Titre: Title:	Defining Best Practices for Using Lean and Agile Principles Within the New Product Development Process
Auteur: Author:	Amir Ghoorchiyan
Date:	2020
Type:	Mémoire ou thèse / Dissertation or Thesis
Référence: Citation:	Ghoorchiyan, A. (2020). Defining Best Practices for Using Lean and Agile Principles Within the New Product Development Process [Mémoire de maîtrise, Polytechnique Montréal]. PolyPublie. https://publications.polymtl.ca/5477/

URL de PolyPublie: PolyPublie URL:	https://publications.polymtl.ca/5477/
Directeurs de recherche: Advisors:	Fabiano Armellini, & Luciana Paula Reis
Programme: Program:	Maîtrise recherche en génie industriel

POLYTECHNIQUE MONTRÉAL

affiliée à l'Université de Montréal

Defining Best Practices for Using Lean and Agile Principles Within the New Product Development Process

AMIR GHOORCHIYAN

Département de mathématiques et de génie industriel

Mémoire présenté en vue de l'obtention du diplôme de *Maîtrise ès sciences appliquées*

Génie industriel

Octobre 2020

POLYTECHNIQUE MONTRÉAL

affiliée à l'Université de Montréal

Ce mémoire intitulé :

Defining Best Practices for Using Lean and Agile Principles Within the New Product Development Process

présenté par **Amir GHOORCHIYAN**

en vue de l'obtention du diplôme de *Maîtrise ès sciences appliquées*

a été dûment accepté par le jury d'examen constitué de :

Mario BOURGAULT, président
Fabiano ARMELLINI, membre et directeur de recherche
Luciana Paula REIS, membre et codirectrice de recherche
Maicon GOUVÊA DE OLIVEIRA, membre

DEDICATION

I dedicate this thesis to my parents, my family, and my soulmate with love and gratitude.

ACKNOWLEDGMENTS

I appreciate the efforts and support of Professor Fabiano Armellini, Professor Luciana Reis, and Professor Carl St-Pierre in helping me to produce this thesis. Without their guidance, completing this step of my education would not have been possible.

RÉSUMÉ

Parmi les stratégies de développement de nouveaux produits (NPD), les méthodologies Agile et Lean Startup (LS) ont été choisies pour comparer dans deux types d'entreprises différents: les fournisseurs de services et les fabricants (producteurs de produits immatériels et tangibles) en fonction du nombre d'employés.

La méthodologie Agile a été développée pour améliorer la productivité des éditeurs de logiciels au début des années 2000. Il a amélioré le processus NPD grâce à des techniques de communication de sprint et de routine et des réponses rapides aux changements du marché.

LS a émergé pour aider les dirigeants à prendre des décisions et réduire le flou pour les entreprises qui lancent de nouveaux produits. Les sociétés informatiques et de logiciels ont amélioré leurs processus grâce au minimum de boucles de rétroaction de produit viable et de construction-mesure-apprentissage (BML) dans leur processus NPD.

De nombreux articles ont abordé les méthodologies Agile et LS dans les domaines informatique et logiciel. Cependant, il existe une lacune dans la littérature sur l'utilisation de l'Agile ou du LS par les producteurs de produits tangibles ou intangibles de taille d'entreprise.

Cette étude évalue l'impact de l'adoption d'outils NPD, de LS et de pratiques Agile sur le processus NPD pour optimiser les performances de l'entreprise sur le marché, en fonction du type de produit.

Sur la base d'une enquête, nous avons constaté que les producteurs de produits tangibles sont prêts à adapter leur processus NPD sans adopter les cadres LS et Agile, tandis que les producteurs de produits immatériels poursuivent leur processus NPD en utilisant la structure Agile et LS. Cependant, toutes les entreprises, quel que soit le type de produit, essaient de trouver le bon processus NPD pour leurs limites et leur situation sur le marché.

Mots clés:

Lean Startup, Développement de nouveaux produits, Agile, Outils NPD, Performance

ABSTRACT

Among new product development (NPD) strategies, Agile and Lean Startup (LS) methodologies were chosen to compare in two different types of companies: service providers and manufacturers (intangible and tangible product producers) based on the number of employees.

Agile methodology was developed to improve productivity in software companies in the early 2000s. It improved the NPD process through sprint and routine communication techniques and fast responses to market changes.

LS emerged to help leaders make decisions and reduce vagueness for companies launching new products. IT and software companies improved their processes through the minimum viable product and Build-Measure-Learn (BML) feedback loops in their NPD process.

Many articles have discussed the Agile and LS methodologies in the IT and software fields. However, there is a gap in the literature on the use of Agile or LS by tangible or intangible product producers with company size.

This study assesses the impact of adopting NPD tools, LS, and Agile practices on the NPD process to optimize company performance in the market, as moderated by product type.

Based on a survey, we found that tangible product producers are willing to adapt their NPD process without adopting the LS and Agile frameworks, while intangible product producers pursue their NPD process using Agile and LS structure. However, all companies regardless of product type are trying to find the right NPD process for their limitations and situation in the market.

Keywords:

Lean Startup, New Product Development, Agile, NPD Tools, NPD Performance

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

This list presents the symbols and abbreviations used in this thesis in alphabetical order, along with their meanings.

BMI	Business Model Innovation
BML	Build-Measure-Learn
CS	Company Size
ERP	Evaluation and Revision Procedure
IFD	Internal Factor Development
KMO	Kaiser-Meyer-Olkin Test
LM	Lean Manufacturing
LP	Lean Production
LPD	Lean Product Development
LS	Lean Startup
MCD	MVP Customer-Based Development
MFD	Market Factor Development
MLR	Multiple Linear Regression
MPT	Managing and Planning Tools
MRP	Material Requirements Planning
MVP	Minimum Viable Product

NPD	New Product Development
ODP	Organizational Development Procedure
PCF	Principle Component Factor
POU	Parallel Operational Units
PQD	Production-Quality Development
PT	Product Type
R&D	Research and Development
RWM	Regular Work-Detecting Meeting
SD	Standard Deviation
SE	Standard Error
SEM	Standard Error of the Mean
TQM	Total Quality Management
WTT	Work/Time Study Tools

LIST OF APPENDICES

CHAPTER 1 INTRODUCTION

1.1 Research background

According to (Björk, Ljungblad, & Bosch, 2013), traditional methods such as stage-gate are not sufficient to support work on or consideration of multiple product or service ideas in parallel, especially when the basis of product or service existence is vague; hence, there is a need to use methodologies with adaptive features to handle the NPD process.

On the other hand, (Schneider & Hall, 2011) listed five common reasons for a new product or service failure: (1) lack of supporting fast growth by the company; (2) product defects or compatibility and performance problems; (3) failing to meet all the customers' needs; (4) not giving enough information about the product to the customers; and (5) no market need.

Failure rates may differ based on product type, but there is one important point in common: mismanagement of the NPD process.

In hence, the Agile manifesto (Fowler & Highsmith, 2001) was developed to help software companies engage in the fast iteration in their product development process, but a lack of documentation, inadequate measurement of the New Product Development (NPD) process, little planning at the beginning, and fear of the unknown led to many problems with the original version of methodology, in hence more advanced models were developed in the Agile category such as Scrum (Fridman, 2016).

Nevertheless, the emergence of the Agile methodology as a solution for unproductive software companies resulted in impressive improvements in their NPD process such as fast product delivery to customers, self-organizing, cross-functional team efforts, fast iteration to help them eliminate defects, and continuous product improvement (Varhol, 2015). Due to the market complex, vague and competition intensity, new methodologies such as Lean Startup (LS) were developed to respond to this uncertainty and intensity.

In *the Lean Startup*, (Ries, 2011) indicates a new roadmap for the startups to test ideas before they waste money and time. He defined startups as "ventures to create a new product or services under conditions of extreme uncertainty" lack of previous experience and the fast-changing business

environment creates challenges for the traditional NPD process (Bortolini, Cortimiglia, Danilevicz, & Ghezzi, 2018). This definition presents a common point between Agile and the Lean Startup (LS) method: the translation of new ideas in a real product or service.

LS and Agile are comprehensive theories that cover the whole NPD process with applied measurement techniques to anticipate Pivot or Persevere decisions in organizations, based on their main idea, which is based on the no-waste principles of the Toyota Production System and the Agile manifesto.

Unlike traditional methods, LS and Agile are marked by extensive collaboration (including face-to-face communication), fast iteration, and fast product delivery. In these methods, the customer works closely with the development team to constantly validate the delivered product; the development process is dynamic and open to changes in areas that can be identified at any given point.

The goal of this research is to map applied practices adopted in the face of new challenges to the business's current and anticipated situation in the internal or external environment and integrate resources for success in the market (Inayat, Salim, Marczak, & Kasirun, 2014).

1.2 Problem statement

Both the LS and Agile methods have had a huge impact on the process of improving and developing new products in the IT and software sector (Dzamashvili Fogelström, Gorschek, Svahnberg, & Olsson, 2010).

Some authors have discussed the use of those methods in different sectors; for instance, (Mason-Jones, Naylor, & Towill, 2000) showed an NPD process improvement in the logistic and supply chain (service) area.

(G. Benefield & Greening, 2013) examined the features and benefits of each method without mentioning how LS and Agile are related or comparing their performance. (Ghezzi & Cavallo, 2018) investigated the use of Agile and LS in digital startups; they analyzed the overlap and coverage area of each method but they did not discuss tools, practices, or a way of implementing the methods.

A widespread transposition of these methodologies as a framework for the NPD process in other industries has not proven easy.

This research connects the LS and Agile methodologies as a package that can be applied in different enterprises to improve the NPD process. We will identify valuable tools, techniques, and practices in different sectors and compare them to understand their importance in each sector and their impacts on outcomes while taking advantage of overlapping features.

This research will contribute to academic studies and help entrepreneurs to develop their NPD process, by examining the differences between Agile and LS. Using the Agile and LS principles as an analytical framework, we will identify lessons from different companies' experiences with NPD (Edison, Wang, & Abrahamsson, 2015).

CHAPTER 2 LITERATURE REVIEW

In this section, we will review the fundamentals and requirements underlying this study to set out the basic knowledge and concepts that will be applied in the empirical part of the research.

2.1 NPD definition

For managers, moving from the initial idea to the real product or service and having success in the market is a barrier, particularly when they lack experience in the market or desirable features for customers; thus, NPD methodologies shape the product development process to reduce the risk of failure and overcome barriers (Brush, Greene, & Hart, 2001)

Product development or innovation is generally understood as the development (or improvement) of physical goods (tangible products) or services (intangible products) (Krishnan & Ulrich, 2001).

Usually, NPD is defined as the development of tangible products that are new to the supplier. Sometimes NPD is expanded to include New Service Development for intangible products which are new to the supplier such as financial services; health care; telecommunications services; information services; leisure and hospitality services; travel services; facilities management services; educational services; legal services; and consulting services which those offers can be sold either to consumers or businesses and sometimes to both (Johne & Storey, 1998).

(Van Echtelt, Wynstra, Van Weele, & Duysters, 2008) consider supplier as an important chain to whole NPD process that it could assess the product or service development process under the customer vision but their involvement as the resources (capabilities, investments, information, knowledge, ideas) help the firm to improve the process and initial product or service before introducing to the market.

In recent decades, many NPD approaches have been developed. (Cooper, 1988) expressed his idea in the stage-gate framework, which is divided into predetermined steps with checkpoints after each one to review the quality and achievement requirements. Although this approach is well known and often applied, the lack of a clear structure to link market activities such as value proposition, interfirm cooperation, and technological aspects meant it required improvement.

(Bolumole, Calantone, Di Benedetto, & Melnyk, 2015) considered the NPD process (including market activity, technical activities, and market intelligence) and product success or failure and found that superior performance concerning market activities would allow a firm to conduct more efficient technical activities to achieve sustainable success in launching a new product or service (Veryzer Jr, 1998).

To respond to the neglect of interfirm cooperation as an effective factor in outcome performance, (Dickson, Lawton Smith, & Lloyd Smith, 1991) noted that such cooperation is driven by technological advantages, and working to improve this competitive benefit is the required direction for cooperative efforts, particularly when the technological aspects determine the company's position in the market (McDonough III & Barczak, 1991).

Nevertheless, making assumptions about the acceptance or rejection of the product idea and features by the market and the related cost emphasizes the importance of having an NPD strategy beyond merely technological innovation (Crawford, 1972). Linking this issue and the related risks and understanding the market and customers' desires and needs should be a sustainable procedure for companies in their NPD process (Evans & Laskin, 1994).

Companies use many techniques to reduce risks and grasp customers' behaviours such as collaboration with rivals, multi-brands, etc. (Hamel, 1989). For example, (Yoshino & Rangan, 1995) highlighted the role of alliances in responding to fast market change; they found that firms take advantage of alliances to respond quickly to the variety of customer requests by applying the capabilities of each company at the right time and place. Determining the right technique and customer-based methodology in the NPD process could be a crucial decision to ensure sustainable success (Goles & Chin, 2005).

Consequently, recognizing useful techniques and practices to keep companies in the race while avoiding feature creep in products and relying on an invaluable R&D process is a necessary step in the NPD process (J. A. Highsmith & Highsmith, 2002).

2.1.1 NPD models transition

2.1.1.1 Spiral model

We can perhaps consider the Agile methodology as a further development of the Spiral model (West, Finch, & Curran, 1995). The benefits of this model are considering customer feedback in each phase, risk control, documentation, applying milestones, and reaching each step by completing the previous steps. The iterative approach in this model helps companies to adapt their processes based on Agile principles (Boehm, 1988).

Figure 2.1. Spiral Model[1]

(Alshamrani & Bahattab, 2015) presented the Spiral model phases in order:

"1. Planning: This phase includes the understanding of the system requirements by conducting continuous communications between the customers and the system analysts.

2. Risk Analysis: In this phase, a process is undertaken to identify risk and alternate solutions. A prototype is produced at the end of this phase.

3. Development/Engineering: In this phase, the software is produced along with the testing.

4. Evaluation Phase: This allows the customer to evaluate the output of the project before the project continues to the next spiral or next round."

[1] Source: http://www.professionalqa.com/spiral-model.

2.1.1.2 Design thinking

Design thinking is a user-centred model that emphasizes the product design process whereby multi-disciplinary teams work to achieve an error-free, user-friendly product. It makes use of extensive user research, feedback loops, and iteration cycles. “In this model, the new market opportunities are created based on emotion-rich innovations in product meanings” (Verganti, 2009), (Buchanan, 1992).

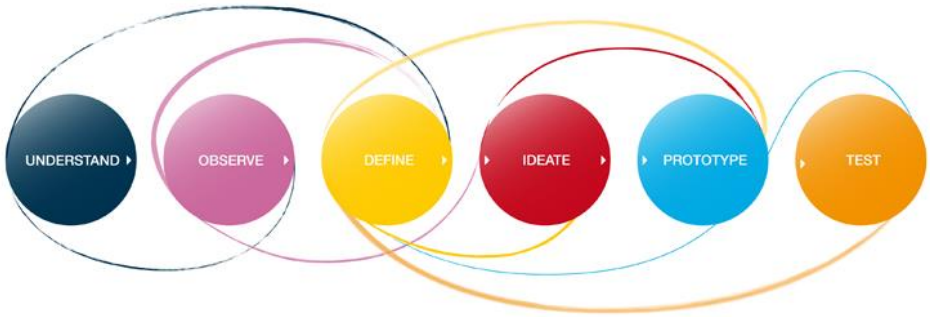

Figure 2.2. Design Thinking Model[2]

The positive points of this model are designing for customers, keeping in touch with customers, and creating value for them (Brown, 2008).

Designing the product is one component of innovation but to explain how a prototyping process should be, we have to admit there is not just one way to determine how we can reach that point (Walters, 2011). Direct communication with customers and considering technical and technology issues in the design are the missing pieces of the puzzle in Design thinking. But in the adapted LS model, we can see how these gaps are filled. However, there are many common points between LS and Design thinking in terms of product typing, customer involvement, feedback loop, and no-waste approach due to the proper design market-fit. Overall, each new methodology seeks to fill the gaps in the previous methodologies; thus, the Agile and LS principles are rooted in the basic rules of earlier methods, such as the Spiral model and Design thinking.

---

[2] Source: Brown (2008).

2.1.2 NPD tools

Although most NPD tools were formed to deal with specific NPD problems, practical research shows that executives tend to use them rather haphazardly applying them at different NPD process phases as they see fit (Mahajan & Wind, 1992).

But they should be aware of the major reasons for utilizing NPD tools: problem recognition, successful boosting in the NPD level process, and collecting data to enhance the company's power in the market (Nijssen & Frambach, 1998).

(Nijssen & Frambach, 2000) conducted a quantitative study of the quality control tools and organizational support tools that companies are likely to adopt in their NPD process. They found "several important implications with previous research have established a link between the use of NPD tools and companies' financial performance, top management may want to stimulate the adoption and use of NPD tools. NPD tools can help analyze problems more systematically and thus help the decision processes involving the NPD process."

(Kärkkäinen, Piippo, & Tuominen, 2001) described tools related to customer-driven product development, production, defect identification, etc. Based on their ideas and those of other authors, we present the most common tools in Table 2.1.

Table 2.1. NPD Tools

No.	Tools and techniques	References
1	Daily meetings	(Katzy, Baltes, & Gard, 2012)
2	Kanban	(Rossi, Kerga, Taisch, & Terzi, 2014)
3	Kaizen	(Caffyn, 1997)
4	Total quality management (TQM)	(Fasil & Osada, 2011)
5	Customer involvement	(Ritter & Walter, 2003)

Table 2.1. NPD Tools (Resume)

6	Direct contact with customers	(Tomes, Armstrong, & Clark, 1996)
7	Face-to-face orientations	(Schmidt, Montoya-Weiss, & Massey, 2001)
8	Training courses	(Nepal, Yadav, & Solanki, 2011)
9	Product road mapping	(Smits, 2007)
10	Project management techniques	(Pons, 2008)
11	Short iteration	(Minderhoud & Fraser, 2005)
12	Scrum master of each product	(Bass, 2014)
13	MRP1 and/or MRP2	(Powell, Bas, & Alfnes, 2013)
14	Prototype	(Duc & Abrahamsson, 2016)
15	3D print prototyping (virtual prototyping)	(Berman, 2012)
16	Virtual testing	(Rosenberger III & de Chernatony, 1995)
17	Sub-brand production	(Furr & Dyer, 2014)
18	Visualization of reports	(Dodgson, Gann, & Salter, 2006)
19	Sprint/backlog list	(Ries, 2011)
20	Split test A/B test	(Ries, 2011)
21	Prioritizing of tasks	(Racheva, Daneva, & Buglione, 2008)
22	Work standardization	(Duran, Cetindere, & Aksu, 2015)

Table 2.1. NPD Tools (Resume and End)

23	Self-control	(Takeuchi & Nonaka, 1986)
24	Milestone	(Bortolini et al., 2018)
25	What-if scenarios	(Golfarelli, Rizzi, & Proli, 2006)
26	In-depth cause finding (5 Whys)	(Ries, 2011)
27	Time standardization	(Duran et al., 2015)
28	Product owner of each product	(Bass, 2013)
29	User story card	(Patel & Ramachandran, 2009)
30	Value proposition	(Cooper, Edgett, & Kleinschmidt, 2004)

Table 2.1 shows the most common tools used in the NPD process. The tools were extracted from the Agile and Lean models to determine which packages of related tools are valuable. We believe these tools have more impact on the success of the NPD process.

Agile methodologies make use of some important tools: product owner and scrum master roles and their responsibilities in navigating the NPD process, such as gathering data from customers, determining errand lists, explanation of duties, executing duties in the shortest possible time, and consistency control on product quality and market reaction make Agile methodologies more functional and operational than others. On the other hand, LS is a more decision-driven method, with tools including the split test to understand valuable functions and identification of the reasons for problems through the 5 Whys, Value propositions, and What-if scenarios, which help steer executives to the right decisions about market behaviour and customers' needs.

The efforts that mentioned above have some prerequisites: product owners and scrum masters or product leaders make errand lists and determine the necessary time to do the work, once they know about the work/time standards and firm limitations such as technology and human resources and

can assess and control the quality of products or services after each iteration and see how the final product meets customers' desires.

2.1.3 NPD performance

As we mentioned above, NPD strategies help companies to adapt quickly to market changes and include all aspects of this process such as technological issues, customer relations, etc. (Cooper & Kleinschmidt, 1995).

NPD performance refers to the consequences of the product development method that was implemented. It can include financial aspects such as products' contributions to the company's sales and profits. It can also describe the launching time to enter the market (Smith, 1998), and the product quality and customer consent levels (Lioukas, 2007),(Cooper & Edgett, 2008).

(Wang, 2009) measured NPD performance in a fuzzy area by examining group decision-making scenarios. The main components of NPD performance are "quality and speed to market; widening customer choice and expectation; competitive priorities of responsiveness, delivery, flexibility, concern for the environment, and international competitiveness" (Ozer, 2006).

The technological aspect is another element may be considered as the NPD outcome. (Salas Martinez, 2016) noted that feature creep can be prevented by reusing valuable features which recognized in the market; this also helps to improve the rate of technology reuse.

Valuable features are a result of technological skills in the firm. (Harmancioglu, Finney, & Joseph, 2009) showed that technological skills lead to higher profitability and ensure that product features are closer to customer needs. The emphasis is on valuable operational activities, which have a major positive effect on NPD process performance.

Table 2.2 shows five elements of NPD performance; each element has some indicators that a company can measure. Those elements involve internal and market factors to show the extent of NPD process success.

Internal factors include employees' ability to make innovations in the NPD process, minimized waste and resource usage, easy information flows across the firm, and the effort to make a quality-based brand.

Market success factors can be good indicators that a firm has taken the right NPD steps. These indicators are more tangible and measurable, such as market share, quality, speed to market, and customer retention.

Table 2.2. NPD Performance[3]

No.	NPD element	Indicator				
1	Market-related	Quality and speed to market	Number of important/major customers	Market share rate	Delivery	Widening customer choice and expectation
2	Innovation-related	Flexibility	Number of new products or processes	Number of patents	Reduction in R&D cost	
3	Organization-related	Productivity	Improved responsiveness to competitive priorities	Brand reputation	Improvement of information systems	
4	Employee-related	Employees on training programs	Employee engagement in the R&D process	Improved employee capabilities		
5	Technical-related	Rate of reuse of technologies or features			Valuable operational activities	

[3] Source: Wang (2009), adapted by the author.

Most market analysts consider market factors as good NPD process results but a closer reveal that internal success indicators are based on efforts to make the right service or product, and we should consider them as important as market factors.

2.2 Agile methodology

The Agile methodology involves acting based on short iterations and sprints and satisfaction of requirements with a short development cycle to decrease the risk of product failures in the market (Zhu, 2009). It was introduced as a solution for internal and external communication, documentation, technical requirements, over scoping, work prioritization challenges, and validating business assumptions.

Agile implies product development methodologies based on iterative, incremental development. It requires joint work on the problem and solution when multifunctional teams try to add a new function to a product at the same time (Santos, Goldman, & De Souza, 2015).

This methodology is based on project management principles. The product manager or leader tries to provide the requirements for the next move, manage time, and allocate resources while focusing on the market- and customer-based improvement in the product and its delivery. These factors distinguish this methodology from others (J. Highsmith, 2009).

Agile methodologies are developed based on the initial concept and companies' specific situation. For example, Extreme Programming "is a systematic approach for high-quality Agile software development, focused on speed and continuous delivery. The Crystal family model addresses the realization that each project may require a slightly tailored set of policies, practices, and processes to meet the product's unique characteristics and each has unique characteristics driven by several factors, such as team size, system criticality, and project priorities" (Strode, 2006).

The SCRUM methodology is the most popular Agile model and will be used in our study. It is known for its efforts to deal with backlogs, which are called Sprints. Daily and monthly reviews are done to improve products with the goal of fast defect recognition and improved product quality. According to (Guang-yong, 2011), to grasp how this methodology works, two roles must be defined: Product Owner and Scrum Master.

"Product Owner has a major responsibility in maximizing the value produced by the team and ensuring stories meet the user's needs and comply with the definition of done."

"Scrum Master is a coach in the team, clarify the team faced obstacles, assign team tasks, develop the planned sprint, sprint review assessment, holding the daily meeting, convene and organize sprint retrospective meeting, by brainstorm ways to review the current sprint and results than finding the neck bottles and solutions."

A model of the Scrum methodology is shown in Figure 2.3.

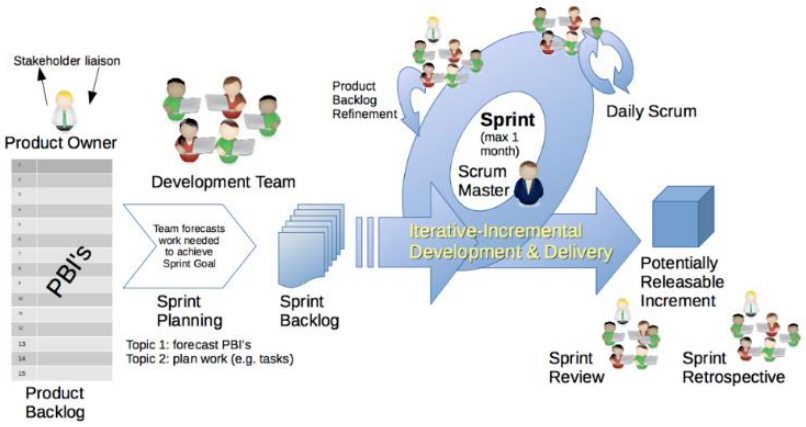

Figure 2.3. Scrum Model[4]

According to (Sharma, Sarkar, & Gupta, 2012), Agile product development has both positive and negative points (Table 2.3).

Agile presents the firm with a fast-changing situation based on the customer's needs. Developers are permitted to do what is necessary and implement new features. However, not knowing customers' needs and how the firms can encourage customer participation are critical questions for this methodology.

[4] Source: https://www.intellectsoft.net/blog/scrum-model-for-agile-software-development/

Table 2.3. Pros and Cons of Agile

Pros	Cons
Adaptive to environmental change	Customer interaction methods
Driven by customer satisfaction	Lack of documentation
Least bureaucracy	Wasted time and resources due to constant changes
Reduces development risks	Work pressures on developers

2.2.1 Agile principles

(Williams, 2012) conducted a study to prioritize Agile principles. Those principles are taken from the Agile manifesto and are fundamental for Agile practices. The principles are set out in Table 2.4.

Table 2.4.Agile Principles[5]

No.	Description
1	Ensure customer satisfaction through continuous development and valuable product delivery.
2	Change requirements anywhere and anytime as a competitive point.
3	Cut down the delivery time and ensure optimization.
4	Provide stable communication throughout the company hierarchy during the process.
5	Maximize employees' collaboration to create synergies based on their capabilities.
6	Establish a reliable information system to support the decision process.

[5] Source: Williams (2012).

Table 2.4. Agile Principles (Resume-End)

7	Consider high-quality, valuable activities during the NPD process.
8	Pursue the feedback loop at the proper time to react quickly to market needs.
9	Pay attention to technical aspects and standards in the design and development phases.
10	Try to break the job down into simple steps.
11	Provide a product overview and the best materials and requirements to achieve it.
12	Ensure that each iteration is more efficient to bring the final product closer to markets' needs.

Those principles help the company to move the right way for the executive phase. The emphasis is on quality, time management, and a customer-centred process from the design phase to the delivery phase. Developers are assumed to act intelligently as a self-organized team to implement Agile product development.

2.2.2 Agile practices

The Agile practice is a procedure to decrease time and respond to changes in active market environments. (Eppinger, 2019) talked about Agile outside of IT companies. He said, "Every company is trying to be more Agile and it's become part of the regular engineering management dictionary" Those practices are divided into ten main streams.

Regardless of the practice's name, companies understand the concept underlying each one and they adopt that advice based on their capabilities and product types.

Table 2.5. Agile Practices [6]

No.	Practice	Description
1	Spiral development cycles	"Finding the problems is more fluid and iterative, addressing a problem through multiple passes, and cycling through the various stages of design until issues are resolved in small increments."
2	Time-boxed sprints	"Splitting development tasks into a series of iterations that must be accomplished within a specific period. It shows progress and keeps everyone working within the same fixed parameters."
3	Scrum teams	"These are groups of individuals charged with working on a set of tasks to meet agreed-upon product requirements by following a common set of goals."
4	Daily meetings	"A key tool in the sprint is the daily meeting. It sets the context for the coming day's work, facilitates coordination, and serves as a forum to address any remaining concerns or problems."
5	What vs. how	"This concept separates authority for what gets done from how it gets done. The product owner prioritizes work based on requirements and maintains a running list of what needs to happen and what is backlogged. The scrum master ensures that the work gets done using mechanisms like a daily meeting or running interference."
6	Kanban	"Kanban is a just-in-time scheduling system that relies heavily on visuals to track real-time manufacturing capacity. This visual roadmap tool is an effective way to keep the team apprised of who is doing what and what's been completed."
7	Feature prioritization	"Not every feature or plan is equally important. Agile practices emphasize the prioritization of work so that high-value tasks are first in line."

[6] Source: (Eppinger, 2019)

Table 2.5. Agile Practices (Resume-End)

8	DevOps	"A mashup of development and operations, DevOps involves getting operations and development to work closely together at early-stage design. The alignment allows issues to be resolved quickly and integration to happen continuously."
9	Branch and merge	"Branch and merge let people work separately on portions of a system and then combine their work in a way that seamlessly preserves changes."
10	Hybridized Agile and planned-staged processes	"Retaining the planning and control elements of the traditional staged-gate development process while allowing for Agile execution. First sight is to break up the work of each stage, with multiple Agile teams doing parallel sprints and work planned incrementally within each stage. Another option is the scaled Agile framework for enterprise (SAFe), which facilitates coordination and planning across scrum teams."

In the Agile methodology, all practices centre on the product owner and scrum master, who determine the work and duties, as well as measurements to assess the quality of the work that has already been done. They break down the work into small scheduled movements and they assign teams to work in parallel. They then take the results of each team and combine them to show all participants at the daily meeting so everyone can grasp the progress and reschedule if necessary based on valuable features and customer needs that are detected in the feedback loop. This routine system makes the firm more creative and lets it respond fast to market needs.

2.3 LS methodology

Lean is an approach that emphasizes reducing waste in the initial step of the NPD process by considering product design based on customers' tendencies and manufacturing capabilities in the real world (Biazzo, Panizzolo, & Gore, 2017), (Miner, Bassof, & Moorman, 2001). After defining valuable features and considering the technical challenges, ideally, an error-free designed product will be introduced to the market (Morgan & Liker, 2006).

(Blank, 2017) and (Ries, 2011) developed the Lean concept in a new framework under the Lean Startup name as a comprehensive approach to the NPD process. We will discuss the component of the LS approach related to the product development process (Frederiksen & Brem, 2017).

There is no single definition of "startup" that covers all angles of the concept (Eisenmann, Ries, & Dillard, 2012). (Ries, 2011) said that "The start-ups are ventures to create a new product or services under an uncertain situation. This uncertainty is caused by the experience shortage, fast changes in markets, and customers' desire for more complicated products (Bortolini et al., 2018).

(Yang, Sun, & Zhao, 2019) stated that "The LS model emerging from Silicon Valley recently has become worldwide practice. In this model, search and execution are the two primary activities conducted by entrepreneurial firms. Search activities focus on learning and discovery, such as exploring new customer and market segments, while execution activities focus on implementing well-defined plans and scaling up."

In the search phase, according to (Gavetti & Levinthal, 2000), there are two kinds of search processes: "forward-looking search, which is based on a cognitive relationships' map between activities and outcomes, and backwards-looking search, which is based on company experience" This phase is a learning process to understand problems and find possible solutions (Huber, 1991).

Firms may "iterate back and forth with their business model" to decide whether the adjustment is required to obtain the best fit (Bosch, Olsson, Björk, & Ljungblad, 2013).

In the execution phase, experiments are the basis for adjusting hypotheses and learning with the actual performance plan. This can be useful to execute a real business plan with the minimum usage of resources, cutting down on waste in the organization and enhancing the chances of success (Humble, Molesky, & O'Reilly, 2014);(Owens & Fernandez, 2014);(Ries & Euchner, 2013).

Experimentation helps developers understand "market opportunities and how they may exploit them" and shows how to optimize customer satisfaction while bridging the gap between the search and execution phases (Gans, Stern, & Wu, 2019),(Baumann, Schmidt, & Stieglitz, 2019).

To comply with the outcomes of the execution and search phrases, and choose the right experiments, (Blank, 2017) argues that product leaders "should search for a repeatable, scalable, and profitable model at first and after doing this, they should enter the execute phase"

Those preliminary activities are set out in the book The Four Steps to the Epiphany (Blank, 2013). He proposed testing business hypotheses in direct interactions with customers. He believed entrepreneurs are looking for reliable, scalable measures to steer their enterprises to success, emphasizing disciplinary entrepreneurship, where entrepreneurs provide the resources needed to create values to exploit opportunities for success in the market

(Blank & Dorf, 2012) describe customer identification and validation flow, creation, and building by running new ideas and organizing resources to create effective movement in the company; these are crucial requirements for the business (Rappa, 2001). LS influences interfirm relations through idea formation and progress measurement to validate learning and "builds a bridge between the information collected from customers and the (perceived) authority of coaches which consumer level products can be designed to effectively supply the under-served market" (Pease, Dean, & Van Bossuyt, 2014).

(Ghezzi & Cavallo, 2018) applied the LS methodology with customer involvement in digital startups; they also discussed the advantages and disadvantages of this methodology. Table 2.6 is based on their experiment.

Table 2.6. LS Pros and Cons[7]

Main advantages of LS:	Main disadvantages of LS:
1. Reduces time and costs to test initial ideas	1. Defining the measure for a prototype
2. Supports business ideas with customer needs	2. "Detecting and engaging early and trial users"
3. Determines the NPD process in real situations	3. Defining priorities
4. Can receive rounds of financing	4. Narrow vision of one market
5. Introduces a new intellectual property strategy	5. Lack of a plan to find reliable information

[7] Source: Ghezzi and Cavallo (2018), adapted by the author.

LS would be a good methodology for launching a new product, but many factors can influence it because of the uncertainty involved. High-risk activities can make a company a pioneer in the market or they can destroy it.

2.3.1 LS principles

The key activity in the NPD process is "to turn ideas into products, measure how customers respond, and then learn whether to pivot or persevere. All successful startup processes should be geared to accelerate that feedback loop" (Ries, 2011).

Before we consider the LS principles shown in Table 2.7, we should examine two approaches that should be avoided (Edison et al., 2015);(Ries, 2011).

- The stylish strategy plan: sitting behind a desk with a cup of tea, planning a strategy that considers the customer as mere dough to be moulded, and ending up with a stylish, attractive plan that supposedly shows that everything is in place.
- Ignorance and mismanagement: it is important to remember that higher education is not an indicator of real knowledge; a manager or entrepreneur who has some applied knowledge, creativity, skill, experience, and leadership characteristics will make a positive impression on project stakeholders.

These principles in Table 2.7, follow from the LS framework; in Figure 2.4, the initial idea journeys through the BML loop and emerges as a successful product in the market:

Table 2.7. LS Principles[8]

No.	Principles
1	Innovation can happen everywhere – In a garage or a big corporation. It requires participants to come up with new ideas and launch initiatives in the internal environment.
2	Entrepreneurship is management – Entrepreneurship is knowledge and it applies in a context of extreme uncertainty; we should consider "entrepreneur" to be a job title in a company that deals with innovation and plans to grow the business in the future. An entrepreneur's coaching skill directly affects LS in the enterprise, as do honest behaviour and acting as a leader to manage resistance to change and bias and implement a process to move the innovation forward to commercialization.
3	Build-Measure-Learn (BML) – This loop is the main logic underlying LS that helps the company implement fast iteration and validate the basic idea of a Minimum Viable Product (MVP) to stimulate a customer response or behaviour, learn about a pivot or persevere step, measure the success of the process and incorporate all activities into the Agile feedback system.
4	Validated learning – The company involves customers in the development stage, which reduces the testing time to confirm ideas.
5	Innovation accounting – To assess the situation, reporting should be focused on measuring progress, defining milestones, and prioritizing work. The end-users' opinion and not income reports will determine success in the market.

[8] Source: Ries (2011), adapted by the author.

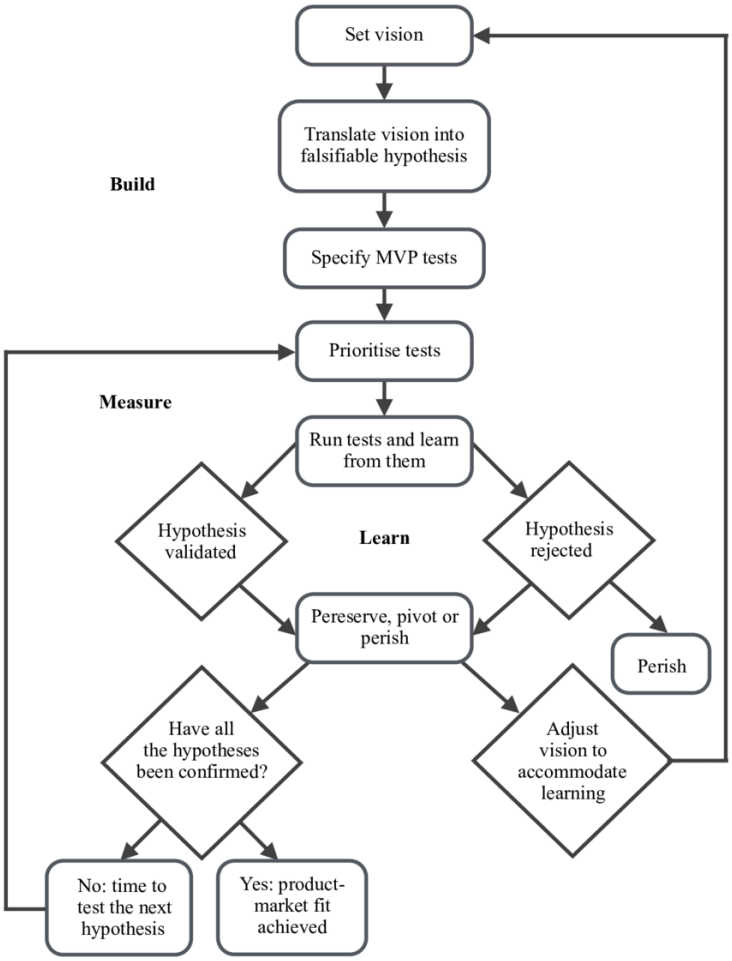

Figure 2.4. LS Framework[9]

2.3.2 LS practices

LS is a rapid cyclical methodology that validates learning by running purposeful experiments to assess product compliance or service features based on real customers' experiences with the MVP and analyzing the data to achieve the best result or pivot (Maurya, 2012); (Ries, 2011); (Mansoori & Lackéus, 2019). Based on this concept, we consider the 10 LS practices set out in Table 2.8.

[9] Source: Eisenmann et al. (2012)

Table 2.8. LS Practices[10]

No.	Practice	Description
1	Minimum Viable Product (MVP)	MVP is the outcome of testing the hypothesis; it may be a smart movement off the BML cycle; once the MVP is recognized, a firm can work on tuning the engine, learning from the market reaction, and measuring with actionable metrics that can prove cause and effect concerning all hypotheses in the final product development.
2	Customer involvement	In the customer involvement process, the firm can discover, test, and validate many business assumptions, such as whether the product is useful for consumers or not and the credit factors for the customer group. This process is rooted in the scientific method; it consists of the front-end in the NPD process. Apart from acceptance or rejection of the assumption, customer involvement is a solution-driven process that shows how to modify current mistakes or defects.
3	Creativity potential	Leaders may have either a direct or indirect influence on employee creativity. Leaders can directly affect employee creativity through their behaviours, which may encourage or discourage employees from taking risks to come up with new and useful ideas that may threaten the status quo. They should encourage employees, who are the main key to the successful implantation of LS, and who also serve as a brand image. Leaders should understand the value of employee commitment during company adaptation.

[10] Source: Ries (2011), adapted by the author

Table 2.8. LS Practices (Resume)

4	Functional BML loop	It is necessary to have an iterative system to control consistency on the market. The feedback loop from understanding needs and changes in requirements to learning and trying to fit them into the internal NPD process in the build section and finally running measurements to determine market satisfaction is vital.
5	Learning validation	The firm has to realize what it needs to learn, and then figure out what needs to be measured by using innovation accounting. This will eventually reveal whether it has gained validated learning or not to determine what product should be built.
6	Real measures	"Three A" measures increase the efficiency of measurement tools and reports. *Actionable* measures demonstrate clear cause and effect, to guide actions necessary to replicate results. *Accessible* means the system should automatically generate the latest data, which should be simple and easy to visualize (e.g., cohort analysis). *Auditable* refers to credible data that can be tested by talking to customers directly and exploiting data from experts.
7	A small batch of change	The small batch of change helps companies make minor changes without inconveniencing customers at minimum cost and time, to respect customers' wishes and make sure the modification is valuable.
8	No-waste efforts	Since quality cannot be traded for time, to avoid the waste of resources, time, and money, companies must control the production process from design to product delivery. Once a defect is recognized, they freeze their activities to resolve the problem. This practice is fostered by Lean manufacturing (LM) and Lean product development (LPD) principles.

Table 2.8. LS Practices (Resume-End)

9	A growing, adaptive approach	LS was initially designed to create fast-growing tech ventures and adapt products as the company grows. The engine of growth steers the firm to achieve a sustainable advanced position in the market. It does not occur at one specific time; it is a progressive trend.
10	Pivot or Persevere	If an idea is not working out, the company needs to change its strategy. Otherwise, leaving the market would be a wise option to avoid further losses. A Pivot is done based on the product development team's reports about recent achievements and goals. The product manager will evaluate the possible solution or change in strategy, seeking all opinions about the problem and will try to make the product closer to customers' expectations.

In LS, most practices are designed to help product leaders make the right decision. Those practices evaluate different aspects of the NPD process. MVP is the main point of identifying customers' needs and values and having them participate directly or indirectly in the development process. The BML feedback loop makes a bridge between the company and the market so the company can discover what the market wants. Valuable features of functional measure reports such as customer growth and retention rates allow the company to take action to correct the product or leave the market.

2.4 The intersection of Agile and LS

Applying the LS method can allow a company to examine market hypotheses and quickly acclimate to findings; on the other hand, applying Agile methods can promote iterative release cycles and "pull risk-reduction earlier" in the NPD process, increasing companies' ability to deliver value to their customers faster (G. Benefield & Greening, 2013).

Many authors believe those methods complement each other; for example, the Kanban system established in LS to operate production procedures (Ikonen, Kettunen, Oza, & Abrahamsson,

2010) has been used in Agile methods as well (Campanelli & Parreiras, 2015). In another example, the Pull techniques in LS have been used in the Scrum model (Barton, 2009).

Despite Agile and LS's similarities and differences (Hallgren & Olhager, 2009), researchers agree that Agility that contains "Leanness" can improve the chance of a successful NPD process (Conboy & Fitzgerald, 2004).

According to (Ghezzi & Cavallo, 2018), [digital] companies in the initial phases of their development invoke Business Model Innovation (BMI), with different levels of uncertainty in their environment; firms may decide to change roles, as a proper response to this dynamic situation. They claim that the "LS approach can be identified as a form of Agile to work at the level of strategy and/or business model". In other words, LS is a part of the Agile group of methods.

Indeed, in the fast-paced environment, consisting of LS effort in the strategic agility apart from the start-up's role and their product was recommended. But in the unknown role apart from the velocity of environment LS embedded in Agile development in the operational agility was recommended. The innovation culture and motivation are preconditions for the entire process.

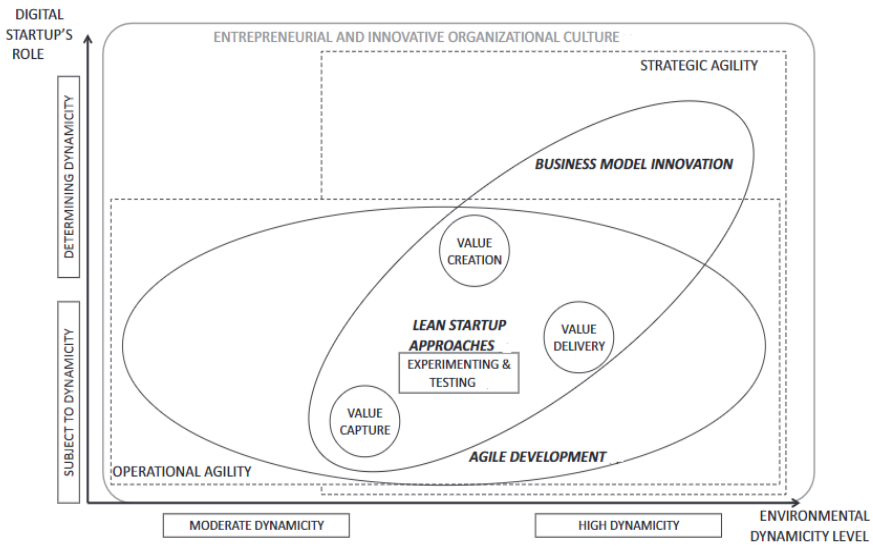

Figure 2.5. Connection between Agile and LS[11]

[11] Source: Ghezzi and Cavallo (2018).

It is hard to distinguish Agile and LS from each other but there is a difference in their purposes: Agile targets *how* to do while LS targets *what* to do. LS is more functional and operational; the distance between LS principles and practice is smaller than in Agile. (Veretennikova & Vaskiv, 2018) put it as follows: "LS solving the problem with minimal cost, step by step with the statement and confirmation of the hypotheses, Agile as the division of the big task into simple subtasks and Customer Development, a deep understanding of a client of their problems and needs, allows the companies to test the business model with the possibility of its scaling, spending the least amount of time and resources".

At the intersection of Agile and LS, we did not find any extensive studies that cover our research goal, although some studies investigated the use of those methods in different industries.

(Inayat et al., 2014) noted that, in Agile, communication failure is the cause of product failure. Because of sudden changes in requirements, an absence of appropriate client representatives, project complexity, and the lack of documentation, multiple problems crop up. They noted that Agile thrives on extensive collaboration, based on direct communication, and upgrades traditional procedures based on the current trends to deal with the technical and market issues.

Agile is more efficient in the NPD process (Eberlein & Leite, 2002) in terms of reducing the waste and risk of failure by short iterations (Xiaohu, Bin, Zhijun, & Maddineni, 2004), and higher fault correction rates (Hossain, Babar, Paik, & Verner, 2009). But the result of those studies aimed at the Agile implementation outcome and the designing phase was neglected.

(Da Silva, Martin, Maurer, & Silveira, 2011) examined "the integration of Agile and user-centred design". They found that Agile did not support the design phase and suggested some corrections to solve this problem, including allocating a user-centred design specialist in the Agile team, prototyping, pilot testing, and building user cooperation depending on the company's size and ability to handle the change in process, product type, or market variety (Barlow et al., 2011). Coordinating each phase of Agile needs a highly organized relation among the teams and company structure and expectations. In hence, (Lindsjørn, Sjøberg, Dingsøyr, Bergersen, & Dybå, 2016) studied the specific relation between teamwork quality and structure and Agile performance; they that those concepts are closely related and they affirmed that the role of product owner has a strong impact on Agile performance. They also observed the effects of a lack of a proper measurement

plan to evaluate performance. To pursue the Agile and achieve success in the market needs proper tools and techniques. (Azizyan, Magarian, & Kajko-Matsson, 2011) surveyed current Agile tool usage and needs in the IT area. They showed that Scrum is the most popular Agile method. They also mentioned the Kanban technique, which implies that firms are using newer Agile methods. They also showed that half of their respondents used project management tools to handle their NPD process.

In the LS concept, (Edison et al., 2015) contrasted internal and external ventures, noting that maintaining internal creativity inside the firm is more efficient than outsourcing it. Based on this statement, the role of LS leaders in encouraging employees to get involved in the creative process is crucial. In his article, (Ellarby, 2013) mentioned leader can steer LS principles such as finding gaps and innovation streams, pivots to move the company forward, sustainable learning from customers and delivering value through the identification of defects and grasp of the market, as well as the use of LM principles to reduce waste in a non-profit organization with social responsibility impacts; to reduce the risk of the product failed in the market. Due to success in this process, (Taipale, 2010) described some unique LS practices in the IT sector: changing the product owner to problem finder, solution teams, identifying problems through metric reports and continuous development with user interface designers, visualization measuring, and determining the root causes of problems led to reduced lead times.

Also, (Veretennikova & Vaskiv, 2018) noted that LS practices can be combined with the business canvas model to identify and validate customers' requirements and problems in the IT area. But out of the IT section,

(Blank, 2013) pointed out that the customer development process in LS emphasizes learning about customers and their problems in the early stages of the NPD process; he considered four steps to

execute this task, matching the customers' involvement with company structure, as shown in Figure 2.6.

Figure 2.6. Customer Development Process

"1. *Customer discovery* tests hypotheses about the nature of the problem, interest in the product or service solution, and business viability.

2. *Customer validation* tests the business viability through customer purchases and in the process creates a "sales road map", a proven and repeatable sales process. Customer discovery and customer validation corroborate the business model.

3. *Customer creation* executes the business plan by scaling through customer acquisition, creating user demand, and directing it toward the company's sales channels.

4. *Company building* formalizes and standardizes company departments and operations."

In the intersection of Agile and LS; (Casselman, 2014) investigated how the LS methodology can be helpful in the development of complex products. He noted that the lack of extensive knowledge of LS is the main cause of the low overall usage rate. Some firms also indicated that they used some LS practices in their NPD without being aware of them or the common points LS shares with other methodologies such as Agile and Design thinking.

(Melegati, Goldman, Kon, & Wang, 2019) conducted a case study in Brazilian software enterprises and found that these companies did not systematically adopt LS and Agile, "but rather ponder the adoption based on a set of influences, such as the founders, market, business model, and the start-up ecosystem".

(Stratton & Warburton, 2003) compared Lean and Agile practices in supply chain management. They showed that the Lean supply paradigm reduces the need for protective inventory, while the

Agile supply paradigm provides a practical method for exploring innovative tactics to mitigate the impact of conflict on protective inventory based on market demand.

In their study, (Isomursu, Sirotkin, Voltti, & Halonen, 2012) argued for the role of user design experience in Agile. The lean transmission was used to reduce wasted time throughout the process and eliminate the design defects.

(Staron & Meding, 2011) described Lean and Agile experiences in a software company. They proposed a measurement system to assess the existence of bottlenecks in the workflow and made some suggestions on monitoring them.

(R. Benefield, 2009) used applicable LPD practices in the Agile environment to provide a useful conceptual guide for businesses that want to adapt and track the software life cycle.

(Rodríguez, Markkula, Oivo, & Turula, 2012) ran a survey to assess the amount of Agile and Lean usage in a software company. They showed most of the companies were using Agile methods. “Although Lean principles appear to be less used than Agile practices, principles such as eliminate waste and excess activities and focus on creating customer value are quite used by the respondents of the survey. To increase the productivity and quality of the products/services as well as to reduce time-to-market are reported as the main goals for adopting Agile and lean methods.”

(Bento & Tontini, 2019) presented lean principles in the Brazilian manufacturing industry, confirming the relationship between Lean and the company’s size. They confirmed that the most frequently used practice is customer focus in terms of external customer involvement in the NPD process. “The most neglected practice is related to the problem-solving process. These results confirm the findings of (Shah & Ward, 2007), that large companies implement lean practices more often than small businesses”.

2.5 Summery

In this chapter, we defined and discussed the NPD process components. We reviewed the related researches in this subject to foster the fundamental of this research.

Most of the above-mentioned studies examined and evaluated the use of Agile and LS in the NPD process separately; even studies that investigated Lean and Agile together did not discuss their

relations or position among NPD tools and the expected performance outcomes. Considering NPD tools and expected performance and determining product types can affect the entire NPD process. Moreover, it is not easy to understand the differences between LS and Agile.

Based on this notion, we found the research goal as a proper treat to the existing gap in this field.

CHAPTER 3 METHODOLOGY

3.1 Research framework

To achieve the research goal ("The applied practices adopted in the face of new challenges to the business's current and anticipated situation in the internal or external environment and integrate resources for success in the market"), we sought to identify the main principles and practices of LS and Agile. The tools applied in the NPD process were identified in Chapter 2. Other steps included defining the specific objectives, defining hypotheses, creating and administering a survey, collecting data, doing statistical analyses of the data, and interpreting the data.

Our approach in this research is quantitative, based on statistical analysis to indicate the importance of LS and Agile practices.

3.1.1 Objectives

This research makes a connection between the LS and Agile methodologies. It seeks to acquire more proficiency and determine the valuable package of NPD components for different enterprises, as well as an understanding of valuable practices in both methodologies. The practices applied in different business sectors will be identified and compared to understand the importance of those practices that are appropriate for each sector and their impacts on outcomes, taking advantage of the overlaps between methods. The following steps were applied:

- Distinguish the data to assess the existing condition.
- Determine the impact of each tool on practices.
- Determine the impact of each practice on performance.
- Investigate inefficient tools and practices and understand the gaps.

3.1.2 Hypotheses

A hypothesis is a recommended solution for an unexplained occurrence that does not fit into the current accepted scientific theory (Bradford, 2017). If there is more than one hypothesis, "multiple testing" helps to validate "more than one hypothesis at a time. It is a subfield of the broader field

of multiple inferences, or simultaneous inference, which includes multiple estimations as well as testing" (Shaffer, 1995).

Thus, we formulated our hypotheses based on relations in the NPD process. This means that we will cover the whole NPD process including choosing the proper tools, practices, and expected results and the relation among tools, practices, and performance, as well as product types, to understand the differences between the NPD process in tangible and intangible product producers.

In this research, based on the points raised in section 2.4 and 2.5 and light of previous studies' limitations, we define the conceptual models (Figure 3.1) used to test the hypotheses.

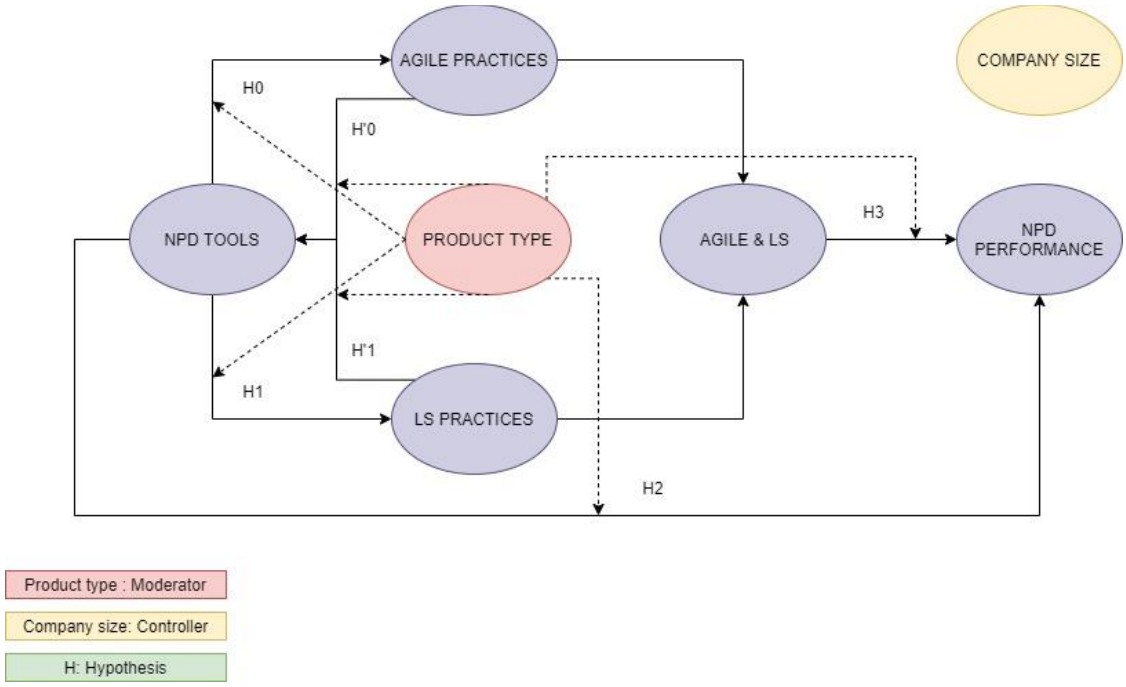

Figure 3.1. Conceptual Model

In this model, each hypothesis tests the relationship between the two variables as dependent and independent variables and we consider the control variable and moderator to compare the results; some hypotheses were presented in previous studies but we will prove those assumptions based on statistical testing to support our results.

H0: Adoption of NPD tools has a significant impact on Agile practice adoption.

H'0: Adoption of Agile practices has a significant impact on NPD tool adoption.

H1: Adoption of NPD tools has a significant impact on LS practice adoption.

H'1: Adoption of LS practices has a significant impact on NPD tool adoption.

H2: Adoption of NPD tools has a significant impact on NPD performance improvement (Yeh, Pai, & Yang, 2010).

H3: Adoption of Agile/LS practices has a significant impact on NPD performance improvement (Bortolini et al., 2018),(Leite & Braz, 2016).

The direction of causality for the NPD tools and Agile/LS practices for H0 and H1 and H'0 and H'1 is not clear, so we will test both sides to confirm the direction.

3.1.2.1 Measures

Table 3.1 indicates the types of variables.

Table 3.1. Variables

Hypothesis	Independent variable	Dependent variable	Other variables
H0	NPD Tools	Agile Practices	Company Size (CS) as a control variable
H'0	Agile Practices	NPD Tools	
H1	NPD Tools	LS Practices	
H'1	LS Practices	NPD Tools	Product Type (PT) as moderator
H2	NPD Tools	NPD Performance	
H3	Agile /LS Practices	NPD Performance	

Company size is determined as shown in Table 3.2, which presents responses to question 2 of our survey. (Bento & Tontini, 2019) categorized companies based on the number of employees. Companies with fewer than 100 employees are considered small (S) and those with more than 101 employees are considered medium or large (ML).

Table 3.2. Company Size

2 A1 A2	How many employees does your company have? ☐<100 ☐101–500	A3 A4	☐501–1,000 ☐>1,001	 A1 A2	Division based on question 2: A1 (Small firms) A2+A3+A4 (Medium & Large firms)

Dividing the companies between tangible product producers and intangible product producers is done based on answers to question 5 in the survey (Appendix A). According to (Levitt, 1981) intangible products cannot be touched and tangible products are touchable (see Table 3.3).

Table 3.3. Company Products

5 A1 A2 A3 A4	What option is the best fit for your company's main offer? ☐We offer a service ☐We license software ☐We sell tangible products (hardware) ☐We offer a service based on software (SaaS)	A5 A6 A7	☐We offer a service combined with a tangible product ☐We offer a tangible product with embedded software ☐Our offer is a combination of a tangible product, software, and service
 A1 A2	Division based on question 5: A1+ A2+A4 A3+A5+A6+A7		

3.1.3 Survey procedure

Opinion-based questionnaires with Likert scales are generally used for evaluating the current and desires situations (Barua, 2013).

Many scales can address the situation being investigated. This survey used different scales for each section, mainly a five-point scale, where 1 is defined as indicating minimum effort or agreement and 5 as maximum effort or agreement.

This survey (Appendix A) was inspired by the 14th Annual Agile Survey[12] structure and contained five sections. Underlying each section of the survey was information from our literature review. The first section investigated the company's background and the respondent's position. The second part tried to assess and understand the current tools and techniques that companies use in their NPD process. In the third section, we asked about Agile practices, using simple terms related to the main ideas of each practice. In section four, we investigated LS methodology. Finally, in the last section, we asked about the tangible results of the outcome of the NPD process in comparison to the situation beforehand.

We implemented our questionnaires on a local platform to ensure quality and safety based on Canadian regulations. This platform keeps data safe and encrypted and protects respondents' identities.

Before running the survey, we obtained an ethics certificate from the research ethics committee at Polytechnique Montréal (Appendix B), which determined how we gathered and processed the data.

Then we invited target participant groups by sending invitations through email, Facebook, and LinkedIn groups and connections.

The invitation was a formal document to inform recipients about the main goal and general situation of the research and invite them to share their relevant experiences (Appendix C); we assumed the target recipients were involved in the NPD process in their companies and understood

[12] 14th Annual Agile Survey by VersionOne: https://www.stateofAgile.com/#ufh-c-473508-state-of-Agile-report.

the main concept and goal of the research based on the consent page for the survey and the contents of the invitation letter.

After launching the survey and sending several thousand emails and invitations around the world, we received complete answers, representing an adequate data set to test our hypotheses (Figure 3.2).

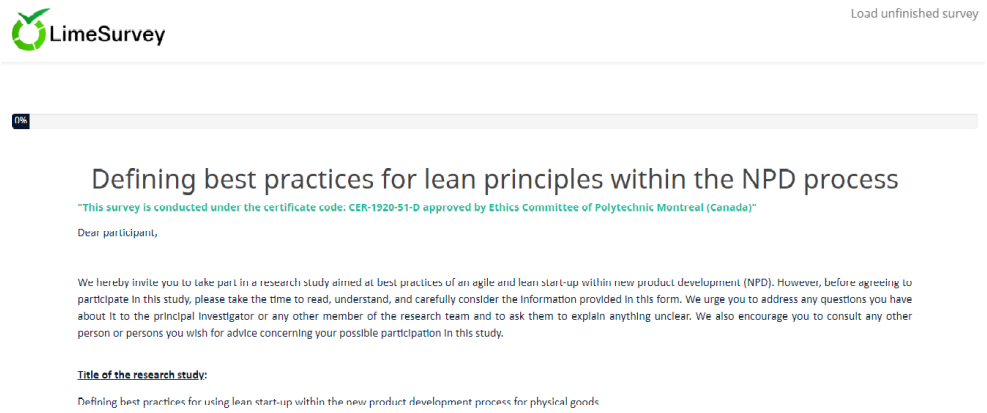

Figure 3.2. Lime Survey Overview

3.1.3.1 Reasons for participation

Our study could be used to evaluate the current situation of participants' NPD process and to inform them of valuable practices and tools to steer the NPD process in their organization. The results of this research can be used to justify organizational change by presenting new products or services and showing the effects of this change in the form of logical steps, unique patterns, or entrepreneurs' actions targeting mass markets.

3.1.3.2 Corporate culture

One of the most important concepts in the NPD file is distinguishing the differences between success in the market against rivals and the realization of a competitive advantage, which may be the outcome of a purely professional organizational culture (Van Muijen, 1999).

Organizational culture has a substantial impact on NPD performance, innovation, motivation, and internal and external integration in a company (Acar & Acar, 2012). Organizational culture is

defined as “a form of basic assumptions invented, discovered or developed by a given group as it learns to cope with the problems of external adaptation and internal integration” (Schein, 1990).

(Cameron & Quinn, 1999), stated that “culture defines the core values, assumptions, interpretations, and approaches that characterize an organization and success-oriented organizational culture increase organizational effectiveness.”

Thus, we collected data about companies’ backgrounds to understand each company’s character and the specific ways it acted during the NPD process as a result.

3.1.3.3 Reasons for and barriers to implementation

Many authors have enumerated the reasons for adopting LS and Agile and the benefits that organizations can receive (Petersen & Wohlin, 2010).

- Emphasis on minimization.
- Enhanced contact with the customer.
- Flexible reaction to changes.
- “Self-organizing, aware of goals, and engagement in the process by the routine meeting.”
- Decisions become data-driven.

The results of a study by (Salas Martinez, 2016) indicate some barriers to proper implementation of those methods across a company, which reduce the expected benefits:

- “Resistance to change towards a more innovative company culture”
- “Insufficient knowledge and understanding of the NPD methods”
- Lack of time for the BML loop to efficiently generate tangible change.
- Lack of proper communication.
- Lack of trust in the new academic methods.
- Absence of top management commitment to communication and performance.

3.2 Overview of statistical analysis

To conduct the statistical analysis, we followed the procedure described in Table 3.4, which constituted a useful analysis providing accurate results to justify our research hypotheses. Inappropriate statistical methods can cause a researcher to miss the statistical significance of results (Dunning, 1993).

Table 3.4. Statistical Procedure

No.	Step	Techniques
1	Sample characterization	Frequency analysis
2	Construct validation	PCF analysis – Reliability test
3	Construct characterization	Descriptive analysis – Correlation test – Independent test
4	Hypothesis validation	Multiple linear regression

In the first step, we conducted sample characterization to find out how our sample was distributed and gain an overview of the respondents, and thus to determine the control variable and moderator.

The second step was construct validation; this step provided a new categorization of the variables in the factor framework in each part of our survey and helped us to distinguish related variables and the most valuable packages of tools, practices, and expected results.

The third step was construct characterization; we ran the descriptive analysis as a logical method to control our data set based on statistical indices such as mean, standard deviation, variance, skewness, and kurtosis. A normality test based on descriptive analysis was run to determine the proper statistical method for independent analysis to reveal differences in our data set based on our control variables. We also ran a correlation test to understand the interrelations among factors. Finally, in the fourth step, we validated our main hypotheses by running a regression test.

CHAPTER 4 RESULTS

4.1 Sample characterization

4.1.1 Frequency analysis

We received 132 complete answers to the survey. We used frequency analysis to get a sense of the companies' background and distribution of the data. SPSS software was the main tool we used for statistical analysis (Spss, 2011).

The frequency analysis reveals how our responses were distributed. This classification helped us to choose the proper control variable and moderator to achieve the research goal. We indicate the results in Figure 4.1.

Most of the respondents worked for IT and software companies; the industrial and education sectors were the second and third most common sectors; construction and telecommunication were the least common in this survey.

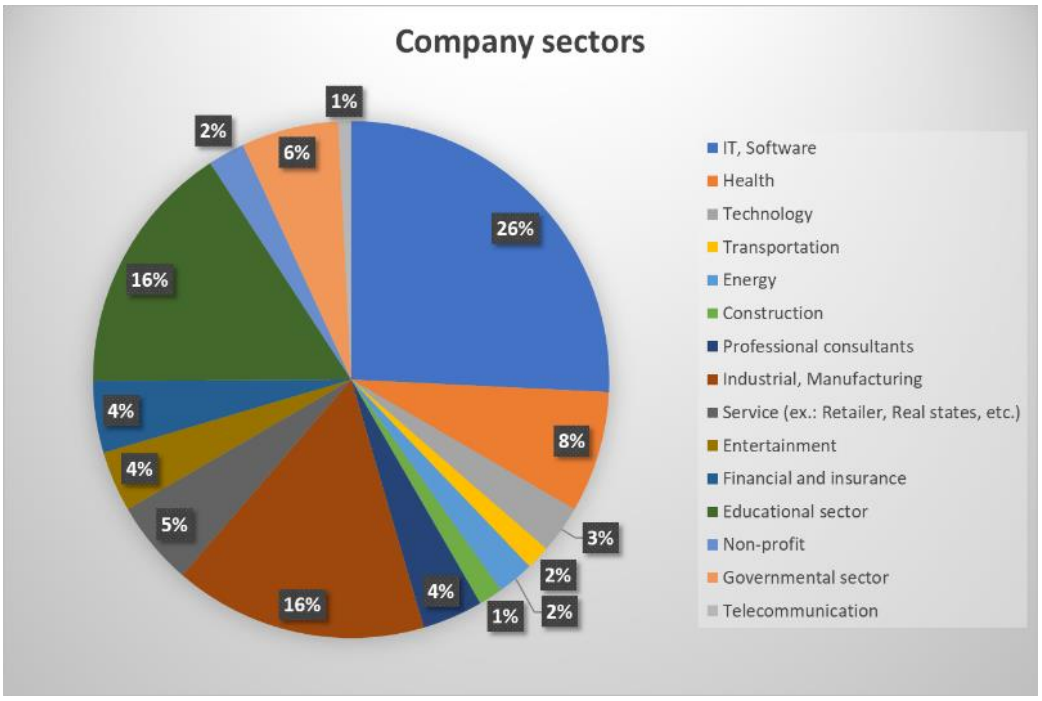

Figure 4.1. Company Sectors

As Figure 4.2 shows, more than half of the respondents worked for small companies, 29% for medium-sized companies, and 20% for large companies.

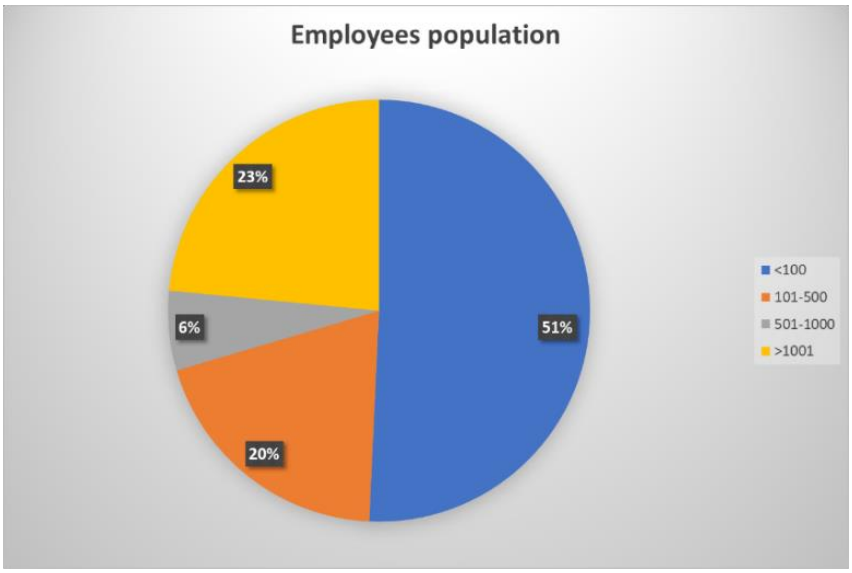

Figure 4.2. Number of Employees

Sixty percent of the respondents stated that their company had been in operation for more than 10 years (Figure 4.3); 10% of the companies were newcomers in the market and were trying to acquire a stable market share and position.

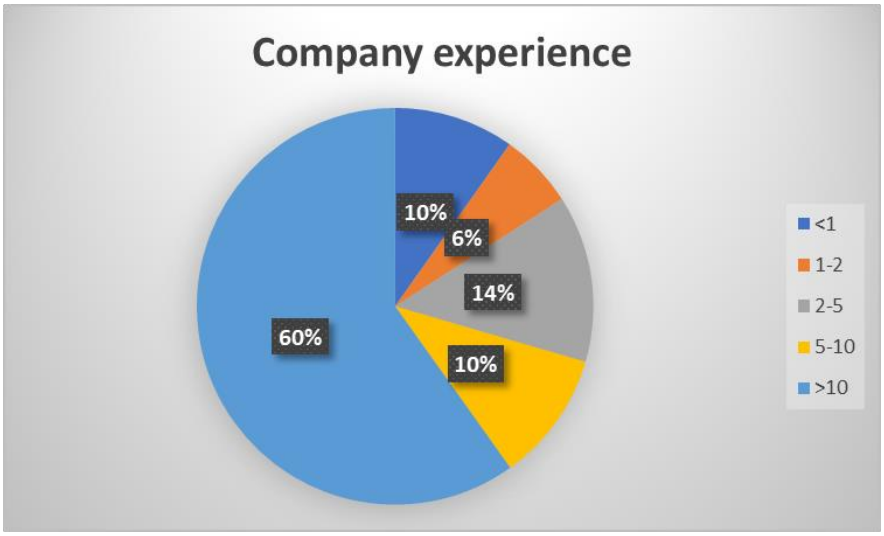

Figure 4.3. Company Experience

As indicated in Figure 4.4, 50% of the companies are located in Europe, and 28% in North America. Only 1% of the respondents said they worked in Africa.

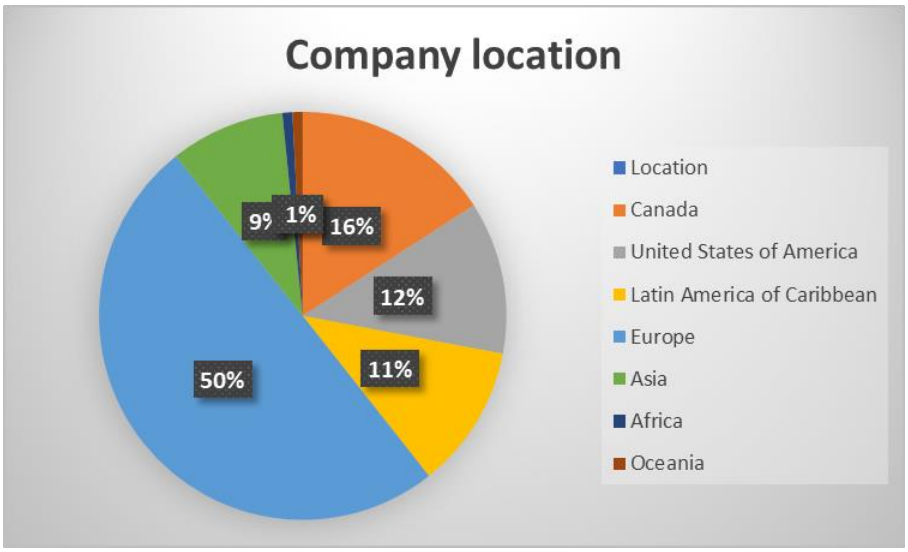

Figure 4.4. Company Location

Figure 4.5 shows that 52% of respondents considered themselves to be service providers. However, according to Figure 4.6, 64% of respondents considered their companies to offer services and/or intangible products and 36% saw themselves as tangible product producers.

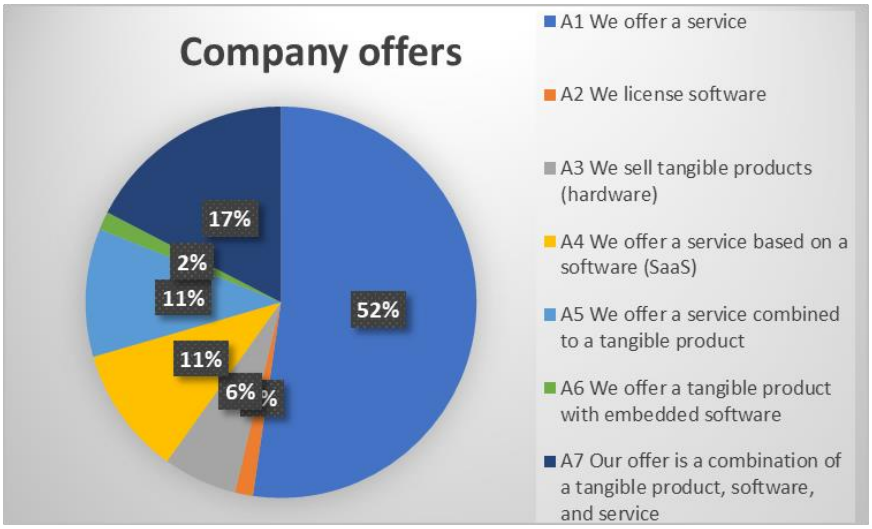

Figure 4.5. Company Products and Services

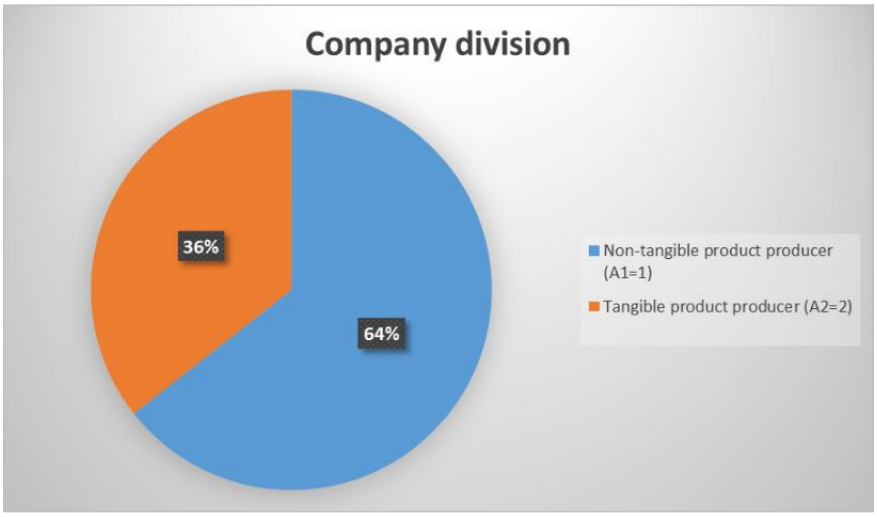

Figure 4.6. Tangible vs. Intangible Product Breakdown

To sum up, 26% of respondents worked in the IT and software sector, more than half worked for small companies with a workforce of fewer than 100 people, but around 60% of respondents were in companies established more than 10 years, so we can hope they already have an appropriate NPD process or else provide essential services in a context of exclusivity.

Most respondents came from European countries. Finally, 64% of the companies produced intangible products and 36% were manufacturers. Based on their main activity and product, we divided companies into two categories: intangible vs. tangible producers. This is our control variable in the statistical analysis.

A closer look at the data set reveals more information about the current situation of the NPD process in the responding companies. Based on our division into two groups, intangible product producers and tangible product producers, Table 4.1 shows the intangible/tangible breakdown in the various sectors represented in percentage. For instance, 28.24% of the respondents who claimed as intangible product producers came from the IT section.

Table 4.1. Company Sectors

Company sector			
		Intangible %	Tangible %
A1	IT, Software	28.24	21.28
A10	Health	11.76	0.00
A11	Technology	2.35	4.26
A12	Transportation	2.35	0.00
A13	Energy	1.18	4.26
A14	Construction	1.18	2.13
A15	Professional Consultants	3.53	4.26
A2	Industrial, Manufacturing	2.35	40.43
A3	Service (e.g., Retail, Hospitality, etc.)	4.71	0.00
A4	Entertainment	4.71	2.13
A5	Financial and Insurance	7.06	0.00
A6	Education	17.65	12.77
A7	Non-Profit	3.53	0.00
A8	Government	8.24	2.13
A9	Telecommunications	1.18	0.00

As Table 4.2 indicates, most respondents worked for small businesses, followed by very companies.

Table 4.2. Company Workforce

Company workforce		
Number of employees	Intangible %	Tangible %
A1 <100	54.1	44.7
A2 101–500	20.0	19.1
A3 501–1,000	2.4	12.8
A4 >1,001	23.5	23.4

Table 4.3, like Figure 4.3, shows that companies in our study have more than 10 years of experience, and thus likely a higher rate of adaptability to new NPD strategies.

Table 4.3. Company Experience

Company experience		
Years in existence	Intangible %	Tangible %
A1 <1	12.9	4.3
A2 1–2	8.2	2.1
A3 2–5	14.1	12.8
A4 5–10	11.8	8.5
A5 >10	52.9	72.3

As mentioned before and as shown in Table 4.4, most responses came from Europe, because during the COVID-19 pandemic, Canadian businesses were closed.

Table 4.4. Company Location

Company location			
Location of respondent		Intangible %	Tangible %
A1	Canada	15.3	17.0
A2	United States of America	9.4	17.0
A3	Latin America or the Caribbean	8.2	17.0
A4	Europe	57.6	36.2
A5	Asia	7.1	12.8
A6	Africa	1.2	0.0
A7	Oceania	1.2	0.0

Table 4.5 provides the main information based on which we divided the respondents into two groups and our reference for defining the moderator variables that we will use in the following sections.

Table 4.5. Company Product Line

Company product line					
Intangible %			Tangible %		
A1	We offer a service	81.2	A3	We sell tangible products (hardware)	17.0
A2	We license software	2.4	A5	We offer a service combined with a tangible product	29.8
A4	We offer a service based on software (SaaS)	16.5	A6	We offer a tangible product with embedded software	4.3
			A7	Our offer is a combination of a tangible product, software, and a service	48.9

Table 4.6 compares the two groups in terms of the tools and practices used. This table reveals that tangible product producers use more NPD tools than intangible product producers. Tangible product producers use Agile practices more often than intangible product producers, while the reverse is true for LS practices. Besides, tangible product producers seek more improvements in their NPD than intangible product producers.

Table 4.6. Comparison of Respondents Answers

NPD Process Items	Intangible (%)	Tangible (%)
NPD tools	17.77	18.51
Agile practices	22.59	22.91
LS practices	20.98	22.49
NPD performance	23.10	24.04

4.2 Construct validation

4.2.1 Principal Component Factor analysis

Construct validation based on Principal Component Factor (PCF) analysis can provide useful information on several problems that may exist in a data set containing certain types of systematic errors (Roscoe, Hopke, Dattner, & Jenks, 1982). PCF analysis identifies a causal relation between a latent variable (which cannot be measured) and the observed variables. PCF analysis is a logical decision approach based on P-value.

4.2.2 Reliability test

After each PCF analysis, we calculated the Alpha to prove that internal consistency was good. "Alpha describes how closely related a set of items are as a group" (source?). It was determined before the hypothesis testing to ensure validity and indicate the amount of measurement error in our analysis (Tavakol & Dennick, 2011). Table 4.7 shows the various statistical tests applied.

Table 4.7. Statistical Measures

Index	Rate	Explanation	Reference
P-value	≤ 0.10	Accept or reject the null hypothesis	(Rothman, Greenland, & Lash, 2008)
KMO test	≥ 0.50	Sample adequacy	(Khudri & Paul, 2013)
Bartlett's sphericity test	≤ 0.05	Shows factor analysis is useful	(Knapp & Swoyer, 1967)
Communalities	≥ 0.40	Estimates the variable variance	(Osborne, Costello, & Kellow, 2008)
Cut-off load	≥ 0.55	Keeps valuable variables	(Perry, Clough, Crust, Earle, & Nicholls, 2013)
Variance explained	≥ 0.50	Consists of half variance loads	(Abdi, 2003)
Cronbach's Alpha	≥ 0.70	Internal consistency	(George & Mallery, 2003)

After conducting Varimax rotations, we found the correlation table with a high value for the KMO test; the result was greater than 0.75, verifying that the sample was adequate. In Bartlett's test, the value indicated that factor analysis may be useful with our data and showed that the data were valid. Communalities for all factors exceeded the minimum rate; after applying the cut-off load, we removed the insignificant variables from our data set. At the end of each section of the questionnaire, we calculated the reliability; with Alpha above 0.7, we documented adequate internal consistency, suggesting that all the items in the test measure the same concept or constructs. The results of the testing are shown in Table 4.8 and Figure 4.7.

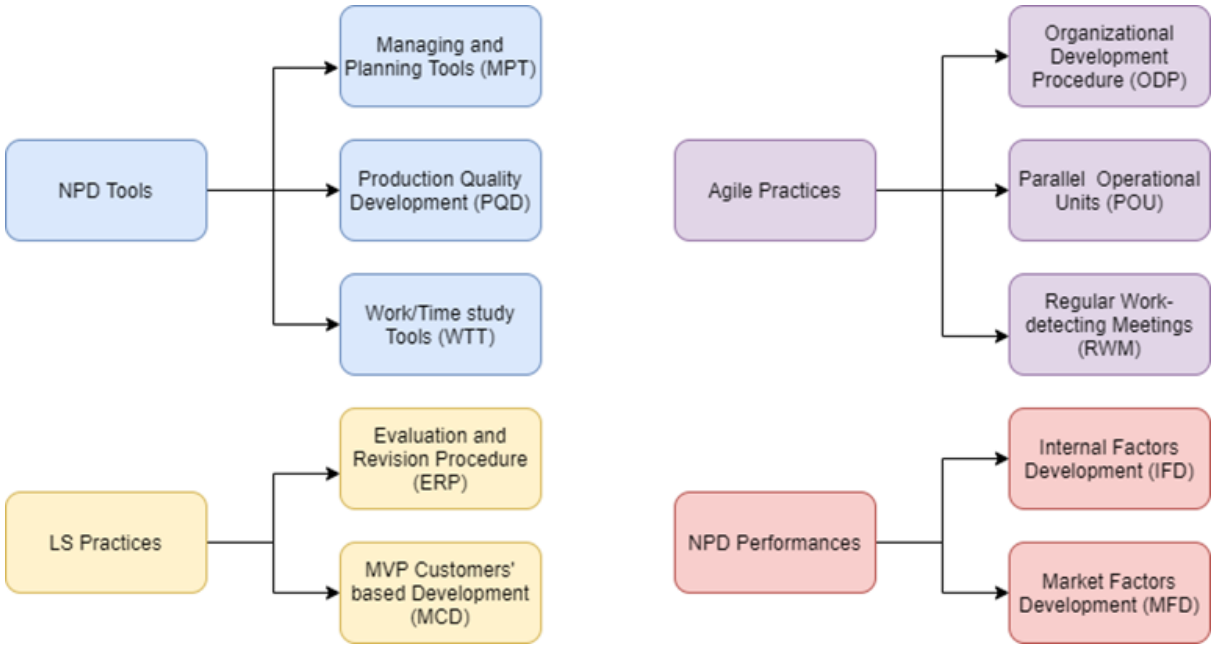

Figure 4.7. Factor Grouping

Table 4.8. PCF and R Statistical Result

Construct	Factor code	Factor initial	Indicator code	Description	Loading	KMO	%Variance		Alpha
							Factor	Sum	
NPD Tools	BF1	MPT	BBA_SQ028	Product owner of each product	0.801	0.819	41.318	68.283	0.88
			BBA_SQ011	Short iteration tools	0.795				
			BBA_SQ019	Sprint/backlog list	0.788				
			BBA_SQ012	Scrum master of each product	0.769				
			BBA_SQ029	User story card	0.749				
	BF2	PQD	BBA_SQ003	Kaizen	0.916		11.47		0.85
			BBA_SQ002	Kanban	0.801				
			BBA_SQ004	TQM	0.799				
	BF3	WTT	BBA_SQ022	Work standardization	0.794		11.47		0.765
			BBA_SQ023	Self-control	0.775				
			BBA_SQ027	Time standardization	0.743				
			BBA_SQ021	Prioritizing of tasks	0.652				
Agile Practices	CF1	ODP	CCA_SQ007	Scrum master duties	0.756	0.852	42.467	62.764	0.844
			CCA_SQ006	Product owner duties	0.748				
			CCA_SQ012	Visualization of work process	0.742				
			CCA_SQ013	Visualization of tasks and duties	0.738				
			CCA_SQ003	Time-boxed sprints	0.589				
	CF2	POU	CCA_SQ019	Branch and merge	0.774		11.257		0.811
			CCA_SQ022	Flowchart of work	0.729				
			CCA_SQ015	Feature prioritization	0.697				
			CCA_SQ021	Planned staged processes	0.687				
			CCA_SQ014	Ordering high value of tasks	0.629				
	CF3	RWM	CCA_SQ009	Daily meetings schedule	0.842		9.04		0.829
			CCA_SQ011	Task orientation	0.786				
			CCA_SQ008	Daily meetings for context set	0.743				
			CCA_SQ010	Tasks explaination	0.667				
LS Practices	DF1	ERP	DDD_SQ010	Learning validation	0.803	0.849	45.762	58.389	0.823
			DDD_SQ011	Data driven decision making	0.799				
			DDD_SQ008	Functional BLM loop	0.698				
			DDD_SQ013	Retention rate	0.681				
			DDD_SQ012	Rate of customer growth	0.632				
	DF2	MCD	DDD_SQ001	MVP quality	0.818		12.626		0.744
			DDD_SQ002	MVP purpuose	0.788				
			DDD_SQ020	Pivot or Persevere	0.629				
			DDD_SQ004	Customers involvement	0.623				
NPD Performances	EF1	IFD	EEE_SQ016	Training courses	0.794	0.867	46.984	60.831	0.89
			EEE_SQ015	Employee's engagement	0.784				
			EEE_SQ014	Employees capability	0.779				
			EEE_SQ012	MIS	0.771				
			EEE_SQ017	No-waste	0.753				
			EEE_SQ013	Organizational advantages	0.664				
			EEE_SQ011	Brand reputation	0.663				
	EF2	MFD	EEE_SQ004	Market-needs	0.766		13.847		0.766
			EEE_SQ002	Customers loyality	0.765				
			EEE_SQ003	Market share rate	0.757				
			EEE_SQ001	Quality and speed to market	0.683				
*Hint: BFT, CFT, DFT, EFT are the average of the related factors codes in the each construct.									

The factor groupings shown in Table 4.8 and Figure 4.7 are explained below.

Managing and Planning Tools (MPT): Roles of product owner and scrum master are created to determine and provide the backlog list based on user story cards to assign duties for the fastest response (Schwaber, 2004).

Production-Quality Development (PQD): Relations among Kanban, Kaizen, and TQM are connected to continuous production-quality development. Kanban affects the production stream and TQM tries to improve its impact since we are considering this activity in the sustainable Kaizen loop (Teeravaraprug, Kitiwanwong, & SaeTong, 2011).

Work/Time Study Tools (WTT): Work/Time study is a job standardization technique that can be adopted as an NPD tool to prioritize tasks (Barnes, 1949) and make sure that the standard is set, which can be used as a self-assessment measure.

Organizational Development Procedure (ODP): The product owner and scrum master are identified; they determine the tasks and movements in the timeline by providing the tools to facilitate the measurement of progress (Polk, 2011).

Parallel Operational Units (POU): Having a peer-to-peer approach in independent development teams sets the pace when presenting valuable features in prior-time, the high-quality mode to bring a zero-defect product to market. Such teams can recognize and overcome bottlenecks (Suri et al., 2003).

Regular Work-Detecting Meeting (RWM): Regular meetings provide an opportunity for all project participants to see a clear job board, which indicates what should be done and how and when (Stray, Lindsjørn, & Sjøberg, 2013).

Evaluation and Revision Procedure (ERP): The feedback loop is based on learning and this validated learning is the outcome o proper measurement, which ultimately leads to a revised plan and product (Ries, 2011).

MVP Customer-Based Development (MCD): The MVP is built on a hypothesis about the market, but its development is based on customer feedback through direct involvement in the development

process so everyone understands the valuable features of the product and necessary modifications (Ries, 2011).

Internal Factor Development (IFD): Participants in our survey understood the tangible changes in internal factors such as organizational and technical elements and their visual brand image, which is considered to be an internal factor and an indicator of a company's effort to be more productive (Mu, Peng, & MacLachlan, 2009).

Market Factor Development (MFD): Another tangible change we see is the significant improvement in market elements after running Agile and LS; this improvement can be validated by real measurements such as DDD1 and DDD2 factors and continuous care about customers' concerns (Mu et al., 2009).

Based on these interpretations, we can understand the combination of NPD tools, Agile and LS practices, and expected NPD performance as an outcome of successfully establishing Agile and/or LS practices.

4.3 Construct characterization

4.3.1 Descriptive analysis

According to (Mann, 2007), descriptive analysis is "a brief statistic that quantitatively describes and it is distinguished from inferential statistics (or inductive statistics) by its aim to summarize a sample, rather than use the data to learn about the population that the sample of data is thought to represent". This means that descriptive analysis, unlike inferential statistics, is not developed based on probability theory and frequently involves the use of non-parametric statistics (Dodge & Commenges, 2006), even when a data analysis derives its main conclusions using inferential statistics.

Hence, this kind of analysis presents the quality of the data. It is an important initial step in conducting statistical analyses and testing hypotheses. For this purpose, we will consider our PCF result and the overall mean for each section as inputs.

Table 4.9. Descriptive Analysis

	Mean		SD	Variance	Skewness		Kurtosis	
	Result	SEM	Result	Result	Result	SEM	Result	SEM
BFT	2.5695	0.07167	0.82348	0.678	0.042	0.211	–0.593	0.419
CFT	3.4183	0.06808	0.78219	0.612	–1.007	0.211	1.166	0.419
DFT	3.1695	0.06874	0.78972	0.624	–0.798	0.211	0.504	0.419
EFT	3.5158	0.06276	0.721	0.52	–0.558	0.211	0.84	0.419

For a data set, the mathematical mean or average is the central value of a discrete set of numbers, specifically the sum of the values divided by the number of values (Underhill & Bradfield, 1996).

The standard error of the mean (SEM) measures how far the sample means of the data are likely to be from the true population mean. The SEM is always smaller than the standard deviation (Fisher & Marshall, 2009). The standard deviation (SD) describes the amount of variation or dispersion of a set of values Meanwhile, the variance is the expectation of the squared deviation of a random variable from its mean. Informally, it measures how far a set of (random) numbers are spread out from their mean value (Bland & Altman, 1996). We will use this definition to check the normality of data. Skewness and kurtosis measures are often used to describe the shape characteristics of a distribution (Joanes & Gill, 1998): “Since the skewness and kurtosis of the normal distribution are zero, values for these two parameters should be close to zero for data to follow a normal distribution. Negative values for the skewness indicate data that are skewed left and positive values for the skewness indicate data that are skewed right”. For kurtosis, the general guideline is that a very high positive number means the distribution is too peaked. Likewise, a very low negative number indicates a distribution that is too flat. Acceptable values of skewness and symmetry of kurtosis are considered to fall between –1.5 and 1.5 (Tabachnick, Fidell, & Ullman, 2007). According to the skewness and kurtosis values in Table 4.9, we confirm that our data set follows the normal distribution.

4.3.2 Correlation test

The Pearson correlation coefficient “is a statistic that measures the linear correlation between two variables X and Y. It has a value between +1 and −1. A value of +1 is the total positive linear correlation, 0 is no linear correlation, and −1 is a total negative linear correlation (Artusi, Verderio, & Marubini, 2002). The perfect correlation value, +1 or −1, occurs when each of the variables is a perfect monotone function of the other.

We used this test to identify linear relations among our variables. Table 4.10 reveals the strong and moderate correlations with consideration of the proper P-value in the data set. So we can confirm that there is a positive and linear relation among our factors (Mukaka, 2012). This result helped us to choose the proper regression method to assess the main hypotheses in this study.

Table 4.10. Results of Pearson's Correlation Test

Pearson Correlation a												
	Descriptive analysis		Skewness		Kurtosis							
Items	Mean	Std. Deviation	Statistic	Std. Error	Statistic	Std. Error	Cronbach's Alpha b		BFT	CFT	DFT	EFT
								Pearson Correlation	1.000			
								Sig. (2-tailed)		0.000	0.000	0.000
								Sum of Squares and Cross-products	88.810			
BFT	2.570	0.823	0.042	0.211	-0.593	0.419	0.856	Covariance	0.678			
								Pearson Correlation	.571**	1.000		
								Sig. (2-tailed)	0.000		0.000	0.000
								Sum of Squares and Cross-products	48.187	80.143		
CFT	3.418	0.782	-1.007	0.211	1.166	0.419	0.777	Covariance	0.368	0.612		
								Pearson Correlation	.486**	.687**	1.000	
								Sig. (2-tailed)	0.000	0.000		0.000
								Sum of Squares and Cross-products	41.389	55.608	81.738	
DFT	3.170	0.790	-0.798	0.211	0.504	0.419	0.814	Covariance	0.316	0.424	0.624	
								Pearson Correlation	.527**	.695**	.613**	1.000
								Sig. (2-tailed)	0.000	0.000	0.000	
								Sum of Squares and Cross-products	40.956	51.325	45.738	68.089
EFT	3.516	0.721	-0.558	0.211	0.840	0.419	0.805	Covariance	0.313	0.392	0.349	0.520
**. Correlation is significant at the 0.01 level (2-tailed).												
a. Listwise N = 132 , b. Alpha total: 0.855												

4.3.3 Independent T-test

An independent T-test is a statistical analysis used to compare the means of each factor and identify their differences and independence to pursue the verification of hypotheses (Kim, 2015). The result of this test led to a sub-objective to reform, shape, and verify the result of the (Bento & Tontini, 2019) study in our hypothesis framework regarding company size (CS) as a control variable.

Table 4.11. Results of Independent T-Tests

Independent Sample Test		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	SE Difference	95% Confidence Interval of the Difference	
									Lower	Upper
BFT	Equal variances assumed	2.402	0.124	–1.119	130	0.265	–0.16032	0.14321	–0.44364	0.12300
	Equal variances not assumed			–1.117	125.892	0.266	–0.16032	0.14354	–0.44438	0.12374
CFT	Equal variances assumed	0.015	0.904	–1.251	130	0.213	–0.16998	0.13588	–0.43881	0.09884
	Equal variances not assumed			–1.249	127.758	0.214	–0.16998	0.13609	–0.43927	0.09930
DFT	Equal variances assumed	0.000	0.993	–1.912	130	0.058	–0.26027	0.13615	–0.52963	0.00908
	Equal variances not assumed			–1.914	129.693	0.058	–0.26027	0.13598	–0.52931	0.00876
EFT	Equal variances assumed	0.033	0.856	–1.210	130	0.229	–0.15158	0.12529	–0.39946	0.09629
	Equal variances not assumed			–1.209	129.526	0.229	–0.15158	0.12535	–0.39958	0.09642

Table 4.11 reveals a significant difference in the DFT (LS practices) between our two groups; ML companies use the selected LS factors more often than S firms. With a P-value < 0.1, Our finding confirms and supports those of (Doolen & Hacker, 2005), (Bento & Tontini, 2019), and (Shah & Ward, 2007) that the Lean methodology is used more by ML companies than by S companies.

4.4 Hypothesis validation

Multiple linear regression (MLR) analysis is used to predict the value of a variable based on the value of another variable. (Hair, 2015) pointed out that MLR produces valid results even for nonparametric data sets. So, based on MLR assumptions for redundancy and validation of the use of linear regression, we should consider compliance with the normality assumption, which applies to errors, not outcome variables. Thus, we tested for normally distributed errors by using the normal probability plot or normal quantile plot of the residuals (Dunn & Smyth, 1996). We confirmed that the residual is follows a normal distribution. “We use the standard method of determining whether a moderating effect exists, which entails the addition of a (linear) interaction term in a multiple regression model. A moderator analysis is used to determine whether the relationship between two variables depends on (is moderated by) the value of a third variable” (Aguinis, 2004).

- *H'0 validation:*

As shown in Table 4.12, with a P-value < 0.1, we can assess whether there is a significant relation between CFT adoption and BFT adoption by considering CS as a control variable and PT as a moderator. CFT has a significant impact on the frequency of BFT usage. This shows that using more Agile practices means companies are more likely to use NPD tools. We did not find any significant relation when we added the control variable and moderator.

Table 4.12. H'0 Validation

MLR	Dependent	BFT
Independent		
Company Size (CS)	Coefficients	0.0540
	SE	0.1200
	P-Value	0.6520
CFT	Coefficients	0.6400
	SE	0.0940
	P-Value	0.0000
Product Type (PT)	Coefficients	0.5140
	SE	0.5720
	P-Value	0.3710
CFTPT	Coefficients	-0.1330
	SE	0.1620
	P-Value	0.4120
N		132
F		15.7840
R^2		0.3320
R^2_a		0.3110
SE		0.6834
P-Value		0.0000

- *H'1 validation:*

Table 4.13 shows that, with a P-value < 0.1, we can assess whether there is a significant relation between DFT adoption and BFT adoption by considering CS as a control variable and PT as a moderator. DFT has a significant impact on BFT adoption, which means that using more LS practices means that companies are more likely to use NPD tools. We did not find any significant relation when we added the moderator or control variable.

Table 4.13. H'1 Validation

MLR	Dependent	BFT
Independent		
Company Size (CS)	Coefficients	0.0290
	SE	0.1290
	P-Value	0.8260
DFT	Coefficients	0.5260
	SE	0.0970
	P-Value	0.0000
Product Type (PT)	Coefficients	0.2570
	SE	0.6060
	P-Value	0.6720
DFTPT	Coefficients	-0.0800
	SE	0.1820
	P-Value	0.6600
N		132

Table 4.13. H'1 Validation (Resume-End)

F		9.8870
R^2		0.2370
R^2_a		0.2130
SE		0.7302
P-Value		0.0000

- *H0 validation:*

As shown in Table 4.14, with a P-value < 0.1, we can assess whether there is a significant relation between BFT adoption and CFT adoption by considering CS as a control variable and PT as a moderator. BFT has a significant impact on CFT frequency. Thus, using more NPD tools makes companies more likely to use the Agile methodology. PT as a moderator has a significant effect on the relation between BFT and CFT. According to the positive coefficient value (0.7130) when we insert PT as a moderator, the type of company has a significant impact on Agile practice adoption. But when we consider tangible product producers, the coefficient has a negative value (–0.2660), which means that greater adoption of NPD tools reduces the adoption of Agile practices.

Table 4.14. H0 Validation

MLR	Dependent	CFT
Independent		
Company Size (CS)	Coefficients	0.0690
	SE	0.1130
	P-Value	0.5430

Table 4.14. H0 Validation (Resume-End)

BFT	Coefficients	0.6450
	SE	0.0890
	P-Value	0.0000
Product Type (PT)	Coefficients	0.7130
	SE	0.3800
	P-Value	0.0630
BFTPT	Coefficients	-0.2660
	SE	0.1390
	P-Value	0.0580
N		132
F		16.9460
R^2		0.3480
R^2_a		0.3270
SE		0.6414
P-Value		0.0000

- *H1 validation:*

As Table 4.15 shows, with a P-value < 0.1, we can assess whether there is a significant relation between BFT adoption and DFT adoption by considering CS as a control variable and PT as a moderator. There is a significant impact of BFT on the frequency of DFT usage. Thus, using more NPD tools means companies are more likely to use LS practices. PT as a moderator has a significant impact on the relation between BFT and DFT. Based on the positive coefficient value (0.9080) when we add PT as a moderator, product type has a positive impact on LS adoption. When only

tangible product producers were included, to understand how the model would be changed, there was a negative coefficient (–0.2880); thus, in these companies, greater adoption of NPD tools leads to less usage of LS practices.

Table 4.15. H1 Validation

MLR	Dependent	DFT
Independent		
Company Size (CS)	Coefficients	0.1600
	SE	0.1200
	P-Value	0.1840
BFT	Coefficients	0.5670
	SE	0.0940
	P-Value	0.0000
Product Type (PT)	Coefficients	0.9080
	SE	0.4040
	P-Value	0.0260
BFTPT	Coefficients	-0.2880
	SE	0.1480
	P-Value	0.0540
N		132
F		12.4030
R^2		0.2810

Table 4.15. H1 Validation (Resume-End)

R^2_a		0.2580
SE		0.6803
P-Value		0.0000

- *H2 validation:*

According to Table 4.16, with a P-value < 0.1, we can assess whether there is a significant relation between BFT adoption and EFT improvement by considering CS as a control variable and PT as a moderator. BFT has a significant impact on the frequency of EFT usage. In other words, using more NPD tools leads to more improvements in the NPD process. We did not find any significant relation when we added the moderator or control variable.

Table 4.16. H2 Validation

MLR	Dependent	EFT
Independent		
Company Size (CS)	Coefficients	0.0750
	SE	0.1090
	P-Value	0.4930
BFT	Coefficients	0.4920
	SE	0.0860
	P-Value	0.0000
Product Type (PT)	Coefficients	0.2110
	SE	0.3680
	P-Value	0.5680

Table 4.16. H2 Validation (Resume-End)

BFTPT	Coefficients	-0.0850
	SE	0.1350
	P-Value	0.5290
N		132
F		12.5090
R^2		0.2830
R^2_a		0.2600
SE		0.6202
P-Value		0.0000

- *H3 validation:*

Finally, according to Table 4.17, with a P-value < 0.1, we can assess whether there is a significant relation between CFT and DFT adoption and EFT improvement by considering CS as a control variable and PT as a moderator. There is a significant impact of mean CFT and DFT on the frequency of EFT usage. Thus, using more NPD practices leads to more improvements in the NPD process. We did not find any significant relations when we added the moderator or control variable.

Table 4.17. H3 Validation

MLR	Dependent	EFT
Independent		
Company Size (CS)	Coefficients	0.0040
	SE	0.0900
	P-Value	0.9640

Table 4.17. H3 Validation (Resume-End)

Mean (CFT, DFT)	Coefficients	0.6860
	SE	0.0750
	P-Value	0.0000
Product Type (PT)	Coefficients	-0.3870
	SE	0.4630
	P-Value	0.4050
Mean (CFT, DFT) PT	Coefficients	0.0960
	SE	0.1350
	P-Value	0.4790
N		132
F		33.1050
R^2		0.5100
R^2_a		0.4950
SE		0.5123
P-Value		0.0000

We summarize the validation of our assumptions in Table 4.18. There is a strong relationship between NPD tools and NPD practices with PT as a moderator and CS as a control variable.

Table 4.18. Summary of Hypothesis Testing

Hypothesis	Validation	Description
H0	CS	With a P-value ≤ 0.1, we reject the null hypothesis and accept the alternative; the test confirmed that there is a relation between NPD tools (BFT), the independent variable, and Agile practices (CFT), the dependent variable.
	PT	
	CS & PT	
H'0	CS	With a P-value ≥ 0.1, we accept the null hypothesis and reject the alternative; the model confirmed that there is no relation between Agile practices (CFT), independent variable, and NPD tools (BFT), the dependent variable, considering PT as a moderator.
	PT	
	CS & PT	
H1	CS	With a P-value ≤ 0.1, we reject the null hypothesis and accept the alternative; the model confirmed that there is a relation between NPD tools (BFT), the independent variable, and LS practices (DFT), the dependent variable.
	PT	
	CS & PT	
H'1	CS	With a P-value ≥ 0.1, we accept the null hypothesis and reject the alternative; one, the model confirmed that there is no relation between LS practices (DFT), the independent variable, and NPD tools (BFT), the dependent variable, considering PT as a moderator.
	PT	
	CS & PT	
H2	CS	With a P-value ≥ 0.1, we accept the null hypothesis and reject the alternative; the model confirmed that there is no relation between NPD tools (BFT), the independent variable, and NPD performance (EFT), the dependent variable, considering PT as a moderator.
	PT	
	CS & PT	
H3	CS	With a P-value ≥ 0.1, we accept the null hypothesis and reject the alternative; the model confirmed that there is no relation between mean Agile and LS practices (CFT, DFT), the independent variables, and NPD performance (EFT), the dependent variable, considering PT as a moderator.
	PT	
	CS & PT	

CHAPTER 5 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 General discussion

This research was designed to determine the best and most valuable Agile and LS practices and tease out the logical relations among the tools, practices, and performances in the NPD process for two categories of companies: producers of intangible products or tangible products.

The outcomes of the survey and statistical analyses lead to some secondary goals in addition to the main hypotheses this research was intended to test.

- Based on PCF analysis, we found certain valuable tools and practices and expected sequences of running LS or Agile in a company, regardless of type or category. Some of those factors are addressed by authors of previous studies. (Sverrisdottir, Ingason, & Jonasson, 2014) presented the roles of product owners and scrum masters and the division of their duties in handling the NPD process. (Kuznetsov, Romanovskaya, Egorova, Andryashina, & Kozlova, 2017) suggested using Kanban and Kaizen to ensure product quality and ensure a successful NPD process. (Meyers & Stewart, 2002) present the work-time study as an initial step toward the No-waste approach in Lean. (Paredes, Anslow, & Maurer, 2014) found that using visualization techniques for designing, developing, communicating, and tracking progress helps NPD teams to increase knowledge sharing and improve awareness of bottlenecks in the process. (Mak & Kruchten, 2006) worked on a model for task allocation and coordination in the Agile methodology; they found that task prioritization increased transparency throughout the project. (Arve, 2010) claimed that merging and branching speed up the Agile process and help to improve the product through small actions. (Stray et al., 2013) noted that, in daily meetings, “team members obtained an overview of what others were doing and were given an opportunity for discussing and solving problems”. (Ries, 2017) discussed how the BML loop covers the NPD process in terms of involving customers, building, and technical features and evaluation procedures to help executives to make the correct decision in the NPD process. (Moogk, 2012) stated that “MVPs engage target customers and test the value and growth”, which help firms to avoid wasting resources before going to market. (Wang, 2009) listed the many positive outcomes of a correct NPD process, such as delivery, flexibility, and employee creativity in the firm.

- We verified the results obtained by (Bortolotti, Boscari, & Danese, 2015), (Ghezzi & Cavallo, 2018), (Conboy & Fitzgerald, 2004), and (Hallgren & Olhager, 2009); we found that LS is part of the Agile methodology in most respects. The differences that distinguish LS from Agile relate to how LS drives the company toward a correct NPD process utilizing special techniques. In the independent T-test, we found that, even with CS as a control variable, the NPD process is almost the same for companies in both size groups (S and ML) (Burke & Cowling, 2020). The exception relates to LS practices.

  These differences in LS practices are supported by the work of (Matt & Rauch, 2013); they found that S and ML companies pursue their NPD process in different ways in the practice phase. We confirmed that companies of different sizes have different definitions of LS practices, such as an evaluation loop to check and verify the technical and market aspects through the correct MVP (Baker, 2018). For instance, in the MCD factor regarding the select of LS practice packages by respondents, (Rea-Guaman, Calvo-Manzano, & San Feliu, 2018) described a difference between how S and ML companies define, build, and introduce their MVP, including financial investments, different definitions of minimum acceptable quality, the methodology applied to recognize and assess customer satisfaction, different technical tools, and push capability to ensure that customers' expectations and the final product features remain close (Alalwan, 2018).

- The correlation test showed some strong and moderate correlations among tools, practices, and performance. So we can confirm that any change in a tool or practice leads to a change in NPD performance in the positive linear condition. Many other authors (Blank, 2013; Cagliano, Caniato, & Spina, 2004; Coram & Bohner, 2005; Ries, 2011) have described the positive impacts of Agile and LS on the NPD process, They found that this methodology makes companies more flexible and productive in a complex business environment. Consistent practices result in error-free products and enhance customers' satisfaction.

- The result of the regression analysis confirmed our assumptions. Of our various hypotheses, we validated H0 and H1. In other words, we saw a significant impact of NPD tool adoption on Agile and LS adoption. As shown in Tables 4.14 and 4.15, "the coefficient value signifies how much the mean of the dependent variable changes given a one-unit shift in

the independent variable while holding other variables in the model constant. A negative coefficient suggests that as the independent variable increases, the dependent variable tends to decrease" (Frost, 2019). Among tangible product producers, this relation is negative, meaning that companies that adopt and use NPD tools move away from Agile and LS practices. On the other hand, intangible product producers are adopting NPD tools along with LS and Agile practices (Mahajan & Wind, 1992), (Pantiuchina, Mondini, Khanna, Wang, & Abrahamsson, 2017).

5.2 Conclusion

This research aimed to investigate the relations among NPD tools, Agile/LS practices, and NPD performance and to compare the use of these two methodologies in different groups of companies in terms of efficiency and capability to adapt to their environment.

The outcomes of this quantitative study were as follows. A) We identified valuable packages of NPD components that can be a roadmap for companies that want to make their NPD strategy structural. B) We found no difference among NPD components with company size except in the case of LS practices. C) We documented a significant linear relationship between all NPD components. D) We discovered that tangible product producers are willing to use NPD tools regardless of whether they have implemented LS or Agile practices. But intangible product producers use organized NPD tools within the scope of Agile and LS practices.

Nevertheless, as we mentioned in section 2.4, LS can be part of the Agile process, depending on the type of product or service. We believe that Agile and LS have much in common. The most important common points the two methodologies share are (1) emphasizing the customer's wishes through customer recognition, making customer connections, and involving customers in the NPD process to make sure the product or service is close to their expectations; (2) a no-waste approach to optimize resource use, product quality, time and all non-value-added activities based on lessons learned; and (3) a quick feedback loop to ensure continuous improvement in internal and external activities such as technical, organizational or supplier relations and delivery quality.

The Agile methodology, with its fast iteration, organizational structure, visualization of tasks, feature prioritization, and consistent examination, ensures that any change in the market situation

is observed fast. Breaking the work into small batches and connecting the results to obtain product/market fit due to the talent and expertise of the product owner and scrum master are the main keys to success.

We found that tangible product producers, based on their product type, technological complexity, market situation, etc., use NPD tools based on their needs to steer their NPD process. We should also mention we did not find evidence that these companies were applying any systematic approach in pursuing their NPD process, at least when it came to Agile and LS methodologies. On the other hand, intangible product producers tended to follow a more organized methodology with NPD tools and practices to steer their NPD process.

5.3 Contribution to theory and practice

Our research in terms of the result was exclusive. Based on the Independent T test we observed the large companies have more desire to use the LS practices in their NPD process this result confirm the (Kirsner, 2016) finding, but how the ML companies shape LS practices based on thein NPD process would be another project to interpretate the result under precise concentration.

According to the hypothesises validation, we observed the tangible product producers by adopting more NPD tools which come from Agile and LS principles, are receding from Agile and LS practices. It shows tangible product producers are using some of NPD tools and techniques, but they are adopting those tools in the other NPD methodology or mixture of several methodologies. This result makes a new research idea to investigate how tangible product producers steer their NPD process.

5.4 Research limitations and recommendations

This research is affected by some limitations, which should be drawn to readers' attention (Price & Murnan, 2004).

This study had a relatively small sample; we recommend running the survey again with a larger sample. Using clustering techniques to distinguish similarities helps to generate pure data for analysis. Prediction methodologies in data mining can be applied to deal with complex business environments. Based on the responses that we got and the definition of the moderator (product

type), most of them classified as intangible product producers which can be considered as constraints in our research.

Each business field based on their need and their product or service may use some tools and techniques or practices, indeed it would be possible to have a low score in some survey items because they are not applicable in a specific industry. We suggest running the targeted survey based on each business field requirements. Also, when applying the most valuable techniques we suggest interviewing experts and implementing these methods first in a case study to verify the results, then designing a second survey to assess the value that respondents received and consider what should be recommended for future studies.

REFERENCES

Abdi, H. (2003). Factor rotations in factor analyses. *Encyclopedia for Research Methods for the Social Sciences. Sage: Thousand Oaks, CA*, 792-795.

Acar, A. Z., & Acar, P. (2012). The effects of organizational culture and innovativeness on business performance in healthcare industry. *Procedia-Social and Behavioral Sciences, 58*, 683-692.

Aguinis, H. (2004). *Regression analysis for categorical moderators*: Guilford Press.

Alalwan, A. A. (2018). Investigating the impact of social media advertising features on customer purchase intention. *International Journal of Information Management, 42*, 65-77.

Alshamrani, A., & Bahattab, A. (2015). A comparison between three SDLC models waterfall model, spiral model, and Incremental/Iterative model. *International Journal of Computer Science Issues (IJCSI), 12*(1), 106.

Artusi, R., Verderio, P., & Marubini, E. (2002). Bravais-Pearson and Spearman correlation coefficients: meaning, test of hypothesis and confidence interval. *The International journal of biological markers, 17*(2), 148-151.

Arve, D. (2010). Branching strategies with distributed version control in agile projects. In: Website. http://fileadmin. cs. lth. se/cs/Personal/lars_bendix/research/ascm ….

Azizyan, G., Magarian, M. K., & Kajko-Matsson, M. (2011). *Survey of agile tool usage and needs.* Paper presented at the 2011 agile conference.

Baker, J. (2018). *Getting to Market with Your MVP: How to Achieve Small Business and Entrepreneur Success*: Business Expert Press.

Barlow, J. B., Giboney, J., Keith, M. J., Wilson, D., Schuetzler, R. M., Lowry, P. B., & Vance, A. (2011). Overview and guidance on agile development in large organizations. *Communications of the Association for Information Systems, 29*(2), 25-44.

Barnes, R. M. (1949). Motion and time study.

Barton, B. (2009). *All-out organizational scrum as an innovation value chain.* Paper presented at the 2009 42nd Hawaii International Conference on System Sciences.

Barua, A. (2013). Methods for decision-making in survey questionnaires based on Likert scale. *Journal of Asian Scientific Research, 3*(1), 35-38.

Bass, J. M. (2013). *Agile method tailoring in distributed enterprises: Product owner teams.* Paper presented at the 2013 IEEE 8th International Conference on Global Software Engineering.

Bass, J. M. (2014). *Scrum master activities: process tailoring in large enterprise projects.* Paper presented at the 2014 IEEE 9th International Conference on Global Software Engineering.

Baumann, O., Schmidt, J., & Stieglitz, N. (2019). Effective search in rugged performance landscapes: A review and outlook. *Journal of Management, 45*(1), 285-318.

Benefield, G., & Greening, D. (2013). *Introduction to Agile/Lean Startup Organizations Minitrack.* Paper presented at the 2013 46th Hawaii International Conference on System Sciences.

Benefield, R. (2009). *Agile deployment: Lean service management and deployment strategies for the SaaS enterprise.* Paper presented at the 2009 42nd Hawaii International Conference on System Sciences.

Bento, G. d. S., & Tontini, G. (2019). Maturity of lean practices in Brazilian manufacturing companies. *Total Quality Management & Business Excellence, 30*(sup1), S114-S128.

Berman, B. (2012). 3-D printing: The new industrial revolution. *Business horizons, 55*(2), 155-162.

Biazzo, S., Panizzolo, R., & Gore, A. (2017). Lean product development implementation approach: Empirical evidence from indian lean manufacturers. *International Journal of Industrial Engineering and Management, 8*(3), 189-201.

Björk, J., Ljungblad, J., & Bosch, J. (2013). *Lean Product Development in Early Stage Startups.* Paper presented at the IW-LCSP@ ICSOB.

Bland, J., & Altman. (1996). DG 1996,'Statistics notes: measurement error'. *BMJ, 312*(7047), 1654.

Blank, S. (2013). The four steps to the Epiphany. 2006. *USA, Quad/Graphics*.

Blank, S. (2017). Why the lean start-up changes everything. *Harvard business review*.

Blank, S., & Dorf, B. (2012). The startup owner's manual: The step-by-step guide for building a great company. K & S Ranch. *Inc, California. PubMed Abstract OpenURL*.

Boehm, B. W. (1988). A spiral model of software development and enhancement. *Computer, 21*(5), 61-72.

Bolumole, Y. A., Calantone, R. J., Di Benedetto, C. A., & Melnyk, S. A. (2015). New product development in new ventures: the quest for resources. *International Journal of Production Research, 53*(8), 2506-2523.

Bortolini, R. F., Cortimiglia, M. N., Danilevicz, A. d. M. F., & Ghezzi, A. (2018). Lean Startup: a comprehensive historical review. *Management Decision*.

Bortolotti, T., Boscari, S., & Danese, P. (2015). Successful lean implementation: Organizational culture and soft lean practices. *International journal of production economics, 160*, 182-201.

Bosch, J., Olsson, H. H., Björk, J., & Ljungblad, J. (2013). *The early stage software startup development model: a framework for operationalizing lean principles in software startups.* Paper presented at the International Conference on Lean Enterprise Software and Systems.

Bradford, A. (2017). What Is a Scientific Hypothesis? Definition of Hypothesis. In: LiveScience.

Brown, T. (2008). IDEO Design Thinking. *Harvard Business Review. Cambridge, MA*.

Brush, C. G., Greene, P. G., & Hart, M. M. (2001). From initial idea to unique advantage: The entrepreneurial challenge of constructing a resource base. *Academy of Management Perspectives, 15*(1), 64-78.

Buchanan, R. (1992). Wicked problems in design thinking. *Design issues, 8*(2), 5-21.

Burke, A., & Cowling, M. (2020). On the critical role of freelancers in agile economies. *Small Business Economics*, *55*(2), 393-398.

Caffyn, S. (1997). Extending continuous improvement to the new product development process. *R&D Management*, *27*(3), 253-267.

Cagliano, R., Caniato, F., & Spina, G. (2004). Lean, agile and traditional supply: how do they impact manufacturing performance? *Journal of Purchasing and Supply Management*, *10*(4-5), 151-164.

Cameron, K. S., & Quinn, R. (1999). An introduction to changing organizational culture. *Diagnosing and changing organizational culture: Based on the competing values framework*, 1-17.

Campanelli, A. S., & Parreiras, F. S. (2015). Agile methods tailoring–A systematic literature review. *Journal of Systems and Software*, *110*, 85-100.

Casselman, T. J. A. (2014). *Beyond the lean startup: applying the lean startup methodology in established firms.* Massachusetts Institute of Technology,

Conboy, K., & Fitzgerald, B. (2004). *Toward a conceptual framework of agile methods: a study of agility in different disciplines.* Paper presented at the Proceedings of the 2004 ACM workshop on Interdisciplinary software engineering research.

Cooper, R. G. (1988). Predevelopment activities determine new product success. *Industrial Marketing Management*, *17*(3), 237-247.

Cooper, R. G., & Edgett, S. J. (2008). Maximizing productivity in product innovation. *Research-Technology Management*, *51*(2), 47-58.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2004). Benchmarking best NPD practices—III. *Research-Technology Management*, *47*(6), 43-55.

Cooper, R. G., & Kleinschmidt, E. J. (1995). Benchmarking the firm's critical success factors in new product development. *Journal of Product Innovation Management: An International Publication of the Product Development & Management Association*, *12*(5), 374-391. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4841176/pdf/JPIM-32-847.pdf

Coram, M., & Bohner, S. (2005). *The impact of agile methods on software project management.* Paper presented at the 12th IEEE International Conference and Workshops on the Engineering of Computer-Based Systems (ECBS'05).

Crawford, C. M. (1972). Strategies for new product development.

Da Silva, T. S., Martin, A., Maurer, F., & Silveira, M. (2011). *User-centered design and agile methods: a systematic review.* Paper presented at the 2011 AGILE conference.

Dickson, K., Lawton Smith, H., & Lloyd Smith, S. (1991). Bridge over troubled waters? Problems and opportunities in interfirm research collaboration. *Technology Analysis & Strategic Management*, *3*(2), 143-157.

Dodge, Y., & Commenges, D. (2006). *The Oxford dictionary of statistical terms*: Oxford University Press on Demand.

Dodgson, M., Gann, D., & Salter, A. (2006). The role of technology in the shift towards open innovation: the case of Procter & Gamble. *R&D Management, 36*(3), 333-346.

Doolen, T. L., & Hacker, M. E. (2005). A review of lean assessment in organizations: an exploratory study of lean practices by electronics manufacturers. *Journal of Manufacturing systems, 24*(1), 55-67.

Duc, A. N., & Abrahamsson, P. (2016). *Minimum viable product or multiple facet product? The Role of MVP in software startups.* Paper presented at the International Conference on Agile Software Development.

Dunn, P. K., & Smyth, G. K. (1996). Randomized quantile residuals. *Journal of Computational and Graphical Statistics, 5*(3), 236-244.

Dunning, T. E. (1993). Accurate methods for the statistics of surprise and coincidence. *Computational linguistics, 19*(1), 61-74.

Duran, C., Cetindere, A., & Aksu, Y. E. (2015). Productivity improvement by work and time study technique for earth energy-glass manufacturing company. *Procedia Economics and Finance, 26*, 109-113.

Dzamashvili Fogelström, N., Gorschek, T., Svahnberg, M., & Olsson, P. (2010). The impact of agile principles on market-driven software product development. *Journal of software maintenance and evolution: Research and practice, 22*(1), 53-80.

Eberlein, A., & Leite, J. (2002). *Agile requirements definition: A view from requirements engineering.* Paper presented at the Proceedings of the International Workshop on Time-Constrained Requirements Engineering (TCRE'02).

Edison, H., Wang, X., & Abrahamsson, P. (2015). *Lean startup: why large software companies should care.* Paper presented at the Scientific Workshop Proceedings of the XP2015.

Eisenmann, T. R., Ries, E., & Dillard, S. (2012). Hypothesis-driven entrepreneurship: The lean startup. *Harvard Business School Entrepreneurial Management Case*(812-095).

Ellarby, P. E. (2013). *Balls for Africa: The Lean Startup in an African Not-for-Profit Social Enterprise.* Paper presented at the 2013 Agile Conference.

(2019). *10 Agile Ideas Worth Sharing* [Retrieved from https://sdm.mit.edu/webinar-steven-d-eppinger-10-agile-ideas-worth-sharing/

Evans, J. R., & Laskin, R. L. (1994). The relationship marketing process: A conceptualization and application. *Industrial Marketing Management, 23*(5), 439-452.

Fasil, T., & Osada, H. (2011). Multiple dimensions of TQM success in developing countries: an empirical study on Deming Prize winners from India and Thailand. *International Journal of Innovation and Learning, 9*(2), 184-203.

Fisher, M. J., & Marshall, A. P. (2009). Understanding descriptive statistics. *Australian Critical Care, 22*(2), 93-97.

Fowler, M., & Highsmith, J. (2001). The agile manifesto. *Software Development, 9*(8), 28-35.

Frederiksen, D. L., & Brem, A. (2017). How do entrepreneurs think they create value? A scientific reflection of Eric Ries' Lean Startup approach. *International Entrepreneurship and Management Journal, 13*(1), 169-189.

Fridman, A. (2016). The Massive Downside of Agile Software Development. Retrieved from https://www.inc.com/adam-fridman/the-massive-downside-of-agile-software-development.html

Frost, J. (2019). How to interpret p-values and coefficients in regression analysis. *URL https://statisticsbyjim. com/regression/interpret-coefficients-p-values-regression*.

Furr, N., & Dyer, J. (2014). *The Innovator's Method: Bringing the Lean Start-Up Into Your Organization*: Harvard Business Review Press.

Gans, J. S., Stern, S., & Wu, J. (2019). Foundations of entrepreneurial strategy. *Strategic Management Journal, 40*(5), 736-756.

Gavetti, G., & Levinthal, D. (2000). Looking forward and looking backward: Cognitive and experiential search. *Administrative science quarterly, 45*(1), 113-137.

George, D., & Mallery, M. (2003). Using SPSS for Windows step by step: a simple guide and reference.

Ghezzi, A., & Cavallo, A. (2018). Agile business model innovation in digital entrepreneurship: Lean startup approaches. *Journal of business research*.

Goles, T., & Chin, W. W. (2005). Information systems outsourcing relationship factors: detailed conceptualization and initial evidence. *ACM SIGMIS Database: the DATABASE for Advances in Information Systems, 36*(4), 47-67.

Golfarelli, M., Rizzi, S., & Proli, A. (2006). *Designing what-if analysis: towards a methodology.* Paper presented at the Proceedings of the 9th ACM international workshop on Data warehousing and OLAP.

Guang-yong, H. (2011). *Study and practice of import Scrum agile software development.* Paper presented at the 2011 IEEE 3rd International Conference on Communication Software and Networks.

Hair, J. F. (2015). *Essentials of business research methods*: ME Sharpe.

Hallgren, M., & Olhager, J. (2009). Lean and agile manufacturing: external and internal drivers and performance outcomes. *International Journal of Operations & Production Management*.

Hamel, G. (1989). Collaborate with your competitors and win. *Harvard business review, 67*, 133-139.

Harmancioglu, N., Finney, R. Z., & Joseph, M. (2009). Impulse purchases of new products: an empirical analysis. *Journal of Product & Brand Management*.

Highsmith, J. (2009). *Agile project management: creating innovative products*: Pearson education.

Highsmith, J. A., & Highsmith, J. (2002). *Agile software development ecosystems*: Addison-Wesley Professional.

Hossain, E., Babar, M. A., Paik, H.-y., & Verner, J. (2009). *Risk identification and mitigation processes for using scrum in global software development: A conceptual framework.* Paper presented at the 2009 16th Asia-Pacific Software Engineering Conference.

Huber, G. P. (1991). Organizational learning: The contributing processes and the literatures. *Organization science, 2*(1), 88-115.

Humble, J., Molesky, J., & O'Reilly, B. (2014). *Lean enterprise: How high performance organizations innovate at scale*: " O'Reilly Media, Inc.".

Ikonen, M., Kettunen, P., Oza, N., & Abrahamsson, P. (2010). *Exploring the sources of waste in kanban software development projects.* Paper presented at the 2010 36th EUROMICRO Conference on Software Engineering and Advanced Applications.

Inayat, I., Salim, S. S., Marczak, S., & Kasirun, Z. M. (2014). *Identifying and reviewing the most relevant socio-technical aspects of requirements-driven collaboration in agile teams.* Paper presented at the International conference on advancements in engineering and technology.

Isomursu, M., Sirotkin, A., Voltti, P., & Halonen, M. (2012). *User Experience Design Goes Agile in Lean Transformation--A Case Study.* Paper presented at the 2012 Agile Conference.

Joanes, D., & Gill, C. (1998). Comparing measures of sample skewness and kurtosis. *Journal of the Royal Statistical Society: Series D (The Statistician), 47*(1), 183-189.

Johne, A., & Storey, C. (1998). New service development: a review of the literature and annotated bibliography. *European journal of Marketing*.

Kärkkäinen, H., Piippo, P., & Tuominen, M. (2001). Ten tools for customer-driven product development in industrial companies. *International journal of production economics, 69*(2), 161-176.

Katzy, B. R., Baltes, G. H., & Gard, J. (2012). Concurrent process coordination of new product development by Living Labs–an exploratory case study. *International Journal of Product Development, 17*(1-2), 23-42.

Khudri, M., & Paul, D. (2013). An application of factor analysis on bank wise interest rate structure in Bangladesh. *J Sci Technol, 11*, 37-44.

Kim, T. K. (2015). T test as a parametric statistic. *Korean journal of anesthesiology, 68*(6), 540.

Kirsner, S. (2016). The barriers big companies face when they try to act like lean startups. *Harvard Bus. Rev*.

Knapp, T. R., & Swoyer, V. H. (1967). Some empirical results concerning the power of Bartlett's test of the significance of a correlation matrix. *American Educational Research Journal, 4*(1), 13-17.

Krishnan, V., & Ulrich, K. T. (2001). Product development decisions: A review of the literature. *Management science, 47*(1), 1-21.

Kuznetsov, V. P., Romanovskaya, E. V., Egorova, A. O., Andryashina, N. S., & Kozlova, E. P. (2017). *Approaches to developing a new product in the car building industry*. Paper presented at the International conference on Humans as an Object of Study by Modern Science.

Leite, M., & Braz, V. (2016). Agile manufacturing practices for new product development: industrial case studies. *Journal of manufacturing technology management*.

Levitt, T. (1981). Marketing intangible products and product intangibles. *Cornell Hotel and Restaurant Administration Quarterly, 22*(2), 37-44.

Lindsjørn, Y., Sjøberg, D. I., Dingsøyr, T., Bergersen, G. R., & Dybå, T. (2016). Teamwork quality and project success in software development: A survey of agile development teams. *Journal of Systems and Software, 122*, 274-286.

Lioukas, S. (2007). Concurrent Engineering: Strategy for Effective Product Development Team to Achieve and Sustain Company's Objective. *Harvard business review, 85*(3), 94-102.

Mahajan, V., & Wind, J. (1992). New product models: Practice, shortcomings and desired improvements. *Journal of product innovation management, 9*(2), 128-139.

Mak, D. K., & Kruchten, P. B. (2006). *Task coordination in an agile distributed software development environment.* Paper presented at the 2006 Canadian Conference on Electrical and Computer Engineering.

Mann, P. S. (2007). *Introductory statistics*: John Wiley & Sons.

Mansoori, Y., & Lackéus, M. (2019). Comparing effectuation to discovery-driven planning, prescriptive entrepreneurship, business planning, lean startup, and design thinking. *Small Business Economics*, 1-28.

Mason-Jones, R., Naylor, B., & Towill, D. R. (2000). Lean, agile or leagile? Matching your supply chain to the marketplace. *International Journal of Production Research, 38*(17), 4061-4070.

Matt, D., & Rauch, E. (2013). Implementation of lean production in small sized enterprises. *Procedia CIRP, 12*, 420-425.

Maurya, A. (2012). *Running lean: iterate from plan A to a plan that works*: " O'Reilly Media, Inc.".

McDonough III, E. F., & Barczak, G. (1991). Speeding up new product development: The effects of leadership style and source of technology. *Journal of product innovation management, 8*(3), 203-211.

Melegati, J., Goldman, A., Kon, F., & Wang, X. (2019). A model of requirements engineering in software startups. *Information and Software Technology, 109*, 92-107.

Meyers, F. E., & Stewart, J. R. (2002). *Motion and time study for lean manufacturing*: Pearson College Division.

Minderhoud, S., & Fraser, P. (2005). Shifting paradigms of product development in fast and dynamic markets. *Reliability Engineering & System Safety, 88*(2), 127-135.

Miner, A. S., Bassof, P., & Moorman, C. (2001). Organizational improvisation and learning: A field study. *Administrative science quarterly, 46*(2), 304-337.

Moogk, D. R. (2012). Minimum viable product and the importance of experimentation in technology startups. *Technology Innovation Management Review, 2*(3).

Morgan, J., & Liker, J. K. (2006). *The Toyota product development system: integrating people, process, and technology*: Productivity press.

Mu, J., Peng, G., & MacLachlan, D. L. (2009). Effect of risk management strategy on NPD performance. *Technovation, 29*(3), 170-180.

Mukaka, M. M. (2012). A guide to appropriate use of correlation coefficient in medical research. *Malawi medical journal, 24*(3), 69-71.

Nepal, B. P., Yadav, O. P., & Solanki, R. (2011). Improving the NPD process by applying lean principles: A case study. *Engineering Management Journal, 23*(3), 65-81.

Nijssen, E. J., & Frambach, R. T. (1998). Market research companies and new product development tools. *Journal of Product & Brand Management*.

Nijssen, E. J., & Frambach, R. T. (2000). Determinants of the adoption of new product development tools by industrial firms. *Industrial Marketing Management, 29*(2), 121-131.

Osborne, J., Costello, A., & Kellow, J. (2008). Best practices in exploratory factor analysis. Best practices in quantitative methods. *J. Osborne. Los Angeles, Sage Publications*.

Owens, T., & Fernandez, O. (2014). *The lean enterprise: How corporations can innovate like startups*: Wiley Online Library.

Ozer, M. (2006). New product development in Asia: An introduction to the special issue. *Industrial Marketing Management, 35*(3), 252-261.

Pantiuchina, J., Mondini, M., Khanna, D., Wang, X., & Abrahamsson, P. (2017). *Are software startups applying agile practices? The state of the practice from a large survey.* Paper presented at the International Conference on Agile Software Development.

Paredes, J., Anslow, C., & Maurer, F. (2014). *Information visualization for agile software development.* Paper presented at the 2014 Second IEEE Working Conference on Software Visualization.

Patel, C., & Ramachandran, M. (2009). Story card based agile software development. *International Journal of Hybrid Information Technology, 2*(2), 125-140.

Pease, J. F., Dean, J. H., & Van Bossuyt, D. L. (2014). *Toward a market-based lean startup product design method for the developing world.* Paper presented at the ASME 2014 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.

Perry, J. L., Clough, P. J., Crust, L., Earle, K., & Nicholls, A. R. (2013). Factorial validity of the mental toughness questionnaire-48. *Personality and individual differences, 54*(5), 587-592.

Petersen, K., & Wohlin, C. (2010). The effect of moving from a plan-driven to an incremental software development approach with agile practices. *Empirical Software Engineering, 15*(6), 654-693.

Polk, R. (2011). *Agile and Kanban in coordination.* Paper presented at the 2011 Agile Conference.

Pons, D. (2008). Project management for new product development. *Project Management Journal, 39*(2), 82-97.

Powell, D. J., Bas, I., & Alfnes, E. (2013). *Integrating lean and MRP: A taxonomy of the literature.* Paper presented at the IFIP International Conference on Advances in Production Management Systems.

Price, J. H., & Murnan, J. (2004). Research limitations and the necessity of reporting them. *American Journal of Health Education, 35*(2), 66.

Racheva, Z., Daneva, M., & Buglione, L. (2008). *Supporting the dynamic reprioritization of requirements in agile development of software products.* Paper presented at the 2008 Second International Workshop on Software Product Management.

Rappa, M. (2001). Managing the digital enterprise-Business models on the Web. In.

Rea-Guaman, M., Calvo-Manzano, J., & San Feliu, T. (2018). *A prototype to manage cybersecurity in small companies.* Paper presented at the 2018 13th Iberian Conference on Information Systems and Technologies (CISTI).

Ries, E. (2011). *The lean startup: How today's entrepreneurs use continuous innovation to create radically successful businesses*: Currency.

Ries, E. (2017). *The startup way: how modern companies use entrepreneurial management to transform culture and drive long-term growth*: Currency.

Ries, E., & Euchner, J. (2013). What large companies can learn from start-ups. *Research-Technology Management, 56*(4), 12-16.

Ritter, T., & Walter, A. (2003). Relationship-specific antecedents of customer involvement in new product development. *International Journal of Technology Management, 26*(5-6), 482-501.

Rodríguez, P., Markkula, J., Oivo, M., & Turula, K. (2012). *Survey on agile and lean usage in finnish software industry.* Paper presented at the Proceedings of the 2012 ACM-IEEE International Symposium on Empirical Software Engineering and Measurement.

Roscoe, B. A., Hopke, P. K., Dattner, S. L., & Jenks, J. M. (1982). The use of principal component factor analysis to interpret particulate compositional data sets. *Journal of the Air Pollution Control Association, 32*(6), 637-642.

Rosenberger III, P. J., & de Chernatony, L. (1995). Virtual reality techniques in NPD research. *Market Research Society. Journal., 37*(4), 1-10.

Rossi, M., Kerga, E., Taisch, M., & Terzi, S. (2014). Engineering and design best practices in new product development: an empirical research. *Procedia CIRP, 21*, 455-460.

Rothman, K. J., Greenland, S., & Lash, T. L. (2008). *Modern epidemiology*: Lippincott Williams & Wilkins.

Salas Martinez, M. (2016). Good Practices of the Lean Startup Methodology: Benefits, challenges and recommendations.

Santos, V., Goldman, A., & De Souza, C. R. (2015). Fostering effective inter-team knowledge sharing in agile software development. *Empirical Software Engineering, 20*(4), 1006-1051.

Schein, E. H. (1990). *Organizational culture* (Vol. 45): American Psychological Association.

Schmidt, J. B., Montoya-Weiss, M. M., & Massey, A. P. (2001). New product development decision-making effectiveness: comparing individuals, face-to-face teams, and virtual teams. *Decision sciences, 32*(4), 575-600.

Schneider, J., & Hall, J. (2011). Why most product launches fail. In: Harvard Business School Publishing Corporation 300 NORTH BEACON STREET ….

Schwaber, K. (2004). *Agile project management with Scrum*: Microsoft press.

Shaffer, J. P. (1995). Multiple hypothesis testing. *Annual review of psychology, 46*(1), 561-584.

Shah, R., & Ward, P. T. (2007). Defining and developing measures of lean production. *Journal of operations management, 25*(4), 785-805.

Sharma, S., Sarkar, D., & Gupta, D. (2012). Agile processes and methodologies: A conceptual study. *International journal on computer science and Engineering, 4*(5), 892.

Smith, R. P. (1998). Teaching design for assembly using product disassembly. *IEEE transactions on education, 41*(1), 50-53.

Smits, H. (2007). *The impact of scaling on planning activities in an agile software development center.* Paper presented at the 2007 40th Annual Hawaii International Conference on System Sciences (HICSS'07).

Spss, I. (2011). IBM SPSS statistics for Windows, version 20.0. *New York: IBM Corp, 440*.

Staron, M., & Meding, W. (2011). *Monitoring bottlenecks in agile and lean software development projects–a method and its industrial use.* Paper presented at the International Conference on Product Focused Software Process Improvement.

Stratton, R., & Warburton, R. D. (2003). The strategic integration of agile and lean supply. *International journal of production economics, 85*(2), 183-198.

Stray, V. G., Lindsjørn, Y., & Sjøberg, D. I. (2013). *Obstacles to efficient daily meetings in agile development projects: A case study.* Paper presented at the 2013 ACM/IEEE International Symposium on Empirical Software Engineering and Measurement.

Strode, D. (2006). *Agile methods: a comparative analysis.* Paper presented at the Proceedings of the 19th annual conference of the national advisory committee on computing qualifications, NACCQ.

Suri, N., Bradshaw, J. M., Carvalho, M. M., Cowin, T. B., Breedy, M. R., Groth, P. T., & Saavedra, R. (2003). *Agile computing: Bridging the gap between grid computing and ad-hoc peer-to-peer resource sharing.* Paper presented at the CCGrid 2003. 3rd IEEE/ACM International Symposium on Cluster Computing and the Grid, 2003. Proceedings.

Sverrisdottir, H. S., Ingason, H. T., & Jonasson, H. I. (2014). The role of the product owner in scrum-comparison between theory and practices. *Procedia-Social and Behavioral Sciences, 119*, 257-267.

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics* (Vol. 5): Pearson Boston, MA.

Taipale, M. (2010). *Huitale–a story of a Finnish lean startup.* Paper presented at the International Conference on Lean Enterprise Software and Systems.

Takeuchi, H., & Nonaka, I. (1986). The new new product development game. *Harvard business review, 64*(1), 137-146.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International journal of medical education, 2*, 53.

Teeravaraprug, J., Kitiwanwong, K., & SaeTong, N. (2011). Relationship model and supporting activities of JIT, TQM and TPM. *Songklanakarin Journal of Science & Technology, 33*(1).

Tomes, A., Armstrong, P., & Clark, M. (1996). User groups in action: The management of user inputs in the NPD process. *Technovation, 16*(10), 541-551.

Underhill, L., & Bradfield, D. (1996). *Introstat*: Juta and Company Ltd.

Van Echtelt, F. E., Wynstra, F., Van Weele, A. J., & Duysters, G. (2008). Managing supplier involvement in new product development: a multiple-case study. *Journal of product innovation management, 25*(2), 180-201.

Van Muijen, J. J. (1999). Organizational culture: The focus questionnaire. *European Journal of work and organizational psychology, 8*(4), 551-568.

Varhol, P. (2015). To agility and beyond: The history—and legacy—of agile development. Retrieved from https://techbeacon.com/app-dev-testing/agility-beyond-history-legacy-agile-development

Veretennikova, N., & Vaskiv, R. (2018). *Application of the Lean Startup Methodology in Project Management at Launching New Innovative Products.* Paper presented at the 2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT).

Verganti, R. (2009). *Design driven innovation: changing the rules of competition by radically innovating what things mean*: Harvard Business Press.

Veryzer Jr, R. W. (1998). Discontinuous innovation and the new product development process. *Journal of Product Innovation Management: An International Publication of the Product Development & Management Association, 15*(4), 304-321. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4841176/pdf/JPIM-32-847.pdf

Walters, H. (2011). Design Thinking" isn'ta miracle cure, but here's how it helps. *Fast Company. http://www. fastcodesign. com/1663480/design-thinking-isnt-a-miracle-cure-but-heres-how-it-helps, 7*.

Wang, W.-P. (2009). Evaluating new product development performance by fuzzy linguistic computing. *Expert Systems with Applications*, *36*(6), 9759-9766.

West, S., Finch, J., & Curran, P. (1995). Structural equation modeling: concepts, issues and applications SAGE Publications. *Thousand Oaks, CA*.

Williams, L. (2012). What agile teams think of agile principles. *Communications of the ACM*, *55*(4), 71-76.

Xiaohu, Y., Bin, X., Zhijun, H., & Maddineni, S. R. (2004). *Extreme programming in global software development.* Paper presented at the Canadian Conference on Electrical and Computer Engineering 2004 (IEEE Cat. No. 04CH37513).

Yang, X., Sun, S. L., & Zhao, X. (2019). Search and execution: examining the entrepreneurial cognitions behind the lean startup model. *Small Business Economics*, *52*(3), 667-679.

Yeh, T.-M., Pai, F.-Y., & Yang, C.-C. (2010). Performance improvement in new product development with effective tools and techniques adoption for high-tech industries. *Quality & Quantity*, *44*(1), 131.

Yoshino, M. M. Y., & Rangan, U. S. (1995). An Entrepreneurial Approach To Globalization. In: Harvard Business Press.

Zhu, Y. (2009). Requirements engineering in an agile environment. In.

APPENDIX A: SURVEY

Defining best practices for lean principles within the NPD process

"This survey is conducted under the certificate code: CER-1920-51-D approved by Ethics Committee of Polytechnic Montreal (Canada)"

Dear participant,

We hereby invite you to take part in a research study aimed at best practices of an agile and lean start-up within new product development (NPD). However, before agreeing to participate in this study, please take the time to read, understand, and carefully consider the information provided in this form. We urge you to address any questions you have about it to the principal investigator or any other member of the research team and to ask them to explain anything unclear. We also encourage you to consult any other person or persons you wish for advice concerning your possible participation in this study.

Title of the research study:

Defining best practices for using lean start-up within the new product development process for physical goods

Research team:

Amir Ghoorchiyan (Researcher)

M.Sc. student at Polytechnic Montreal-Canada

Phone:+1-(514) 433-2444

E-mail: amir.ghoorchiyan@polymtl.ca

Fabiano Armellini (Main supervisor and responsible for the research)

Assistant professor at Polytechnic Montreal-Canada

Phone:+1-(514) 340-4711 ext. 4622

E-mail: fabiano.armellini@polymtl.ca

Luciana Paula Reis (Co-supervisor)

Assistant professor at Federal University Ouro Preto-Brazil

Phone:+55-(31) 3852-8709

E-mail: lucianapaula@ufop.edu.br

Presentation of the research study and its objectives:

The objectives of this research study are the following:

i. Recognizing the best practices of lean start-up and agile within NPD

ii. Assess the differences in the adoption of lean practices for software, hardware and service companies

iii. Identify opportunities for adopting lean practices outside the software context

This study is part of the research master program of Amir Ghoorchiyan under the supervision of Fabiano Armellini and Luciana Paula Reis.

The emergence of the Lean methodology goes back to Toyota Production System in the 1960s. Later, the so-called Lean principles have been incorporated to design and product development activities. More recently, the third generation of the Lean methodology, also known as the Lean start-up, is an agile method conceived to improve and develop new products within the IT and software areas. Although successful and widespread, the transposition of the methods that resulted from the Lean Startup movement into the development of the physical good is not evident. Therefore, this project aims at understanding how companies that produce physical goods are currently developing their NPD process and to identify best practices for lean product development under this context.

This research will be based on a literature review followed by a survey and interviews with NPD process practitioners. The data collected will be analyzed by statistical methods to verify our research hypothesizes which aim at defining the best practices to the adaptation of the Lean principles for NPD for physical goods.

Nature and duration of your participation in this research study:

Participation in this study will involve answering a series of questions based on their knowledge and experience in the field of the new product/service development process. All the answers you provide will remain confidential. It should take approximately 20 minutes to complete the questionnaire. If you agree to participate in this study, simply click on the “I agree” button at the bottom of this page and complete the online survey.

Potential benefits of participation in this research study:

You will not receive any personal benefit from your participation in this research project, however, you will contribute to the advancement of knowledge within this field of research.

Risks and inconveniences of participating in this research study:

There are no risks associated with your participation in this survey beyond those encountered in your daily life. The only inconvenience is the time to complete the survey (about 20minutes) and the fatigue that it may

cause you.

Financial compensation:
You will not receive any financial compensation for your participation in this study.

Compensation in the event of prejudice, and the rights of participants:
Should you suffer any prejudice whatsoever as a result of your participation in this study, you do not waive any of your rights nor does such prejudice relieve the researchers or Polytechnique Montréal from their legal and professional liabilities.

Voluntary participation and withdrawal:
Your participation in this study is voluntary. You are therefore free to refuse to participate in it, and you can choose to withdraw from it at any time without having to justify your decision or suffering any prejudice.
Your data will only be taken into account in the research if they reach the end of the questionnaire and click the "submit" button on the last page of the survey. After that, withdrawal is no longer possible, because of the anonymous nature of the questionnaire (we will not be able to identify your response in the database).
The principal investigator, or Polytechnique Montréal's REB, may withdraw participants without their consent if they fail to follow the instructions or if there are any administrative reasons for abandoning the study, including safety reasons or feasibility concerns.

Confidentiality:
This survey is anonymous, which means that no personal information is collected. Your confidentiality is therefore protected.

All information collected in this survey concerns NPD practices of your company, and the only information required about the company is the industry sector and the nature of the product you provide (software, hardware, service or a combination of those).

The data collected will be kept under-protected servers located in Polytechnique Montréal's buildings. The information collected during the study will be used by the principal investigator for the sole purpose of this study.
To preserve the scientific integrity of the research study, the information collected in the survey will only be accessible once the study is complete. In compliance with current standards, the data will be kept for seven (7) years, after which it will be destroyed.
For monitoring or control purposes, your research file may be consulted by a person mandated by Polytechnique Montréal's REB or by a person mandated by the organization(s) funding the research. All these individuals and organizations adhere to strict privacy policies.

Conflicts of interest:

There are no actual, potential, or perceived conflicts of interest involving any member of the research team, his/her home institution, or the organization(s) funding the study.

Dissemination and commercialization of the research results:

The result of this research will be published as an article by the end of this year under the research title that would be accessible on the polytechnic library website or you can ask the electronic version of the article by directly contact the research group responsible.

Contact persons:

If you have any questions regarding this study, feel free to contact with Mr. Amir Ghoorchiyan, a student in charge of the project by e-mail (amir.ghoorchiyan@polymtl.ca), with Mr. Fabiano Armellini, responsible for the research at Polytechnique Montréal by e-mail (fabiano.armellini@polymtl.ca) or telephone at (514)340-4711 ext. 4622.

If you have any questions regarding your participation in this study, feel free to contact the Chair of Polytechnique Montréal's Research Ethics Board, Ms. Farida Cheriet by telephone at 514-340-4711, ext. 4277, or by email at farida.cheriet@polymtl.ca (mailto:farida.cheriet@polymtl.ca).

Consent:

By completing this questionnaire, you agree to participate in this study following the conditions set out herein. Please keep a copy of this document for your records.

Estimated time for filling up: 15-20 minutes
There are 10 questions in this survey.

A. Initial Information

A.A. Company Background and Responder situation

1 Which sector best describes the field of business of your company? *

Choose one of the following answers

Please choose **only one** of the following:

- ◯ IT, Software
- ◯ Industrial, Manufacturing
- ◯ Service (ex.: Retailer, Food, etc.)
- ◯ Entertainment
- ◯ Financial and insurance
- ◯ Educational sector
- ◯ Non-profit
- ◯ Governmental sector
- ◯ Telecommunication
- ◯ Health
- ◯ Technology
- ◯ Transportation
- ◯ Energy
- ◯ Construction
- ◯ Professional consultants
- ◯ Other

2 How many employees does your company have? *

Choose one of the following answers
Please choose **only one** of the following:

- ◯ <100
- ◯ 101-500
- ◯ 501-1000
- ◯ >1001

3 How long is your company established? [in year(s)] *

Choose one of the following answers
Please choose **only one** of the following:

- ◯ <1
- ◯ 1-2
- ◯ 2-5
- ◯ 5-10
- ◯ >10

4 Where is your company located? *

Choose one of the following answers
Please choose **only one** of the following:

- ◯ Canada
- ◯ United States of America
- ◯ Latin America of Caribbean
- ◯ Europe
- ◯ Asia
- ◯ Africa
- ◯ Oceania

5 What option is the best fit for your company's main offer? *

Choose one of the following answers
Please choose **only one** of the following:

- ◯ We offer a service
- ◯ We license software
- ◯ We sell tangible products (hardware)
- ◯ We offer a service based on a software (SaaS)
- ◯ We offer a service combined to a tangible product
- ◯ We offer a tangible product with embedded software
- ◯ Our offer is a combination of a tangible product, software, and service

6 Please divide the company revenue for 2018-9

❗ Only numbers may be entered in these fields.
Please write your answer(s) here:

Revenue for selling the service in %	
Revenue of selling the good in %	
Revenue of selling the software in %	
Revenue for selling or other income in %	

Please provide the percentage from range 0-100 with consideration of 100% as a total of all cells.

B. Agile – Lean Startup Technics

B.B. Hint of this table:
Those tools are the most common techniques that make the process trackable and measurable. This part is based on the Likert Scale [7], the hint table proposed the meaning of the number in color columns:

1 – Never use
2 – Almost never
3 – Occasionally/Sometimes
4 – Almost every time
5 – Frequently use

7

How often do you use those tools and techniques?

Those tools are the most common techniques that make the process trackable and measurable. This part is based on the Likert Scale, the hint table proposed the meaning of the number in color columns:

1 – Never use
2 – Almost never
3 – Occasionally/Sometimes
4 – Almost every time
5 – Frequently use

*

Please choose the appropriate response for each item:

	1	2	3	4	5
Daily meeting	○	○	○	○	○
Kanban	○	○	○	○	○
Kaizen	○	○	○	○	○
TQM	○	○	○	○	○
Customers involvement	○	○	○	○	○
Direct contact with customers	○	○	○	○	○
Face to Face meeting and orientations	○	○	○	○	○
Training courses	○	○	○	○	○
Product road mapping	○	○	○	○	○
Project management technics	○	○	○	○	○

	1	2	3	4	5
Short iteration	◯	◯	◯	◯	◯
Scrum master of each product	◯	◯	◯	◯	◯
MRP1 and/or 2	◯	◯	◯	◯	◯
Prototype	◯	◯	◯	◯	◯
3D print prototyping (virtual prototyping)	◯	◯	◯	◯	◯
Virtual test	◯	◯	◯	◯	◯
Sub-brand production	◯	◯	◯	◯	◯
Visualization of reports	◯	◯	◯	◯	◯
Sprint/backlog list	◯	◯	◯	◯	◯
Split test A/B test	◯	◯	◯	◯	◯
Prioritizing of tasks	◯	◯	◯	◯	◯
Work standardization	◯	◯	◯	◯	◯
Self-control	◯	◯	◯	◯	◯
Milestone	◯	◯	◯	◯	◯
What-if scenarios	◯	◯	◯	◯	◯
Deeply cause finding(5Whys)	◯	◯	◯	◯	◯
Time standardization	◯	◯	◯	◯	◯
Product owner of each product	◯	◯	◯	◯	◯

	1	2	3	4	5
User story card	◯	◯	◯	◯	◯
Value proposition	◯	◯	◯	◯	◯

C. Agile Practices Assessment

C.C. Hint of this table:

Those questions in blows assess and classify Agile practices in the current situation of your company. This part of the survey is structured based on the Likert Scale. The hint table is proposed:

1 – Strongly disagree
2 – Disagree
3 – Neutral
4 – Agree
5 – Strongly agree

8

Those questions in blows assess and classify Agile practices in the current situation of your company. This part of the survey is structured based on the Likert Scale. The hint table is proposed:

*

Please choose the appropriate response for each item:

1 – Strongly disagree
2 – Disagree
3 – Neutral
4 – Agree
5 – Strongly agree

	1	2	3	4	5
The company is using the iterative control for finding and solving the problem.	◯	◯	◯	◯	◯
The solving problem from design phases through small movement in multiple passes and cycling.	◯	◯	◯	◯	◯
Splits development tasks into a series of iterations that must be accomplished within a specific time period.	◯	◯	◯	◯	◯
Time boxing helps demonstrate progress and keeps everyone working within the same fixed parameters.	◯	◯	◯	◯	◯

	1	2	3	4	5
Groups of individuals charged with working on a set of tasks meet agreed-upon product requirements.	○	○	○	○	○
Existing someone in charge of requirements and prioritizing tasks within the sprint cycle is necessary.	○	○	○	○	○
Existing someone whose job it is to enlist new resources when necessary and resolve problems is necessary.	○	○	○	○	○
Always there is on schedule a daily meeting for tracking the project.	○	○	○	○	○
Daily meetings set the context for the coming day's work. (even formal or informal)	○	○	○	○	○
Prioritizing of work based on requirements and express what needs to happen and what is backlogged.	○	○	○	○	○
Ensuring that the work gets done using mechanisms like a daily meeting or running interference.	○	○	○	○	○

	1	2	3	4	5
Visualization of tasks is being done in terms of following the work progress.	◯	◯	◯	◯	◯
The visualization shows the duties and completed tasks.	◯	◯	◯	◯	◯
Ordering high value of tasks and features accelerate to delivery cycle.	◯	◯	◯	◯	◯
Features are categorized by their value based on product owner decisions.	◯	◯	◯	◯	◯
The development part is done separately from the operation part.	◯	◯	◯	◯	◯
In current situation operations and development work closely together at the early stage of design.	◯	◯	◯	◯	◯
People work separately on portions of a system and then combine their work like a preserve change.	◯	◯	◯	◯	◯
The company uses an open-source distributed version control system.	◯	◯	◯	◯	◯

	1	2	3	4	5
Work is breakup to each stage, with multiple teams doing parallel sprints and work planned incrementally within each stage.	◯	◯	◯	◯	◯
Putting milestones after each phase to control tasks quality and time table is the current activity to measure the progress.	◯	◯	◯	◯	◯
Using the entire flowchart of work to distinguish the faulty points and synchronizing whole activities in one frame. (SAFe)	◯	◯	◯	◯	◯

D. Lean Startup Practices Assessment

D.D.Those questions in blows assess and classify Lean Startup practices in the current situation of your company. This part of the survey is structured based on the Likert Scale. The hint table is proposed:

1 – Strongly disagree
2 – Disagree
3 – Neutral
4 – Agree
5 – Strongly agree

9
Those questions in blows assess and classify Lean Startup practices in the current situation of your company. This part of the survey is structured based on the Likert Scale. The hint table is proposed:

*

Please choose the appropriate response for each item:

1 – Strongly disagree
2 – Disagree
3 – Neutral
4 – Agree
5 – Strongly agree

	1	2	3	4	5
The MVP (Minimum Viable Product) lacks many features that may prove essential later on.	○	○	○	○	○
Cause of creating MVP, to test new ideas and running experiments to tune the engine of growth.	○	○	○	○	○
Interaction designers led the way by developing a clear customer archetype that was based on extensive in-person conversations and observation.	○	○	○	○	○
Customers often don't know what they want, the small scale of customer reaction in the pilot period can help to develop the product.	○	○	○	○	○

	1	2	3	4	5
The company takes advantage of the adaptability,creativity, and wisdom of individual workers to create and develop new products.	◯	◯	◯	◯	◯
The company considers a personal stake for innovators.	◯	◯	◯	◯	◯
The innovation team should keep hidden the details of innovating.	◯	◯	◯	◯	◯
The company uses a fast feedback loop to solve the quality problem of products.	◯	◯	◯	◯	◯
Feedback loops can cut down the waste and sub-optimize the individual functions.	◯	◯	◯	◯	◯
There is a strict process of demonstrating empirically that a team has discovered valuable truths about a company's present and future business prospects.	◯	◯	◯	◯	◯
There is a backed up by empirical data collected from real customers to deeply understand the needs and mitigate the waste.	◯	◯	◯	◯	◯

	1	2	3	4	5
The company measures the retention rate of new buyers and sellers if people stick around the product that means the market will grow.	○	○	○	○	○
The rate of customer growth is the index that the company assesses to succeed in the product.	○	○	○	○	○
The company by making small batches allows the team to make a cheap mistake quickly and start learning.	○	○	○	○	○
The biggest advantage of working in small batches is that quality problems can be identified much sooner.	○	○	○	○	○
The company makes sure production processes are tuned to levels of customer demand.	○	○	○	○	○
There is a plan to defines value as providing benefit to the customer and else is waste.	○	○	○	○	○
Viral growth is dependent on person-to-person transmission as a necessary consequence of normal product use.	○	○	○	○	○

	1	2	3	4	5
The company makes the new product based on the value creation hypothesis and the growth hypothesis.	◯	◯	◯	◯	◯
Change in course or strategy might lead to more significant growth.	◯	◯	◯	◯	◯
There is a meeting often to review changing in product or quite the market, each meeting requires the participation of both the product development and business leadership teams.	◯	◯	◯	◯	◯
Lunching low-quality products because of speed helps us to make real and right decisions.	◯	◯	◯	◯	◯

E. Performance

E.E. How do you judge the impact of using Agile and/or Lean Startup practices on the new product development performance in your company with consideration of the process situation before and after launching the Agile and/or Lean startup methodology?

1–Much worse
2–Somewhat worse
3–About the same
4–Somewhat better
5–Much better

10
How do you judge the impact of using Agile and/or Lean Startup practices on the new product development performance in your company with consideration of the process situation before and after launching the Agile and/or Lean startup methodology?

*

Please choose the appropriate response for each item:

1–Much worse
2–Somewhat worse
3–About the same
4–Somewhat better
5–Much better

	1	2	3	4	5
Quality and speed to market (QSM)	◯	◯	◯	◯	◯
Number of the important/major customers (NMC)	◯	◯	◯	◯	◯
Market share rate (MSR)	◯	◯	◯	◯	◯
Widening customer choice & expectation (WCCE)	◯	◯	◯	◯	◯
Delivery (D)	◯	◯	◯	◯	◯
Flexibility (F)	◯	◯	◯	◯	◯
Number of new products or processes (NPP)	◯	◯	◯	◯	◯
Number of patents (NPT)	◯	◯	◯	◯	◯

	1	2	3	4	5
Reduction of R&D cost (RC)	◯	◯	◯	◯	◯
Productivity (P)	◯	◯	◯	◯	◯
Brand reputation (BR)	◯	◯	◯	◯	◯
Improvement of information system (IIS)	◯	◯	◯	◯	◯
Responsiveness improvement of competitive priorities (RCP)	◯	◯	◯	◯	◯
Employees capability improvement (EC)	◯	◯	◯	◯	◯
Increasing employee's engagement in R&D process (EE)	◯	◯	◯	◯	◯
Increasing employees train (ET)	◯	◯	◯	◯	◯
Improving the rate of reusing the technologies or features (reducing unnecessary re-work) (RRT)	◯	◯	◯	◯	◯
Increased added value for the customer in product development activities (AVC)	◯	◯	◯	◯	◯

Thanks for your participation and good luck!
07.07.2020 – 12:06

Submit your survey.
Thank you for completing this survey.

APPENDIX B: ETHICS COMMITTEE CERTIFICATE

POLYTECHNIQUE MONTRÉAL
UNIVERSITÉ D'INGÉNIERIE

CER-1920-51-D

Montréal, le 18 mars 2020

Objet: Approbation éthique – « Defining best practices for using lean principles within the new product development process for physical goods » -
Projet CER-1920-51-D

M. Amir Ghoorchiyan,

J'ai le plaisir de vous informer le Comité d'éthique de la recherche, selon les procédures en vigueur, en vertu des documents qui lui ont été fournis, a examiné le projet de recherche susmentionné et conclu que ce dernier répond aux normes en vigueur au chapitre de l'éthique de la recherche énoncées dans la *Politique en matière d'éthique de la recherche avec des êtres humains* de Polytechnique Montréal.

Veuillez noter que le présent certificat est valable pour une durée d'un an, soit du 18 mars 2020 au 19 mars 2021, pour le projet tel qu'approuvé au Comité d'éthique de la recherche avec des êtres humains.

Veuillez noter que conformément aux exigences auxquelles l'institution et son personnel sont assujettis afin d'être admissibles aux fonds des organismes subventionnaires, il est de votre responsabilité de déposer au CÉR un rapport annuel ou un rapport final avant l'expiration de la présente approbation éthique afin de l'informer de l'avancement de vos travaux. Le formulaire à remplir est disponible à l'adresse suivante : (http://www.polymtl.ca/recherche/formulaires-et-guides).

De plus, il est de votre responsabilité d'informer le CER de toute modification importante qui pourrait être apportée au protocole expérimental avant sa mise en œuvre, de même que de tout élément ou évènement imprévu pouvant avoir une incidence sur le bien-être ou l'intégrité des participant(e)s impliqué(e)s dans le projet de recherche. Nous vous invitons aussi à nous signaler tout problème susceptible d'avoir une incidence sur les membres de l'équipe de recherche.

Je vous souhaite bonne chance dans la poursuite de vos travaux.

Nous vous prions d'agréer, Monsieur, l'expression de nos sentiments les meilleurs,

Farida Cheriet, présidente
Comité d'éthique de la recherche
Polytechnique Montréal

c.c. Direction de la formation et de la recherche; Service des Finances
Fabiano Armellini, professeur adjoint, Département de mathématiques et génie industriel
Luciana Paula Reis, assistant professor,
p.j. Certificat # CER-1920-51-D

Comité d'éthique de la recherche avec des êtres humains
Tél.: 514 340-4711 poste : 3755
Fax : 514 340-4992
Courriel : ethique@polymtl.ca

Adresse postale
C.P. 6079, succ. Centre-Ville
Montréal (Québec) Canada H3C 3A7

Campus de l'Université de Montréal
2900, boul. Édouard-Montpetit
2500, chemin de Polytechnique
Montréal (Québec) Canada H3T1J4

POLYTECHNIQUE MONTRÉAL
UNIVERSITÉ D'INGÉNIERIE

CER-1920-51-D

CERTIFICAT D'APPROBATION ÉTHIQUE

Le Comité d'éthique de la recherche de Polytechnique Montréal, selon les procédures en vigueur, en vertu des documents qui lui ont été fournis, a examiné le projet de recherche suivant et conclu qu'il respecte les règles d'éthique énoncées dans sa Politique en matière d'éthique de la recherche avec des êtres humains.

Projet	
Titre du projet	**Defining best practices for using lean principles within the new product development process for physical goods** **CER-1920-51-D**
Étudiant requérant	**Amir Ghoorchiyan**, Candidat à la maîtrise, Département de mathématiques et génie industriel
Sous la direction de:	**Fabiano Armellini, professeur adjoint**, Département de mathématiques et génie industriel, Polytechnique Montréal & **Luciana Paula Reis, assistant professor**, Federal University of Ouro Preto.

Financement	
Organisme	Non financé
No de UBR	

MODALITÉS D'APPLICATION

Toute modification importante qui pourrait être apportée au protocole expérimental doit être transmise au Comité avant sa mise en œuvre.

L'équipe de recherche doit informer le Comité de tout élément ou évènement imprévu pouvant avoir une incidence sur le bien-être ou l'intégrité des participant(e)s impliqué(e)s dans le projet de recherche ainsi que tout problème susceptible d'avoir une incidence sur les membres de l'équipe de recherche.

Selon les règles universitaires en vigueur, un suivi annuel est minimalement exigé pour maintenir la validité de la présente approbation éthique, et ce, jusqu'à la fin du projet. Le questionnaire de suivi est disponible sur la page web du Comité.

Date de délivrance : **18 mars 2020**

Date de fin de validité : **1er avril 2021**

Farida Cheriet, présidente
Comité d'éthique de la recherche
Polytechnique Montréal

Date du prochain suivi : **19 mars 2021**

Comité d'éthique de la recherche avec des êtres humains
Tél.: 514 340-4711 poste : 3755
Fax : 514 340-4992
Courriel : ethique@polymtl.ca

Adresse postale
C.P. 6079, succ. Centre-Ville
Montréal (Québec) Canada H3C 3A7

Campus de l'Université de Montréal
2900, boul. Édouard-Montpetit
2500, chemin de Polytechnique
Montréal (Québec) Canada H3T1J4

APPENDIX C: INVITATION

Dear Madam / Sir,

I send you this e-mail on behalf of the Industrial Engineering department of the Polytechnique Montréal.

The purpose of this e-mail is to invite you to take part in a research project on "Defining best practices for using lean principles within the new product development (NPD) process for physical goods", which consists of a web-based survey that can be assessed the following link:

https://sondage.mgi.polymtl.ca/index.php/416821?lang=en

This research aims to benchmark best practices of lean product development (LPD) and the Lean Startup Method (LSM) to assess how different if the approach to these methods between software, hardware and service companies. More particularly, our goal is to contribute to an emerging trend within researchers and practitioners to identify opportunities to integrate lean practices in NPD outside the software development context.

In the survey, we will inquire about the current situation of the NPD process in your company, as well as the tools, practices and their respective tangible and intangible benefits.

The time required to complete this survey is about 20 minutes. The survey is anonymous and no personal information is requested. However, if you want to receive a report with the results of this research, you can fill in your email address to receive it. However, this is an optional field.

This project is complied with the Canadian Tri-Agency Framework for Responsible Conduct of Research and is certified by Polytechnique Montréal's Research Ethics Board (certificate attached). You can, therefore, be assured that your privacy will be respected, and that the data you provide us will be carefully handled, analyzed and stored, and that only data in an aggregated form will be used for any publications resulting from this research project.

If you have any questions about the research project, please feel free to contact us.

Once again, thank you very much in advance for your attention and for helping us by participating in the research.

Yours sincerely,

Amir Ghoorchiyan
M.Sc. Industrial Engineering - MAGI Department

P.O. Box 6079, Station Center-Ville, Montréal (Québec) Canada, H3C 3A7 - Polytechnique Montréal - (Bureau: A306.7) - Phone: + 1- (514) 340 -4711 Ext. 4622
Amir.ghoorchiyan@polymtl.ca
Amir.ghoorchiyan@umontreal.ca
Amir.ghoorchiyan@hec.ca

POLYTECHNIQUE MONTRÉAL
LE GÉNIE EN PREMIÈRE CLASSE