of the abstracted model. The ideation phase includes the following stages of the BAH model: *idea generation, idea screening* and *business analysis*. The stages from the stage-gate model that belong to the ideation phase are: *discovery, scoping* and *business case*.
The design phase encompasses the *development* and *testing* stages of the BAH model, and the *development, testing and validation* stages of the stage-gate model.
Lastly, the launch phase includes the *commercialization* stage of the BAH model, and the *full production and launch* stage of the stage-gate model.

4. SMART PRODUCT DATA IN THE NEW PRODUCT DEVELOPMENT PROCESS

This chapter will discuss what effect smart product data will have on the three success factors of the process, according to literature and experts (under which the interviewee).

4.1 Maximizing the fit with customer requirements

It is not hard to imagine how the availability of smart product data can attribute to a better understanding of the customer. Diwanji & Verma (2015) state that "by using data and analytics, companies can now see and predict a product's behavior and, by extension, the wants and needs of its user by interpreting the data and anticipating how a product could solve current and future needs."
The following sections discuss these opportunities in more detail as well some expected challenges by means of four subcategories: iteration, micro segmentation, continuous product improvement and increased complexity.

4.1.1 Iteration

Various pieces of literature discussed the opportunity to use smart product data in the iteration loop from launch to ideation. This means that smart product data from already launched products, or past development processes can be used to improve the quality of future development processes and their subsequent products. This process is illustrated in figure 4.

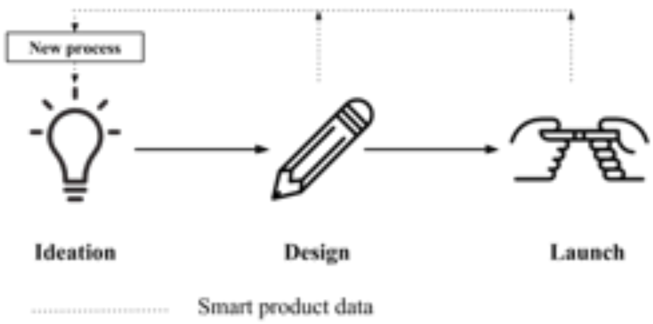

Figure 4. Iteration loop of smart product data

Rajpathak & Narsingpurkar (2013) state that today's top manufacturers use data from warranty claims, quality testing and diagnosis as feedback to New Product Development processes. They analyze and identify correlations from this data to eventually develop better products. The most modern sources of information include customer feedback on social media and sensor data. (Note that sensor data is a large part of smart product data) According to Rajpathak & Narsingpurkar, organizations that have embedded IT and Big Data analytics are using this information to improve product design, product quality, cost reduction and customer satisfaction through data-driven decision making and processes. They give the example of a telecom equipment manufacturer that increased its gross margin with 30% in 2 years by eliminating costly features that weren't of value to the customer and by adding features that were of a greater relevance to the customer, and for which the customer was willing to pay a higher price. By using enriched data (i.e., sensor data) as a feedback input in to each New Product Development process, this manufacturer increased the fit with customer requirements by offering more relevant products and better understanding their willingness to pay.

[2] Note the subtle difference between the interpretation of the words '*stage*' and '*phase*'. *Stages* assume clear transitions in between them, whereas *phases* assume more gradual transitions.

Diwanji & Verma (2015) exemplify the use of smart product data in pharmaceutical companies. According to them, many pharmaceutical companies are already trying to optimize manufacturing processes for new products by using data from various phases from previous processes in new processes. By doing so, they can identify success formulas or 'golden recipes' that have proven to 'work' before. This supports the notion of Rajpathak & Narsingpurkar that integrating data in the iteration loop can help businesses create a better fit with customer requirements.

4.1.2 Continuous product improvement

Continuous product improvement seems very similar to the iteration loop as discussed in the previous section. However, in this case, continuous improvement is interpreted as increasing the value of an existing product during its own lifecycle, instead of improving future products. This process is illustrated in figure 5.

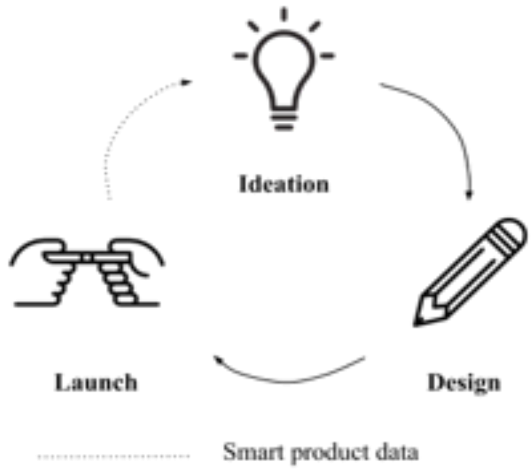

Figure 5. Continuous product improvement

Manyika (2014) argues that smart product data can allow products to become better while in service. Instead of depreciating in value, products can now grow in value during their own life cycles. IBM Analytics (2014) supports this notice. They state that smart products can receive remote software updates based on analysis of smart product data. IBM Analytics adds that this data can help inform decisions about changes in design, performance, reliability or new features.

An example from practice is how Tesla sends regular updates to its cars, offering new features and improved performance to its customers. The model X and S cars for example, are now sharing data with Tesla in order to improve the autopilot feature. This feature was introduced in October 2015 through a software update and is expected to improve in the coming years with the help of the collected data from the cars itself. Users won't need to buy a new high-end car, but simply have to update their software to enjoy this feature. (McHugh, 2015)

4.1.3 Micro segmentation

Another opportunity that is widely supported is that of micro-segmentation. Rajpathak & Narsingpurkar give an example of how smart product data could help identify the needs of specific customer groups. They discuss the field of automotive OEM's, in which there is talk about fitting vehicles with sensors that are able to track the performance of the vehicle and the driver. These sensors provide product development teams with real-time performance and failure data and allow them to convert it into useful insights in the specific requirements of different segments. For example, driving behavior and road conditions differ across countries. By analyzing these differences a single car model can be tuned to fit multiple international markets. The opportunity to enable micro segmentation is supported by Porter & Heppelmann (2014), Manyika (2015) and Davis (2015). Porter & Heppelmann state that smart products have the characteristic to be able to be controlled by their software. This allows a high degree of product customization that wouldn't have been possible without their smart components and connectivity. They give the example of the Philips Lighting Hue lightbulbs: with the help of a smartphone customers are able to program them to react to a certain change in the environment. For example, they can program the lightbulb to blink red if it detects an intruder, or it could automatically dim the lights at 10 pm. Porter & Heppelmann argue that analyzing such data can help firms segment markets in more sophisticated ways and offer products that are tailored to these segments. Even more close to the customer, Porter & Heppelmann argue that this kind of customization possibilities make it possible to customize products for individual customers, enabling the ultimate match with customer requirements.

Manyika et al (2014) also states that a continuous, detailed stream of real-time data enables both micro segmentation and insights into consumer willingness to pay. Davis (2015) supports this by stating that this kind of usage data can influence strategic moves into connected markets, as customer segments and new product uses can be identified. He adds "the product development process will improve as data starts to flow into and around the business. The R&D, production, marketing and customer service functions gain new insight into how customers use (and want to use) products, as well as the interactions between sets of products and processes."

4.1.4 Increased complexity

The previous sections have shown the three key opportunities that smart product data can provide to maximize the fit with customer requirements. However, IBM Analytics (2014) warns that especially when product systems and 'systems of systems' are involved, the complexity of smart product data increases drastically. Linking back to the characteristics of Big Data : more complexity would come in the form of higher volumes of data, in even more miscellaneous formats in real-time. As has been discussed before, Big Data requires a fair amount of analytics in order to gain insights. An increase in complexity would put a strain on this challenge, especially if a business is not familiar with handling Big Data. An accompanying challenge lies in the fact that so called 'systems' and especially 'systems of systems' can exist of smart products that originate from various manufacturers. Apart from the challenge of managing the bulk of data coming from these systems, businesses would have to decide on the ownership of this data. Data from other manufacturers or other third-parties can only be accessed by working together and sharing data and insights. By doing so, businesses can get the full potential out of the data. Interestingly, Davis (2015) states that one of his findings in a survey was that 32% of business leaders[3] are open to share data, collaborate and co-invest. Davis underpins the value that lies in sharing and co-investing : "If product data is combined with input from a third-party supplier or a third-party data feed, then the ability to personalize a product dramatically increases."

Porter & Heppelmann (2014) see the danger of increased complexity in another perspective. According to them, the functionality of products will increasingly move to a digital interfaces, as was the case with Philips Lighting Hue light bulbs which are controlled through a smartphone. They expect that the more

[3] N= 205 (R&D, product design and innovation executives and CEO'S from healthcare, retail and manufacturing sectors and involved with developing smart products.)

smart products evolve, the more human-machine interactions will move to such a digital interface. Porter & Heppelmann argue that the complexity of the user-interfaces within those environments will increase with it, having the danger to be too complex for consumers to enjoy and backlash on the customer experience.

4.2 Minimizing cycle time and controlling development costs

The effects of introducing smart product data, are often interconnected. Cost and cycle time are both factors that relate directly to the efficiency of the process. The literature shows that one key way to lower costs is to make faster decisions and move faster throughout the cycle, without too much trial and error. This interconnectivity becomes clear in section 4.2.1 (*Design efficiency)*. The sections that follow relate separately to cost control (section 4.2.2.) and cycle time (section 4.2.3).

4.2.1 Design efficiency

As mentioned in section 4.1.4 (*Increased complexity*) the complexity of product development is expected to increase with the Internet of Things involved. However, Rajpathak & Narsingpurkar (2013), Diwanji & Verma (2015) and IBM Analytics (2014) argue that at the same time, complexity could actually be decreased with the help of smart product data.

Tushar Rajpathak and Atul Narsingpurkar from TATA Consultancies created a white paper about Big Data management in the product development process. As has been argued in Chapter 2, smart product data accounts for Big Data because of its velocity, variety and volume. Rajpathak & Narsingpurkar argue that the right interpretation of Big Data can help reduce costs and cycle time during the New Product Development process: "linking useful knowledge obtained through Big Data analysis with rules, logics etc. can help faster and right-first-time decision making, contain cost, improve reusability and reduce product development cycle time."

They exemplify the situation in which product data can be used to see how a specific component was designed in the past and what challenges were encountered. Rajpathak & Narsingpurkar state that organizations that utilize this information find that "they not only help in the design of new parts and assemblies, but can also promote standardization by harvesting old parts from existing databases." In this example, Rajpathak & Narsingpurkar talk about the use of product information obtained within the product development process itself. Diwanji & Verma (2015) argue the same in their report '*Connected products for the industrial world*'. They argue that data generated during the product development process allows businesses to detect failure patterns of components at an early stage.

Again, the ability to predict component or product performance (and failure) with smart product data is argued to be valuable for future product design.

However, IBM Analytics (2014) argues that design efficiency can be reached with smart product data retrieved from launched products instead data retrieved in the process itself. IBM Analytics proposes the reuse of product design information across all different products to reduce overall complexity in the product portfolio. This 'product design information' refers to data obtained from products that are already used by the market. It contains the real-time performance data of product components and features. If successful product components and features can be standardized, overall complexity within the organization can be kept in line.

This, again, relates directly to the estimated increased complexity discussed in section 4.1.4, *increased complexity*). By reusing design elements across the product portfolio, the challenge of complexity could be kept in line.

4.2.2 Costs

Porter & Heppelmann (2014) have a more critical outlook on the effect on cost control during the New Product Development process. They argue that the cost structure of smart products will entail higher fixed costs and lower variable costs. The higher fixed costs are said to be due to the costs of software development, more complex product design and the investment in connectivity, data storage , analytics and security mechanisms. However, it must be noted that this argument partially rests on the assumption that the product in question *is* a smart product. It does not imply that the use of smart product *data* increases fixed costs. But the mention of the costs associated with analytics and software development are still relevant in New Product Development processes that use smart product data as an input. Therefore, it should still be considered in this context.

Contrarily, Davis (2015) expects financial risk to decrease because of the increased collaboration between businesses (this expectation is also mentioned in section 4.1.4, *increased complexity)*. He states: "Products become intertwined as companies combine product data and co-invest in smart product development. New corporate structures emerge to reduce the risks of working collaboratively, and partnership models evolve to reduce development costs, access external capacity, and share risk and reward."

4.2.3 Clock time for hardware vs. software

Porter & Heppelmann (2014) also point out that product development processes will need to be able to accommodate late stage and post-purchase design changes quickly and efficiently. Hardware and software development can have very different 'clock speeds', but can both deliver new value. Software development might have had up to 10 iteration loops in the time it takes to develop one new version of hardware. This point is interesting, as it emphasizes that the possible improvement of the success factor 'cycle time' also depends on the type of product in question. Given that software will be the main deliverer of value in an Internet of Things context, as opposed to hardware (recall section 4.1.2, *continuous product development*), one could conclude that the product development cycle time will decrease greatly when software is involved. However, it is important to note that the right 'time to market' is relative to competition. While software development may be less time consuming, businesses will have to make sure they get to market in the right time, compared to their competitors.

4.3 Empirical results

4.3.1 Expert study

The expert study attracted five respondents (see the responses in Appendix C). All five respondents agreed that smart product data could help businesses maximize the fit with customer requirements during product development. David Langley, senior researcher at the Rijksuniversiteit Groningen, argues that product use can be finely followed by the producer or service provider, allowing them to offer them what the customer wants at any moment in time. Joris Castermans, business developer at Caesar Experts, mentions something similar to section 4.1.1 (*iteration*). He states that gathered information on user behavior can used for next generation solutions.

The expectations of the effects on cost control of the New Product Development process were divided. Three out of four respondents expected costs to increase. Markus de Haan, CTO at Datacon, states that because the Internet of Things is an additional channel it will require an additional budget. Joris Castermans states that the development of smart products will be more expensive because of the need for new technologies and product elements. However, the latter argument seems to be

based on the development of smart products, rather than the use of smart product data in a development process. Therefore it says nothing about the effect of smart product data on the cost control during the New Product Development process.
In contrast, John Moor, managing director at the Internet of Things security foundation, argues that smart product data makes it possible to 'field-test' certain product attributes before fully committing to new product variants. This implies that this can decrease uncertainty and consequently decrease financial risk.

As for the effect of smart product data on the cycle time, Joris Castermans, argues that the increase of complexity could slow the process down. Contrarily, John Moor argues that smart product data could actually increase the number and speed of product introductions to the market (similarly to Porter & Heppelmann argument in section 4.2.3, *Clock time for hardware vs. software*) Markus de Haan argues that if innovative and mature platforms for the Internet of Things are used, the cycle time could be decreased.
The latter argument seems to make the argument of Castermans redundant, as happened earlier when increased complexity was argued to be minimized with the use of efficient design and sophisticated data analytic capabilities.

4.3.2 Interview

In the interview with Aimée van Nunen, business consultant for the IT Production department at PostNL, the integration of the Internet of Things within PostNL was discussed. One of the main findings was that PostNL, as a service and logistics company, has a slightly different take on the expected value of the Internet of Things than manufacturing companies.

PostNL uses smart product data to identify and support strategic moves, such as new market opportunities or even completely new product categories. Aimée van Nunen clarifies that the volume of letters is decreasing, and the volume of packages is increasing in the postal market. In addition, PostNL notices that the relation of businesses and customers is becoming more and more flexible and personalized. This too has implications for the postal market. Therefore, van Nunen mentions the importance of using smart product data to identify new revenue models. She adds that smart product data can help identify models that revolve around additional postal services, but also around non-postal sectors. This means that PostNL is exploring sectors that lie outside its traditional product portfolio. The latter approach to using smart product data seems to lean more towards radical innovation then incremental innovation.
Interestingly, van Nunen states that by analyzing smart product data, new strategic questions arise. This implies that smart product data may not only be a source of solutions and insight, but also a source of new relevant questions that have strategic value.

There was one application however, that links to 'maximizing the fit with customer requirements'. Similarly to the findings in section 4.1.2 (*continuous product improvement*), PostNL sees value in using smart product data for continuous improvement of existing services. The service for delivering mourning postage, for example, is a delicate one. By ensuring real-time localization (which can be realized with the help of sensors and connectivity to a central platform), the risk of a failed delivery can be reduced. Consequently, the risk of recovery costs can be reduced too. The latter lightly links to the success factor 'cost control'. It may not decrease the cost of the actual development of the service, but by reducing the risk of recovery cost, development costs are more likely to be recouped.

However, because PostNL mostly uses smart product data for strategic insight, cost control and cycle time of the New Product Development process are not necessarily a priority. It is hard to ensure cost control and cycle time in a structured way if the retrieved data is also used for radical innovation.

5. CONCLUSION

The articles, experts (under which the interviewee) were clear on what positive and negative effects the use of smart product data could have on the success factors of the New Product Development process. Table 1 shows which articles and experts argued that smart product data either improved or challenged each success factor of the New Product Development process. The positive effects of smart product data on the success factors depend on certain conditions, such as decent data analytic capabilities. Therefore positive effects (indicated with a '+') can be regarded as opportunities, and negative effects (indicated with a '-') as pitfalls. Any section with a '/' indicates that that article or expert did not address that particular success factor, or argued that it would remain unchanged. Opportunities can be exploited and pitfalls can be avoided by meeting certain conditions. These conditions will be specified in section 5.1.

Table 1. Summary of expected effects on success factors

Articles	**Matching customer requirements**	**Cycle Time**	**Cost Control**
Davis (2015)	+	/	+
IBM Analytics (2015)	+, -	+	+
Porter & Heppelmann (2014)	+, -	+	-
Manyika (2015)	+	/	/
Diwanji & Verma (205)	+	+	+
Rajpathak & Narsingpualar (2013)	+	+	+
Expert Panel			
Paul de Metter, CEO at Arlanet	+	+	+
David Langley, senior researcher at the Rijksuniversiteit Groningen	+	/	-
Joris Castermans, business developer at Caesar Experts	+	-	/
Markus de Haan, CTO at Datacon	+	+	-
John Moor, managing director at the Internet of Things security foundation	+	+	+
Interview PostNL			
Aimée van Nunen	+	/	+

The articles and experts discussed an array of (mostly) positive effects that the use of smart product data can have on maximizing the fit with customer requirements. In fact, all twelve sources expressed positive expectations. Many opportunities recurred throughout the different sources. In short, it is expected that businesses that use smart product data will be able to :

- Use smart product data in the feedback loop between product launch and ideation to improve future New Product Development processes.
- Continuously improve products during their own life-cycle, and with that, continuously increase their value post-purchase.
- Identify market segments in detail, down to the individual level.

Two articles also expressed their concerns despite their positive expectations. The two pitfalls that put a strain on the ability to match customer requirements are:

- The inability to handle the new, complex stream of data.
- The inability to maintain user-friendly interfaces across digital interfaces.

Aimée van Nunen clarified in the interview, that PostNL mostly uses smart product data to gain customer, market and strategic insight as well.

It can be concluded that the articles are overall positive about the value that smart product data could add to maximizing the fit with customer requirements. This success factor seems to reap the largest positive effect from the use of smart product data. The opportunities mentioned above all relieve the traditional pitfalls that businesses encounter in trying to match customer requirements. (recall the traditional pitfalls discussed in section 3.2, *success factors*)
Firstly, smart product data allows organizations to capture real-time information about what features the customer uses and does not use. This will reduce the risk of the pitfall of offering undervalued features. Furthermore, this kind of data can predict the customer's willingness to pay. This can help avoid the mistake of overpricing or overestimating the importance of certain features. Lastly, smart product data allows businesses to understand the needs and wishes of particular customer groups, and even individual customers.
To reap these benefits, managing complexity is important to assure that decisions are based on rightly interpreted data.

Only eight out of twelve sources discussed the possible effect on the cycle time of the New Product Development process. The opportunity for increasing design efficiency is argued to decrease complexity and inherently, decrease the cycle time of future New Product Development processes. In fact, seven out of eight sources that discussed this topic argued that cycle time will decrease with the help of smart product data. A challenge however, is to adapt to an increasingly competitive environment where relatively simple software updates with short cycle times can function as the 'new product'. The arguments stays, that businesses have to make sure to get to market on the 'right time' rather than as quickly as possible.

The articles and experts were a bit more divided about the effects on cost control. Seven out of ten sources that discussed development costs expected positive effects on cost control. This does not only entail the reduction of costs during the process itself, but also the reduction of financial risk throughout the process. After all, cost control is about making sure that development costs are recoupable. The example of PostNL showed that by reducing the risk of recovery costs, PostNL is able to improve cost control. Davis (2015) expects an increase in collaboration and shared risk, and therefore the increased ability to control costs. Three out of seven argued that costs would decrease if smart product data is to be used for improving design efficiency.
However, Porter & Heppelmann (2014) argue that fixed costs of data analytics and software development will increase.

Table 2 shows a short overview of the answers to the subquestions of this research. Together they form the answer to the main research question: '*How does the use of data retrieved from the Internet of Things affect the success factors of the New Product Development process?'*

Table 2. Answers to subquestions

Will the input of smart data help…	Answer
Maximize the fit with customer requirements?	Yes, the literature study, expert study and interview all point out that smart product data can provide extensive customer insight.
Minimize development cycle time?	Most likely, most sources agreed that cycle time could decrease with the help of smart product data. It is expected by most that design efficiency and the focus on software will decrease cycle time.
Control development costs?	Unclear, both literature and experts were divided on this subject. The reduction of financial risk and increased design efficiency might ease cost control. But increased complexity and the expectation of higher fixed costs might challenge cost control.

5.1 Conditions

The literature study and expert study often pointed out arguments that seemed to counterbalance each other. It seems that the opportunities and pitfalls discussed in this research could be dealt with appropriately by ensuring a few key conditions.
A recurring theme throughout all articles was the importance of competencies related to data analytics. It has become clear that the amounts of data streaming in to a business will increase when smart products are involved. Knowing how to accumulate and visualize this data is a must to gain insights. The real value lies in knowing how to act on these insights. The greatest value seems to lie in developing more specific customer insights, allowing businesses to create greater value for their existing and future customers.

Another worry was that because of the new nature of products, complexity can grow drastically. The data coming in, as well as the design of the products may become more complex. At the same time, various articles argued that smart product data can reduce complexity. If design efficiency can be implemented and cooperation with third parties can be fostered, complexity can be kept in line, and the pitfalls related to high complexity could be avoided all together.

6. DISCUSSION

This chapter will discuss the limitations of this research, followed by possible areas for future research topics based on the conclusions and other insights gained during the research. Also, suggestions for better research design will be given.

6.1 Research limitations

This research was subject to various limitations. These limitation are mostly related tot he expert survey. Firstly, only 5 experts filled in the survey for the expert study. This makes that any conclusions subtracted from the expert study are merely an indication of the general opinion. In addition, the survey did not always attracted rich answers, making it hard to understand the reasoning behind their opinion or expectation. This can mean that some findings in this research lacked the rich foundation that they could have had with additional expert insights.

Lastly, some responses did not answer the sub-questions. This could imply that some survey questions were not clear to the respondents and could have been designed better. Especially the question '*What effect do you expect the IoT to have on the costs of the new product development process?*' is misleading in hindsight. It could imply that the main objective is to reduce costs. Although this is one way to control costs, the focus must lie on making sure that costs are recoupable in the end. Blindly reducing costs can cause quality to diminish.

The interview with Aimée van Nunen provided valuable insights for this research, and allowed for follow-up questions if a certain answers was not clear. It is therefore advised to choose for more interviews in future research, instead of a survey. Especially when qualitative information is desired, an interview allows for richer insights.

Another limitation is connected to the fact that the growth of the Internet of Things is a recent development. Because of this, there is little academic research that discusses the subject in relation to the new product development process. The literature used in this research therefore mostly stems from consultancy firms or research departments from businesses.

6.2 Future research

The answers to the subquestions show that the effects of smart product data on cycle time and cost control are not completely clear. Especially as regards the cost control of the process. Future research could be done to identify why there is such a discrepancy in expectations on this subject.

Furthermore, the results from the interview with Aimée van Nunen implied that service companies might have other opportunities and challenges when using smart product data as opposed to manufacturing companies. It could be further researched wether there is actually a difference between service and manufacturing companies.

In addition, the interview clarified that PostNL also uses smart product data for radical innovation (i.e., new-to-the world products and new-to-the-company products). This implies that smart product data can be of aid for radical innovation as well. It could be researched to what extent smart product data can aid businesses to develop more radical innovations.

Lastly, as mentioned is the section above, it should be considered to make use of more interviews instead of a survey in future research, if qualitative data is desired.

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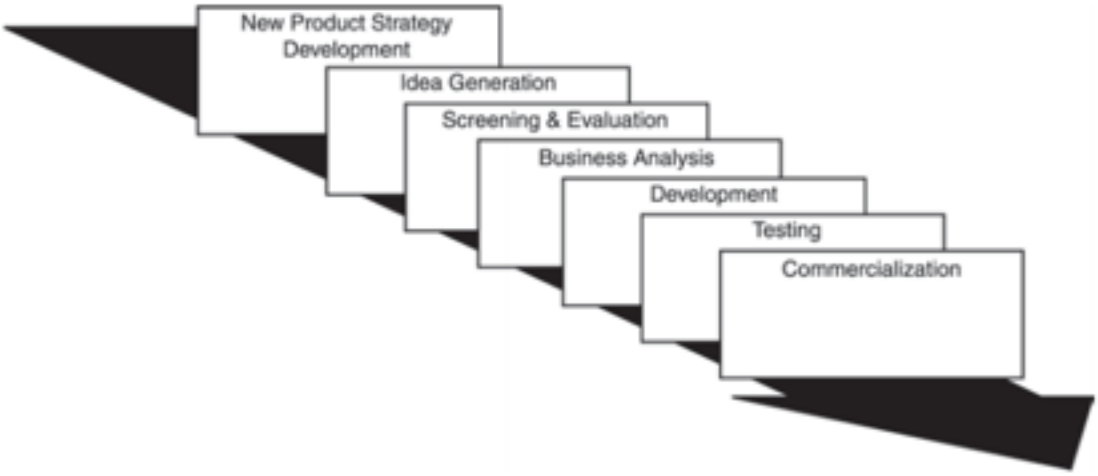
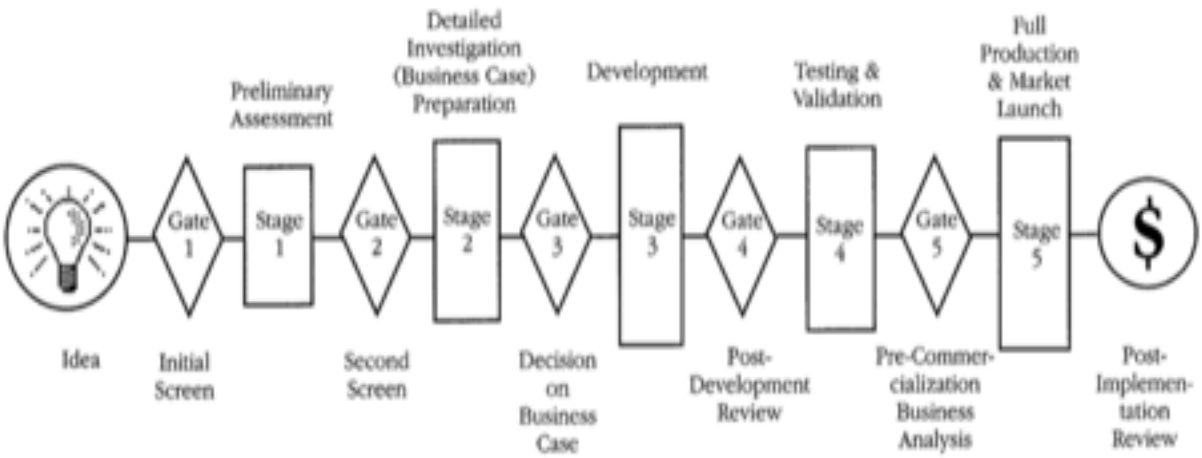
8.APPENDIX

A. BAH Model



source: Booz, Allen & Hamilton Inc. (1982)

B. Stage-Gate model



source: Cooper (1990)

C. Expert panel responses

	Company/Organization	Position	"What effect do you expect the Internet of Things to have on the ability to match customer needs in the New Product Development process?"	"What effect do you expect the Internet of Things to have on the speed of the New Product Development process?"	"What effect do you expect the Internet of Things to have on the costs of the New Product Development process?"
Paul de Metter	Arlanet - Digital Engineers	CEO	Much more seamless integration of offline with online.	Faster.	Lower.
David Langley	TNO / RuG	Senior researcher	A huge effect. Use and optimalization can be finely followed by the producer / service provider, allowing them to offer just what the customer wants at any moment in time.	No change.	Increase.
Joris Castermans	Caesar Experts	Business Developer	gathering information on user behaviour using as insight for next gen sollutions	risk is that it slows down because of increased complexity	Internet of Things is very multidiscipinairy, new element/technologie is involved so compared to just fysical products developmentcosts increase
Markus de Haan	Datacon	COO/CTO, end responsible for HR and responsible for sales & marketing for a part in our integration/API proposition that uses innovative tooling	Internet of Things will play a very important role in the entire customer journey as the customer will also interact through devices with the product.	It can run in parallel to other initiatives so it doesn't need to slow it down, but can be kept on the same speed or maybe faster by using innovative, but mature tooling and platforms for Internet of Things	Internet of Things as additional channel will require additional budget, but the outcome will be a better product and customer experience of the product
John Moor	Internet of Things Security Foundation	Managing Director	It will be easier to identify early adopters or early majority adopters hence targeting should be more effective	It could have the effect of increasing the number and speed of new product introductions (and retirement of older products) - i.e. product churn	It may be possible to field trial certain product attributes before committing to new product variants