This paper was presented at The ISPIM Innovation Summit, Kuala Lumpur, Malaysia on 4-7 December 2016. The publication is available to ISPIM members at www.ispim.org.

Agile Innovation – Challenges while implementing agile approaches within complex mechatronic processes of large corporations.

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Abstract: Increasing innovation dynamic requires faster processes and more flexibility for complex products (Link, 2014). There are many innovation and innovation management related studies in agile software development. However, there is a research gap for on a detailed view on how the agile teams innovate exactly (Tomi Juhola et al., 2013). It is especially interesting to consider the corporate constraints and the related stakeholders within the corporation. What kind of agile methodologies are used while pushing innovation projects within the corporate boundaries and how do these happen? Innovation is especially challenging, where it is most disruptive not only of existing markets but rather organizational structures (Smith, 2007). Considering agile approaches within highly regulated context, the paper provides an insight into the challenges while implementing agile approaches within automotive industry.

Keywords: agility; product innovation; innovation management; agile innovation; uncertainty; interdependencies; agile project path; mechatronic process; enterprise.

1 Introduction

A business's long term sustainability is determined by its ability to address a constantly changing market and economic environment. Until recently developing new products was a haphazard affair, based on a combination of past performance and good instinct. Nowadays technology has a very short life cycle. The challenge of innovation is getting technology to market more quickly. The competition is not the other enterprise, but start-ups that are geared for rapid execution. (Owens and Fernandez, 2014)

As companies get bigger they scale, things slow down and lose speed because there are many systems, structures and processes. Moreover, they lose the ability to take risks and are currently experiencing volatile markets with very short product life cycles due to rapid technological innovation (Aytac and Wu, 2013; Cross, 2012). The complexity

within products and processes increases and the need for operative agility is seen as a key factor of success (Link and Lewirck, 2014).

Research indicates that many traditional companies are experimenting with agile practices in discrete pilot projects (Link and Lewirck, 2014). Unfortunately, most often companies are facing the challenge of "How to bring it home" (Thienen and Meinel, 2015). While the ideation and prototyping phases usually run smoothly, the implementation of these agile principles is a torture within large organizations (Link and Lewirck, 2014).

The mechatronic development of today's products in mechanical engineering effects on the close interaction of various disciplines whereupon a high level of integration prevails. Processes have to adapt to the continuously change in technology and user needs. Multiple-discipline mechatronic engineering needs to cope with the high level of uncertainty and complexity.

This paper outlines the challenges while implementing agile approaches by reference to an OEM within the automotive industry. Two innovation projects were observed to increase the understanding for a situative application of agile methods.

Based on the experience made, strategies to overcome the internal interdependencies are outlined. This may help to bring home more innovations and to increase the agile capability of large corporations.

2 Background

Agility combines Flexibility with Speed

The term "agility" is defined as the capability to react, and adopt to (un)expected changes within a dynamic environment constantly and quickly; and to use those changes (if possible) as an advantage (Böhmer *et al.*, 2015).

Changes are caused externally (e.g. change in customer needs) or internally (e.g. product complexity) and occur for many reasons, some of which are difficult to predict or anticipate (Thomke and Reinertsen, 1998). Unfortunately, many companies are stuck using traditional methods in which all requirements must be defined in beforehand.

An agile company comprises two main factors: responding to changes in a proper way and exploiting changes as opportunities (Sharifi and Zhang, 2001). Change is seen as an opportunity for flexibility (Smith, 2007). The main strategies to accomplish the challenge of being agile is handling uncertainty that goes hand in hand with change. In the context of innovation agile methods are a way to handle internal and external complexity (Link, 2014).

The term "agile" describes a set of values and principles, which are implemented by several practices, methods and tools (Link and Lewirck, 2014).In contrast to plan-driven approaches the development goal is continuously adjusted to the user feedback or rather changes that may occur because of regulatory adjustments or new technologies. The specification and development is done in several cycles using several prototype versions. Processes, rules and working methods are also not pre-determined, but are developed during the progress of the project (Boehm and Turner, 2006).

Agile drivers cause the need for agility and affect the development of an agile strategy to gain agile capabilities (responsiveness, flexibility, speed, and competency). These drivers are assigned to seven clusters: Marketplace, Competition, Customer Requirements, Technology, Social Factors, Suppliers, and Internal Complexity. Internal Complexity has the highest turbulence of the business environment within mechatronic product development. It comprises the number of products, the product and complexity itself as well as the product design process complexity. (Sharifi and Zhang, 2001)

Agile drivers trigger an enterprise to look for agile providers in order to attain the necessary agile capability. The determination of agility capabilities to be acquired or enhanced base on the firm's ability to react, and adopt to (un)expected changes within a dynamic environment constantly and quickly.

According to a global survey, executed by the MIT, agile building blocks are identified as a team's competence in project management. "Agile Project Management" is supported by a set of practices, tools and techniques encapsulated in so-called "agile methods" (Conforto *et al.*, 2014). However, being "agile" is more a "team's competence" that goes beyond practices and tools (Conforto *et al.*, 2014). The agility of a team relies on people's skills, culture, abilities, experiences and diversity, to be able to work in a very dynamic and innovative project environment.

In order to develop this team competence, it is necessary to use the appropriate practices, tools and techniques combined with so called "agility critical factors". These are inherent to the organization structure, project type, team characteristics, market characteristics, etc. Similar to (Sharifi and Zhang, 2001)'s model, it is indispensable to identify the agile abilities to maximize agility as a competence through the use of agile providers (e.g. tools, practices and techniques). The situative combination of different approaches for different projects in the organization's portfolio is an organizational challenges to be able to deal with more innovative projects (Conforto *et al.*, 2014).

The challenges with agile in the context of large corporations

Over the years, different strategies have evolved to support agile procedural models, such as "Design Thinking", "Lean Development", "Open Innovation" or "Scrum". These approaches are characterized by rapid and early prototyping, the avoidance of non-value-creating activities (Lean Development), the use of different possibilities of cooperation (Open Organization) and a tight short clocking in teamwork (Scrum). (Lindemann, 2016)

Agile methods aim for fast feedback and providing crucial knowledge early in the project (Eliasson *et al.*, 2014). Core problem in the automotive sector is the integration of organizational silos, highly specializes on standardized processes that deliver reliably high quality (e.g. quality management or buying department) (Nuhn *et al.*, 2016).

The product development processes need room for dealing with late requirements and specifications, and hybrid procedures. This can be achieved by means of placeholder concepts, which are later filled in the process by "Minimal Viable Products" (MVP), according to the authors. These MVPs must have a degree of quality that depends on strategic budgeting and on the quality of the developing team itself (Nuhn *et al.*, 2016). Above all, engineers as well as their colleagues from the supporting functions are concerned. The automotive sector, like any other industry, sees itself in an environment that is strongly characterized by increasing complexity and dynamism (Nuhn *et al.*, 2016).

Corporations often try to manage innovation projects by separating the team from the commercialization process in remote locations (Freeman and Engel, 2007). A common problem of such Innovation Cells or Skunk Work strategies is caused directly by its remoteness. The team loses contact to the core business and its involved managers. Most projects end up in one of various transfer barriers.

Innovation is especially challenging, where it is most disruptive not only of existing markets but rather organizational structures (Smith, 2007). Integrating inventions into an existing product line causes political defensiveness and slows the innovation process (Freeman and Engel, 2007). Added to this, the rapid increase in problem complexity is attending structural and business process complexity.

When separating a team, protectors by general managers who have the political skills, contacts, and reputation are required to secure resources and protect them from poachers. They buffer the team from interference emanating from interference emanating from rivalry and cultural incompatibility (Burgelman, 2002).

In the context of engineering, agility is defined as the ability to develop functional product artefacts incrementally, while adapting to the environment flexibly and repeatedly, considering factors of context (Klein, 2016). Agile practices are very important in regard of innovation capability, time-to-market, quality, motivation and transparency, for example. Changes that occur by the customer, the supplier, the market or due to failure situations are considered step by step. Agile models foster self-organization and intend a close interaction with the user.

Many corporations are currently trying to combine agile (software) development with conventional stage-gate process (Link, 2014). (Boehm and Turner, 2006; Smith, 2007) argue that there is a pragmatic need to balance stability and agility. Their study analyses the “home grounds” of agile and traditional approaches based on application, management, technical, and personnel characteristics. The potential for hybrid or agile procedures in mechanical development processes and the tools that are relevant for their execution are unclear, yet (Nuhn *et al.*, 2016).

The development of the business model should also be agile and be tested and further developed with customers or rather (internal) users (Link, 2014). Agile development and the agile processes for defining the business model and the marketing concept must be linked and synchronized via a suitable management decision-making system (Smith, 2007).

The introduction of agile practices in development and product management does not mean that stage-gate processes and milestone decisions are completely abandoned, but that they are deliberately bypassed with the complexity and changing circumstances (Link, 2014).

3 Research Approach

There are many innovation and innovation management related studies in agile software development. However, there is a research gap for on a detailed view on how the agile teams innovate exactly (Tomi Juhola *et al.*, 2013). It is especially interesting to consider the corporate constraints and the related stakeholders within the corporation. What kind

of agile methodologies are used while pushing innovation projects within the corporate boundaries and how do these happen?

Objective of this paper

Research is focused on instrumenting innovation teams to understand, support, and improve agile practice. Agile driver, which cause the need for agility are identified. Based on the corporation's ability to react and adopt to changes, agile enabler (practices, methods, tools and models) will help to acquire the needed agile capabilities.

Considering agile approaches within highly regulated context, the paper provides an insight into the challenges while implementing agile approaches within automotive industry.

The analysis starts with the classification of the projects within the corporate context. Agile approaches are identified. The role of prototypes and agile development artifacts within project progression are addressed. Challenges and limits of agile approaches are outlined by explaining the internal interdependencies in more detail.

Data collection and evaluation

This paper represents an explorative study of two exemplary innovation projects by an OEM within the automotive industry. Interviews with the innovation project team members are made continuously to check with their understanding. A complete history of all presentations and the associated documents, protocols, and relevant e-mails have been provided for data collection. Based on the involved persons, departments and decision-making committees a dependency matrix has been generated. The main organizational phases and the specific product development process steps of the project were modelled. The results have been assessed with further innovation projects by experienced innovation managers to verify the qualitative findings quantitatively.

Figure 1 illustrates the relevant internal dependencies. Reading of the matrix follows: Employees belong to a certain department and assigned to a project team. Departments are functionally structured and affect each other.

	People	Department	Team	Committee	Process Phases	Process Steps	Technology	Component
P	-	belongs to	is assigned to	-	-	-	-	-
D	-	affects	-	-	is assigned to	performes	-	responsible for
T	-	-	-	provides input to	-	-	-	-
CM	-	-	-	affects	is assigned to	-	-	Decide on
PP	-	-	-	-	-	contains	-	-
PS	-	-	-	-	-	-	affects	specifies
T	-	-	-	-	-	-	-	affects
CP	-	-	-	-	-	-	-	-

Figure 1 Internal dependency matrix within organization; People (P), Department (D), Team (T), Committee (CM), Process Phases (PP), Process Steps (PS), Technology (T), Component (CP).

Being "agile" is not simply the use of agile elements and techniques. Therefore, Agile Critical Factors according to (Conforto *et al.*, 2014) are evaluated for both innovation teams to analyze the internal agility of those teams within the corporate organization.

4 Results

Corporate context

The innovation projects observed were initiated both, top-down and bottom-up (compare (Freeman and Engel, 2007)). The projects were classified as a resort-wide project. Most of the required manager were involved, who acted as protector against political or budgeting aspects. Both projects faced competitors in the domain of rising startups. The innovation projects may be classified as radical or rather disruptive innovation, since they comprise new technology and a (for the company) new way of sales. The degree of innovation in regards to the corporate context was very high. Both projects implicated product innovation, process innovation and business model innovation.

Identified agile abilities

Based on the collected data, innovation projects have five finale states: “to late”, “washy”, “no offer”, “to old”, or “to expensive”. Reasons and effect are diverse. Because of the established distribution channels, the initial innovative idea becomes an add-on to the existing product not evolving its full potential. Another aspect was that nobody wanted to take over responsibility for the idea since it was not assignable to one main responsible department. Another reason was the missing availability of a supplier due to high technology innovation.

Kappa and resource limitations within the department are omnipresent. Delays or a slow progress of the teams in contrast to the fast technology change result in outdated technology. For lower products, the one-off expenditure mostly is too high for the expected take rates and estimated profit.

Within the company, too many stakeholders were involved in the project, causing too many specific requirements and quality claims, limiting the original innovative idea. Late changes are difficult to handle and cost intensive. But also the development time left may be too short for the responsible department, causing a considerable delay due to transferring the innovation to the next version of the product.

Agile approaches

Increasing innovation dynamic requires faster processes and more flexibility for complex products (Link, 2014). Company-wide innovations can only be handled with clearly defined roles, procedures, accurate deliverables and iterative involvement of related stakeholders. Having said this, both innovation projects used agile elements and techniques based on agile procedural models, like Scrum, Design Thinking, Open Innovation, and Lean Development.

Table 1 gives an overview of the identified agile practices and techniques.

Table 1 Extract of identified agile practices and techniques in relation to (Klein, 2016).

Tools and Methods	*Procedures*
To-Do-List	Weekly meeting
Creative Workshop	Review with management
Tool to track the assigned man-hours	Stakeholder evaluation

Roles	*Activities*
Team	Quality
Product Owner	Early integration of suppliers
Management	Start-up collaboration
Scrum Master + Team Leader	Pilot studies
Stakeholder	Prototyping (3D printing, concept integration)

Artefacts	
User Stories	Offering concept
Release / Approval	Integration concept
Take Rates	3D printed models
Production Cost	Rough User journey

Prototypes and role of Artefacts

User Stories help at the beginning of the project to create a common understanding of the project's vision. Rapid Prototyping or rather an early visualization of the project idea supports the internal marketing, and helps to solicit feedback. The results of the pilot studies were non-relevant for "planned-solution" manager due to missing links to traditional approaches. However, the user journey helped to foster the challenges within the established distribution processes.

Estimating the market potential of the project idea, artefacts like, retail price, take rates, production cost, and integration concept were needed. Those were brought together calculating a business case, based on profound, but prognostic statistics. Gathering real market potential data, approaches like selling a **MVP** was planned, but discarded, due to warranty and security reasons. An established company faces the contradiction between knowing its customer and market, and exploring the market potential due to increasing uncertainty.

Business Model Level

Main challenge for companies from the manufacturing industry are **business model innovations**. Facing volatile markets and experiencing the impact of digitalization, many groups need to transform into a service provider. In this context, e.g. take rates cannot be predicted based on conservative markets. Servitization can be seen as a transformation or rather paradigm change. Servicizing describes the associated (sales) transaction in which the customer benefits is provided by the complete solution. Basic requirement is direct customer interaction, wherefore the after sales departments becomes more important.

Agile has a lot in common with start-up practices, meaning exploration rather than exploitation (see Figure 2). Large groups try to explore in means of **pilot studies**. With users, selected for this study they get specific user feedback or rather learn along the process. In addition to being late, the pilot study results won't have a big impact on the internal business case, dominated by Take Rates, one-off expenditure, part number costs, and the rate of return regarding the product itself.

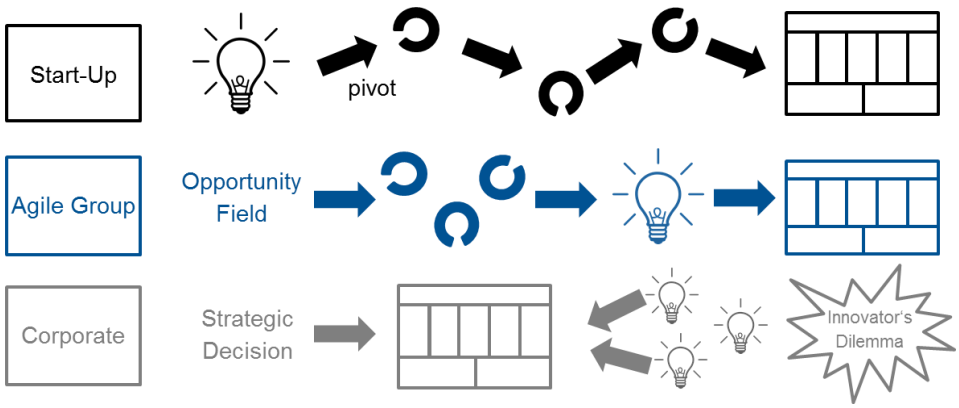

Figure 2 Business Innovation of Start-ups, Agile Corporates and Traditional Corporates

Innovation can be seen as cost factor that comes in addition to the initial product costs. Instead of capturing a market, innovations are more like a marketing aspect and must pay off. Innovation also cause substitution of existing extra equipment, which are already break even and disrupting a "cash cow".

Full potential of an idea may be not seen or the innovation idea will be to reduce to absurdity due to existing business models. The learning cycle with respect to the user needs (**desirability**), product concepts (**feasibility**), and business perspectives (**viability**) is punctuated with historic requirements and the experience of former projects.

Responsibility Level

Large groups face the challenge of **organizational structures** by assigning focus teams or rather task forces. Increasing complexity of innovation projects also leads to decentralized responsibility within a team; meaning there is not only one team leader assigning tasks and planning next steps, but every team member contributing his specific knowledge and competency. Often such agile approaches fail due to sceptical and problem-focused culture.

Innovative ideas face the challenge of being not assignable to a certain department. Focusing on quality within highly specialized processes, additional **responsibility** is an abnormal risk. One solution is an independent project leader (scrum master), who is in charge of the project progress, but without the competent to give a ruling. Nonetheless, the team is always dependent on the releasing department and the decision making of various managers. In the same way new business models are challenging, since they require responsibility within the existing organizational structure.

The **support of top management** protects innovation teams within the organization. However, they won't solve the challenge of a necessary assignment in order to couple into the waterfall process of the core business.

Interviews revealed various innovations transfer barriers, clustered into four categories of: not-knowing, being not allowed to, being not able to, or refusing to do (see Table 2). Inter-divisional innovations demand more management attention, but can also be more rewarding, because they represent a new and possibly unique combination of company strengths (Wördenweber and Weissflog, 2005).

Table 2 Extract of main organizational barriers of innovation projects

Barrier Category	*Innovation Transfer Barrier*	*Explanation*
Being not allowed to	Legal concerns for the adoption of technology	Non-automotive technology contradicts quality values
	No permission to work a topic by supervisor	Aim of the supervisor is to ensure efficiency and high standard of quality
Not-Knowing	Uncertainty through knowledge gaps	only fully secured technologies is valid
	Advantages of the technology cannot be experienced	Enthusiasm within the responsible department is too low
Being not able to	Overload: missing Kappa within responsible departments	Increasing complexity has significant influence on company's workload
	Department representative has no power	decision-making processes comprise internal agreement
Refusing	not-invented here	responsible department is not willing to take over the R&D solution
	Status Quo vs. Change	too many departments involved

Source: Interviews with several stakeholders across the company.

Complexity Level

Company-wide project lead is not manageable for one single person. The amount of correlated stakeholder within the highly complex automotive system asks for strictly regulated processes. A product innovation being accompanied by a process a business innovation, brings up various aspects of correlating departments. Mentors, who promote the decision making process and the agreement within the hierarchy are helpful. Nonetheless, even teams, assigned by board members need to go through the internal committees.

Figure 3 illustrates the dependency matrix for project A, mapping involved employees, department, teams, committees mapped to the innovation phases and related process steps as well as the technology and affected component of the system.

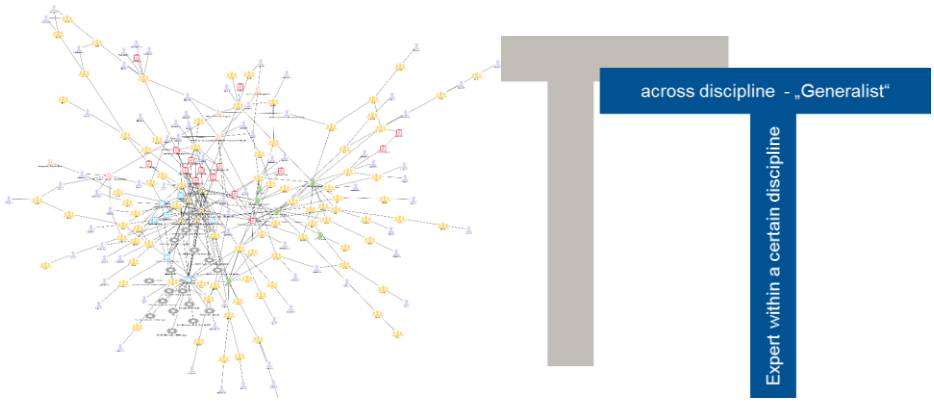

Figure 3 Visualization of dependency matrix (left); T-Profile of agile team members, being generalists or rather experts (right).

Most teams are not fully allocated to one specific innovation project. The resulting multiple project management leads to high degree of inefficiency due to risk-averse and routine actions. Identifying a critical path to market for the innovation, also demands deeply involved team members, capturing the big picture and interacting with the most relevant stakeholders.

A generalist captures the big picture within the company and responsible specialists are involved iteratively. This stakeholder integration needs to be handled carefully not causing a "not-invented here" syndrome or slowing down the progress due to excessive requirements.

Internal coordination and synchronization takes about 90% of the project working time. This effort is in direct correlation with the innovativeness or rather internal complexity of the project. Main avoidable delay is caused by the absence of the team members and number of concerned departments.

Another aspect is the early involvement of suppliers or contractors, which is necessary to enable and handle late changes without high risks.

Key issues in migrating to agile

Complexity of innovations increase both externally (rapid technology change, increase of software and electronics within mechanical engineering) and internally (organizational collaboration, early involvement of various departments).

This paper focuses on the challenges while implementing agile approaches with regards to complexity and uncertainty. Therefore, one need to differentiate between internal and external agility.

External agility addresses volatile markets, political or legal frameworks, which need an increased capability of reaction and adaptability. Changed requirement specifications of customer, supplier or even employee, leads to collaborations or even company acquisitions. Another external factor are the different speeds of technology innovations, (e.g. software and electronics).

The internal agility is analyzed using the Agile Characteristics and Agile Critical Factors according to (Conforto *et al.*, 2014). Figure 4 below illustrates the relevant Agile Critical Factors (ACF) based on the two observed innovation projects. Data was gathered by the team members and arithmetically averaged.

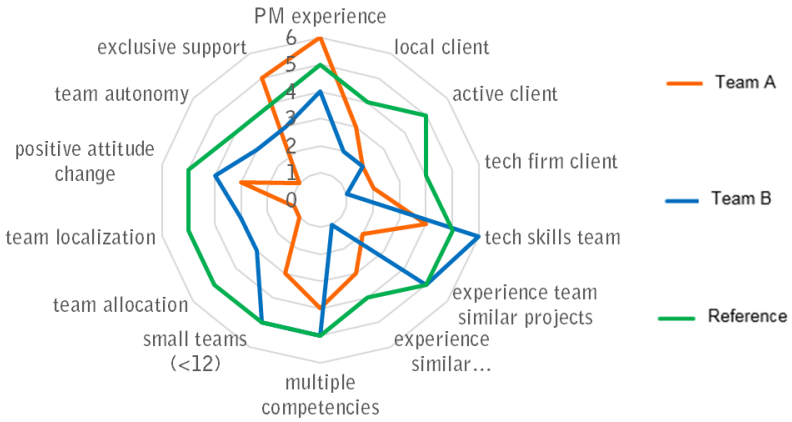

Figure 4 Agile Critical Factors according to (Conforto *et al.*, 2014)

Both teams had a good team competency and an acceptable mindset. Team B had experience with regard to similar projects or rather challenges in contrast to team A. The project's size and proximity of the team members had a significant influence, since it encourages communication. Both teams were highly collaborative and mostly pro-active. However, team A suffered from skeptical people, who did not think outside the box, but were focusing on their field of responsibility. For team B, the project leader mainly conducts the "project orchestra", and facilitates the progress of the team. The project leader of team B also tried to act in that way, but the non-pro-active team forced him to act as a team leader, assigning tasks to the team members.

Internal agility presumes, that the team is allowed to make decisions or rather has fast access to decision-makers. Team B was mainly responsible for the technology. In contrast team A was dependent on many releasing department, but had exclusive support from top management. Most critical factor is the involvement of the client, relevant supplier and stakeholder to validate interim solutions. For team A, the client was part of the team, and team B actually tried to circumvent the relevant stakeholders due to new innovative approaches.

Innovation capabilities help to overcome challenge while transforming from a traditional to an agile organization (Nerur *et al.*, 2005). The key challenges migrating to agile are related to management and organizational issues, people factor, process focus, as well as used tools and techniques (Link, 2014).

Innovations emerging from agile teams are not limited to just product innovations, but also process and business model innovations have been observed. According to (Tomi Juhola *et al.*, 2013), the research mainly concentrates on product innovation, and neglecting related innovations to improve e.g. development processes for agile development teams.

6 Summary and Agile Innovation strategy

Top three challenges for corporations are business innovation, responsibility within the organization, as well as the internal and external complexity. As illustrated in Figure 5, the degree if innovation is related to the internal organization. A company-wide responsibility is not acceptable for a certain department or rather one single project leader. Innovations need a pilot market to explore the market potential with minimum viable products. However, hardware innovation projects are also limited for pilot studies due to security and liability.

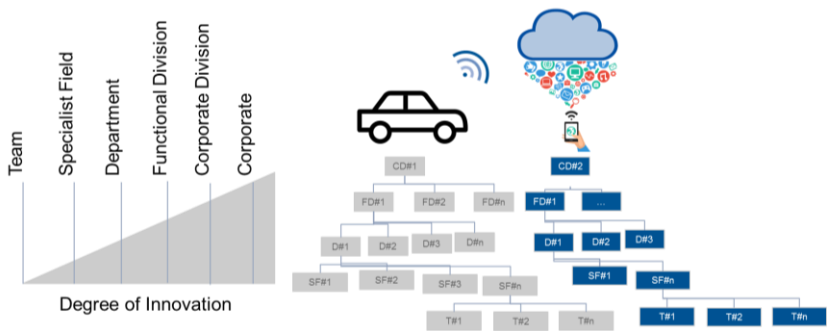

Figure 5 Agility and the degree of innovation within an organization.

Traditional development practices tend to subjugate innovative ideas to the requirements specification, which often leads to a limited opportunity for innovative ideas. Agile development reduces interdependencies significantly and facilitates the dialogue between customers, users, and various developers (Aaen, 2008).

Particularly large corporations, which are prone to inertia and immobility, agile work can be a contemporary solution. This allows the company to react faster and more flexibly to internal and external changes. In the increasingly shorter cycles of automotive development, agile work is, a "must-have" in the toolbox of every project manager. Responsibility, complexity and rigid structures asks for transparency in interdisciplinary and directly communicating teams.

This paper presents an analysis of two representative innovation projects within a large automotive group. The challenges of the innovation teams lead to diverse approaches yielding agile practices into the engineering of innovative mechatronic products.

To combine the advantages of both conventional (waterfall) and agile models, a systematic and scalable agility is pursued that estimates agile potential best. To solve the challenge of becoming, the internal contradictions needs to be solved.

The purpose for agile product development principles is to foster speed and flexibility, starting with an abstract idea to a detailed increment. Most large industries are still stuck with old methods, whereby requirements, supplier, business case etc. need to be specified before the actual development.

Figure 6 illustrates two different project path when considering traditional or agile approaches. Existing processes, quality and brand standards, and distribution channels hinder non-incremental innovations. Innovation projects get stuck or lose their innovativeness. Enterprises face conflicting goals between exploration and exploitation.

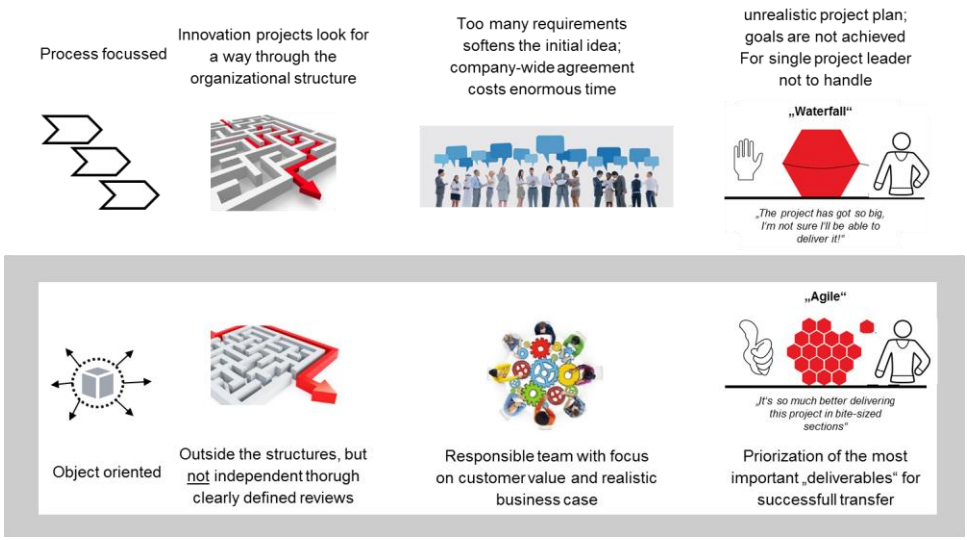

Figure 6 Traditional vs. Agile project path.

5 Discussion and Outlook

Frequent challenges in companies are the management of complexity and uncertainty, as well as the flexibility of processes and value chains (Nuhn *et al.*, 2016). The determination of the agile status quo is a first step towards an agile transition. Metrics need to be defined to measure the positive effect of agile techniques within mechatronic innovation projects.

A deeper understanding of the benefits from agile methods needs deeper assimilation of practices. Further work and implications for research and practice will be the analysis of agile systems to increase the innovation capability. Moreover, agile driver, enabler, and capabilities will be explored in more detail, to map them to the related agile methods and practices.

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