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How to monitor the front end of innovation in the new product development: defining performance indicators.

The case study of an accelerator of technology commercialization

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Abstract

The new product development process represents one of the biggest opportunities for innovative firms to remain competitive and to strengthen growth. The upstream part of the process, the "front end" of innovation, is a key step as it influences the success of the product. Evaluating the front end performance is particularly challenging since typical financial measures of product development do not often apply.

This paper has the ambition to define performance indicators that monitor the performance all along the front end process. In order to answer the following research question:" What are the relevant performance indicators when monitoring the front end of innovation?" the dissertation starts with a literature review followed by observations based on a case study of the accelerator of technology commercialization "Cohitec".

The results revealed the importance to subdividing the front end into distinct periods in order to find the appropriate indicators for each moment in the process. Three periods were identified namely exploration, validation and business case.

The relevant indicators in the exploration part concern the technology, the value proposition and product. In the validation, the market potential is evaluated while in the business case stage, the plan of development is given evaluations. Finally, team dimension is split into team composition which is assessed at the beginning of the process and the team dynamics which must be assessed throughout the front end.

Key-words: Front end of innovation, performance indicators, monitoring

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1. Introduction

1.1 Context

Nowadays, being innovative has become an imperative for firms evolving in competitive markets. As a matter of fact, innovation and especially new product development offer great opportunities to create and to strengthen competitive advantages (Reguia, 2014). The last few decades, studies were devoted on managing the innovation process in the most effective possible way and some of them attempted to break the innovation process into manageable stages in order to ease control and the conduct (Booz, Allen & Hamilton, 1982; Cooper, 1988; Khurana & Rosenthal, 1997). Even though there exists numerous literatures on the innovation management, only a few are dedicated to the upstream part of the innovation process – the so called "front end" of innovation.

Yet, many known authors (Cooper 1988; Cooper & Kleinschmidt, 1991, 1994; Frishammar & Florén, 2008; Herstatt & Verworn, 2001; Langerak et al., 2004,) have raised awareness about the importance of the earliest stages and based on their studies, have proved the strong influence that the front end has on the innovation and the product successes, named the *leverage effect* by Verworn (2009).

The front end of innovation has recently become the focus of many studies. Most of them aims at identifying the key success factors and the best practices in order to succeed in the front end (Herstatt & Verworn, 2001; Kim & Wilemon, 2002b; Koen et al., 2002). However, a very few researches in the area of performance control have been carried out.

Yet, the perks of controlling the well-conduct of the front end are major and well-known: it can enable to avoid time delays, increased costs and future problems during the development phase (Ho & Tsai, 2011). Moreover, it can reduce the probability of failures, prevents supplementary loops further in the process and can permit to emphasize the weaknesses and subsequently, improve the process effectiveness (Gassman & Schweitzer, 2014).

The present paper gives an opportunity to monitor the front end of innovation by proposing a set of quality criteria.

1.2 Problematic and method

Relatively few researches focus on the indicators of performance in the front end of innovation (reduced to the FEI). Hence, this thesis has the purpose to rectify this deficiency by proposing a set of performance indicators applicable in the early stages of the innovation process.

The problematic of this thesis is formulated as the following:

> How to monitor the front-end of innovation in the new product development: defining performance indicators.
> *The case study of an accelerator of technology commercialization.*

In order to fulfill the objective, beforehand, a literature review dealing with the concepts of innovation, new product development, front end of innovation and performance indicators is presented. Stemming from the academic literature on performance indicators, several performance indicators are considered for the research.

The following task is to identify the relevant indicators required in a practical situation with the case study of "Cohitec". The aim of this method is to confront the academic theory and the practices and usages of an organization. From this confrontation, the researcher is able to highlight the eventual gaps between theory and practical case, write conclusions and make general recommendations.

In addition, it has come to light that Cohitec has not developed performance indicators yet and showed keen interest in establishing some in its training program. Cohitec is a 4-month technology commercialization accelerator training program. It supports Portuguese entrepreneurs, R&D institutions or companies to take their technology to global markets.

The methodology applied along this thesis is described in the beginning of the practical part of the thesis.

1.3 Structure

The paper is divided in two main parts: a literature review and the case study of Cohitec

In the first part, the paper presents three sections. The first section starts with some notions of innovation such as the definitions and the scope of innovations. Also, the new product development (NPD) process is introduced.

In the second section, the paper deals with the upstream part of the NPD process- the “front end” of innovation. It encompasses definitions of the concept and provides some illustrations of the front end of innovation process according three approaches: linear, circular and entrepreneurial.

Following this, the subsequent section is a literature review on the indicators of performance related to the front end of innovation. At the end, a summary of the literature review is handled.

The second part of the thesis aims at defining a set of quality criteria in the front end of innovation with the case study of Cohitec. The observations section presents the results collected through the analysis of the findings.
Then, discussions between the literature review and the findings take place prior the general conclusions. The latter includes managerial implications, limitations of the study with thoughts for further researches.

THEORETICAL PART: LITERATURE REVIEW

2. Notions of innovation

2.1 Definitions

Beforehand, it is necessary to understand what innovation is and what it includes in the definition. For this purpose, some definitions of the concept are being explored in the present section.

The problematic of the thesis deals with the new product development process. Hence, the present research only covers *product innovation*. It is defined by the generation and the development of new and/or improved products and services (Weiermair, 2004).

The development of new products and services constitutes, for many industries, one of the most important factors responsible for the company success or failure and is the leading driver of competition between firms and industries (Schilling & Hill, 1998).

The term innovation does not possess a common definition in the academic literature. In their paper "Towards a multidisciplinary definition of innovation", Baregheh, Rowley & Sambrook (2009) explain the absence of an universal definition of innovation by the fact that innovation concerns a range of business and management disciplines such as the human resource management, operation management, entrepreneurship, marketing and strategy, engineering, product design, R&D and IT.

Each of these disciplines suggests a different definition of innovation that is aligned with the dominant paradigm of the discipline. Therefore, according to these authors, innovation has numerous definitions because it is a concept that is applied to an array of disciplines and hence, it is defined according different perspectives (Baregheh, Rowley & Sambrook, 2009).

At its very basic purpose, innovation is a process starting with an idea, operates with the development of an invention and results in the launch of a new product to the marketplace (Edwards & Gordon, 1984).

Dodgson, Gann & Salter (2008) encompass in the definition of innovation, all the business activities that are required in the elaboration of a new or improved product or service.

Trott (2005) is more explicit about the activities and he claims that innovation reunites theoretical conception, technical invention and commercial exploitation. He claims that theoretical conception is about generating new ideas and record it. Technical invention means turning ideas into new product concept and finally, commercial exploitation has the objective to launch new products on the market in order to produce commercial value.

What is common between the aforementioned definitions is that the innovation process consists in the technological development of an idea or an invention combined with the introduction of this idea to end-users on the market through adoption and diffusion (Garcia & Calantone, 2002).

For the research, innovation is considered as a process along which new ideas are generated, developed and commercialized on the market in the form of new products and new services.

2.2 Scope of innovations

Although the present paper focuses on the generation of new products and services in the market place, innovation involves a broader scope. The most common types of innovation are made explicit by the Oslo Manual (2005) from the OECD which includes the introduction of new products, new process, new marketing method and new organizational forms.

Trott (2005) improves the list made by the OECD with three extra more types of innovation namely new management methods, new production means and new services. Even though the type of innovation is not only restricted to the mentioned areas, these are the most common types.

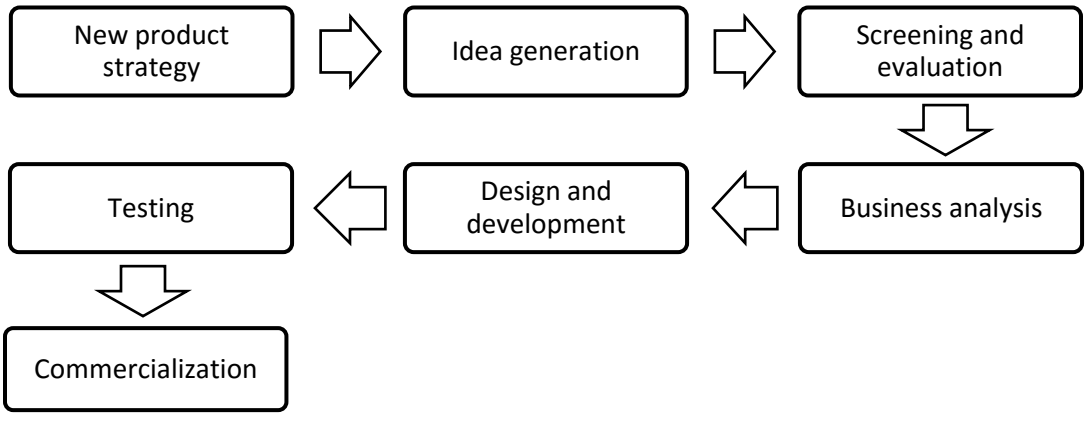
2.2.1 New product development process

Since the scope of the research is limited to product innovation, the interest is carried on the innovation process aiming at launching new products[1] on the market.
In the literature, it is referenced as the "New Product Development process "(NPD) and it includes the complete process and the activities by which a new- improved- product or service is brought on the market (Cooper, 1988).

In the literature, the NPD process is usually split into several theoretical phases, presenting a standard framework of the process which has the aim of lessening risk (Booz, Allen & Hamilton, 1982).

One of the best-known illustrations of the NPD is developed by the American management consulting company Booz, Allen & Hamilton in 1982 and is called the BAH model.
The BAH model separates the new product development process into seven stages through which new products must pass namely: product strategy, idea generation, screening and evaluation of ideas, business case analysis, development, testing and commercialization (Booz, Allen & Hamilton, 1982).

Figure 1: The BAH model (Booz, Allen & Hamilton, 1982)

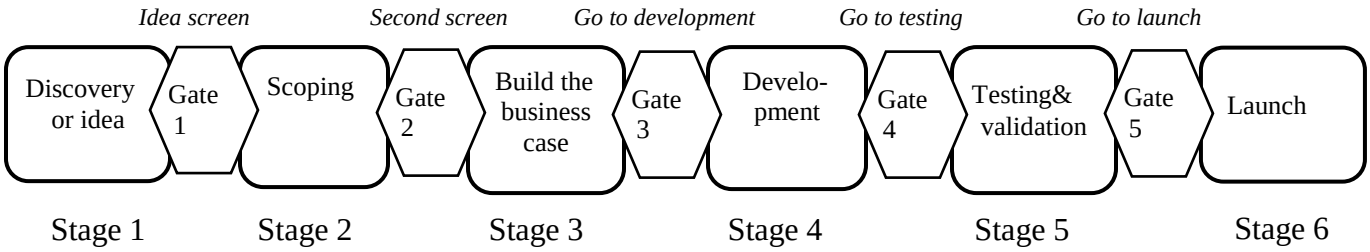


[1] Throughout this thesis, when using the term product, we refer to products and services.

A second very well-known NPD model, having found its inspiration from the BAH model, is the Stage-gate model developed by Cooper (1988).

The Stage-gate model (SG model) is a conceptual roadmap that breaks the product innovation into a predetermined sequential set of stages separated by management decisions gates. Throughout the process, teams are expected to collect information aiming at reducing the project uncertainty and risk until facing a management gate in which the project is being evaluated against quality criteria (Cooper, 2008).

Figure 2: The Stage-Gate model by Cooper (1988)



Although, the Stage-gate builds its framework based on the BAH model, the former mainly differs from the latter in two elements: the introduction of management gates and the absence of a product strategy stage prior to ideation.

Commonly, the gates in the SG model represent checkpoint moments in the process during which the project is being evaluated against a set of quality criteria- must meet and should meet criteria and during which the person in charge of innovation takes the go/kill decision to continue the project or to terminate it (Cooper, 1990). While quality checkpoints are frequent in the Stage-gate model, the BAH model does not draw up an assessment of the project during the process.

A second divergence between the two models stands in the first phase of the process. The BAH model's very first step consists in identifying the strategic business requirements resulted from the objectives and the strategy of the company that the new product must comply with (Booz,

Allen & Hamilton, 1982) whilst the SG model starts the development of new products with a discovery or the generation of ideas. In Cooper 1988's model, the linkage between the new product and the company 'strategy does not occur at the beginning of the process. It comes later on, when the product is being evaluated against quality criteria during the management gates (Cooper, 1990).

For the purpose of this research, the Stage-gate model will be further considered at the expense of the BAH model. The objective of the paper is to propose a set of performance indicators which works similarly as the quality criteria used for each management gate in the SG model.

3. The front end of innovation

Now that NPD process has been introduced and illustrated, the focus is on the upstream part of the NPD process, named the "fuzzy front end" by Reinertsen (1991), the "front-end" of innovation by Koen et al. (2001), the "pre-development" activities by Cooper & Kleinschmidt (1994) or the "pre-phase 0" by Khurana & Rosenthal (1997, 1998).

Therefore, the following section clarifies the fuzziness usually associated with the earliest stages of the NPD and provides definitions as well as illustrations of the concept.

3.1 Definitions

According to Koen et al. (2001, 2002), the front end of innovation stands as the earliest stage of the NPD process and refers to the unpredictable and unstructured activities taking place before the development stage.

Similarly, Khurana & Rosenthal (1998) incorporate in the front end of innovation, all activities taking place before the Management takes the formal go/no go decision to move the project to the development stage.

Kim & Wilemon (2002b) and Moenaert et al. (1995) provide a definition of the FEI related to a period of time: the front end begins when an opportunity is identified and estimated to be worth enough to be explored, and it ends when the management takes the decision to terminate the project or to commit to larger investments in the development stage.

Kim & Wilemon (2002b) state that the early stage derives its ambiguous name from its non-routine, uncertain and dynamic path.
Eric Stevens (2014) resumes the causes of the fuzziness in the early front-end in three elements: uncertainty, equivocality and complexity. The uncertainty comes from a lack of information regarding the customer, the technology and the market competition (Doll & Zhang, 2001).
Equivocality is the situation where multiple meanings can be made from the same facts or data. As a consequence, multiple decisions may be taken according to the diverse interpretations (Stevens, 2014).
Finally, the complexity is initiated in information processing where a decision of one facet of the project influences the other aspects.
The challenges for innovative firms is to manage the uncertainty and equivocality reductions as well as the complex information process in order to succeed in the predevelopment stage (Frishammar, Florén & Wincent, 2009).

For the purpose of the study, the term front-end of innovation (reduced to the terms FEI or FE) is used as suggested by Koen et al. (2002) who claim that the front end of innovation is opposed to the term fuzzy front end in the way that the latter implies the inability of the process to be critically evaluated.

3.2 Importance and characteristics

For a long time, the front end has been an area of too little attention and a great weakness in product innovation (Khurana & Rosenthal, 1998) although it represents one of the most important opportunities to improve the global innovation process (Koen et al., 2001).

Recently, Management, initially concentrated on the development phase where large investments are made, has shifted its interest to the front end activities (Jetter, 2003). The front end of innovation is a key step in the development of new products whose purpose is to provide a well-defined product concept before the development stage (Kim & Wilemon, 2002b) which is source of product success (Cooper & Kleinschmidt, 1991).

Dr. Roger G. Cooper (1988, 1990) is one of the first scholars to be conscious of the role that efficient pre-development activities have on the success of the new product. He states that the front end stage is of paramount importance since decisions made during the FEI can condition the following stages of the NPD process and more specifically, the development phase in which large investments are being made.

In 1991, Cooper & Kleinschmidt identify two factors playing a central role in product success – both related to the front-end activities: the quality of execution of front end activities and the establishment of a well-defined product preceding the development phase. As a result, they conclude a few years later that what separates new product winners from losers is the success of the front end of innovation (Cooper & Kleinschmidt, 1994).
In addition, Herstatt & Verworn (2001) declare that costs, quality, timing and the selection of projects are mostly set or at least estimated during these primary activities and convince of the attention that must be paid during the stage.

3.3 Models of the front end of innovation

The activities of the front end of innovation are informal and unpredictable by nature (Gassman & Schweitzer, 2014). Nevertheless, three main approaches modelling the front end of innovation can be identified in the literature explicitly linear, dynamic and entrepreneurial. This subsection describes the different approaches.

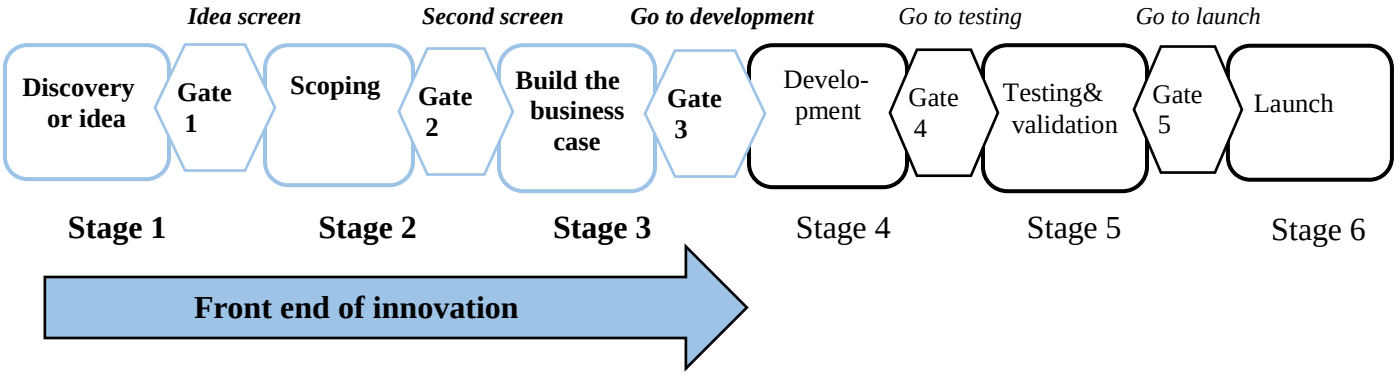
3.3.1 Linear approach

Sequential NPD models adopt a linear conduct of the front end (Gassman & Schweitzer, 2014). A sequential model means that in order to move to the next step and progress in the process, the project must succeed the previous stages. Even though iteration may occur, it is mostly a step-by-step model (Du Preez & Louw, 2008). This method eases the transparency and the predictability of the process and it facilitates the recommended actions to undertake (Frishammar & Florén, 2008; Khurana & Rosenthal, 1998).

As an example, the front end of innovation present in the Stage-gate model follows a linear course as it integrates a pre-determined sequence of front end activities (Cooper, 1988).

In this linear model, the front end of innovation corresponds to the first three stages - idea or discovery, scoping and build the Business Case and the first three gates – Idea screen, second screen and go to development.

Figure 3: The front end in the Stage-gate model



According to the conduct of the process describes in the entitled book “Stage-gate systems: a new tool for managing new products” by Cooper (1990), the front end start with the generation of ideas or a discovery which is submitted to Gate 1 for initial screen.

Gate 1 verifies the compliance of the product ideas with a set of quality criteria dealing with strategic alignment (referring to the product strategy mentioned in the BAH model earlier), project feasibility, potential of the opportunity etc. (Cooper, 1990).

Stage 2 stands for preliminary assessments that determine the technical and market characteristics of the project mainly related to the market acceptance and the technical manufacturing feasibility.

Gate 2 is a repetition of the first gate but considering this time the information collected during the scoping stage.

During the last stage of the front end, Build the business case, the project must be clearly defined. Therefore, the third stage undertakes market studies, technical appraisals and detailed financial analysis in order to build a strong business case before committing to heavy investments in the fourth stage, development.

The business case includes the product and project definitions, the justification of the project and a plan of actions for development (Garcia, 2014). Finally, the front end finishes at Gate 3 during which the Management examines the business case and decides whether moving the project forwards or killing it.

3.3.2 Dynamic approach

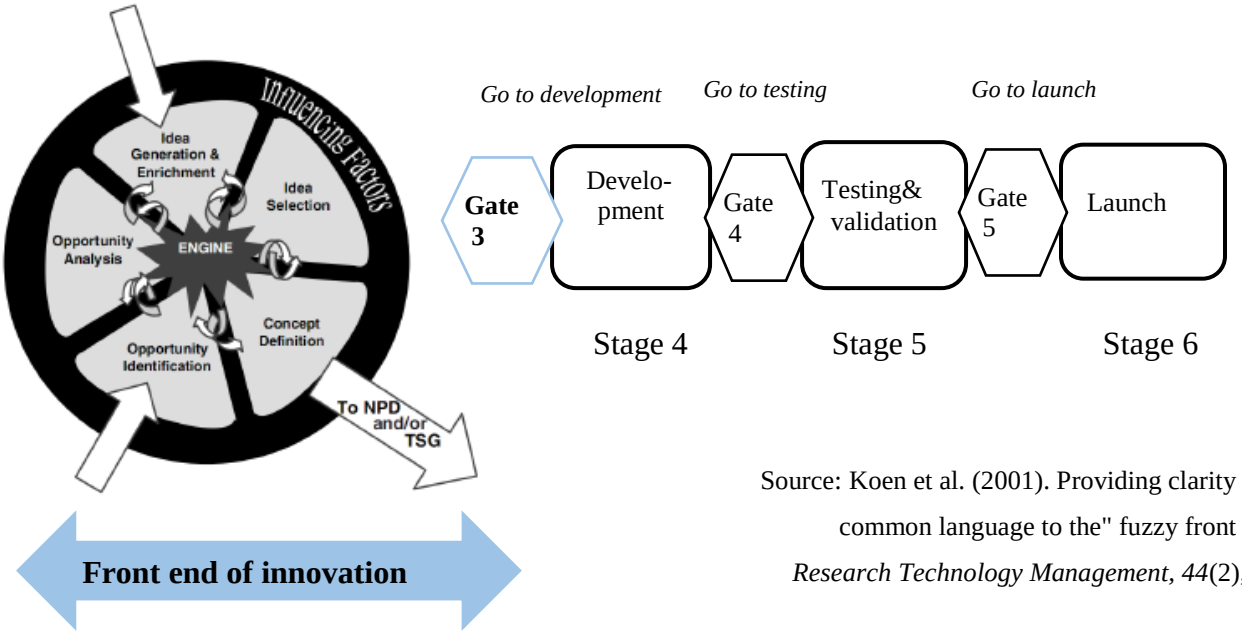
Sequential models of front end of innovation are subject of much criticism. Some NPD theorists (Cooper, 2014a; Gassman & Schweitzer, 2014) claim that they are running the risk of not corresponding to the market reality and do not sufficiently provide creative exchange and feedback loops. Therefore, new forms of front end more dynamic were introduced.

As an example of dynamic approach, the “New Concept Development model” (NCD) of front end designed by Koen et al. (2001) is described.

Koen et al. (2001) argue that a sequential model is not appropriate to model the front end because of its unpredictable nature. De facto, they recommend a circular model in which actions are performed in a non-sequential way. According to the circular shape of the front end, ideas can flow in any combination of activities, they are allowed to iterate and to use the front end activities more than once. There is no specific order among the five elements (Koen et al., 2001).

In this model, the front end of innovation corresponds to the five activities identified by Koen et al. (2001, 2002), namely opportunity identification, opportunity analysis, idea generation and enrichment, idea selection and finally concept definition.

Figure 4: The NCD model of front end of innovation by Koen et al. (2001)



Source: Koen et al. (2001). Providing clarity and a common language to the" fuzzy front end". *Research Technology Management*, *44*(2), p.46

Based on Koen et al. (2001)'s paper, the NCD model works in the following way: in opportunity identification phase, the company identifies the business and technological opportunities it wishes to pursue depending on its business goals.

In opportunity analysis phase, the opportunity is assessed in order to check whether it is worth pursuing. For this, preliminary market and technology assessments are made. However, despite the efforts, technology and market uncertainty remain significant.

The idea generation and enrichment references to the birth, the development and the maturation of an idea (Koen et al., 2001). During this step, ideas are produced, shaped, refined, and modified until they are estimated to show sufficient potential.

Ideation selection stage picks the idea the company wishes to pursue with the most business value. There is no a single process that guarantees the right selection of ideas; it can involve a one-step or a multi-stages process.

Concept definition is the final element of the NCD model. In order to move to the development stage or the technological stage-gate (TSG), a convincing business case must be delivered. Usually, the latter addresses amongst other a project plan including resources and timing, a business plan that specifies the value proposition, the financial impacts and the objectives (Koen et al., 2001).

3.3.3 Entrepreneurial approach

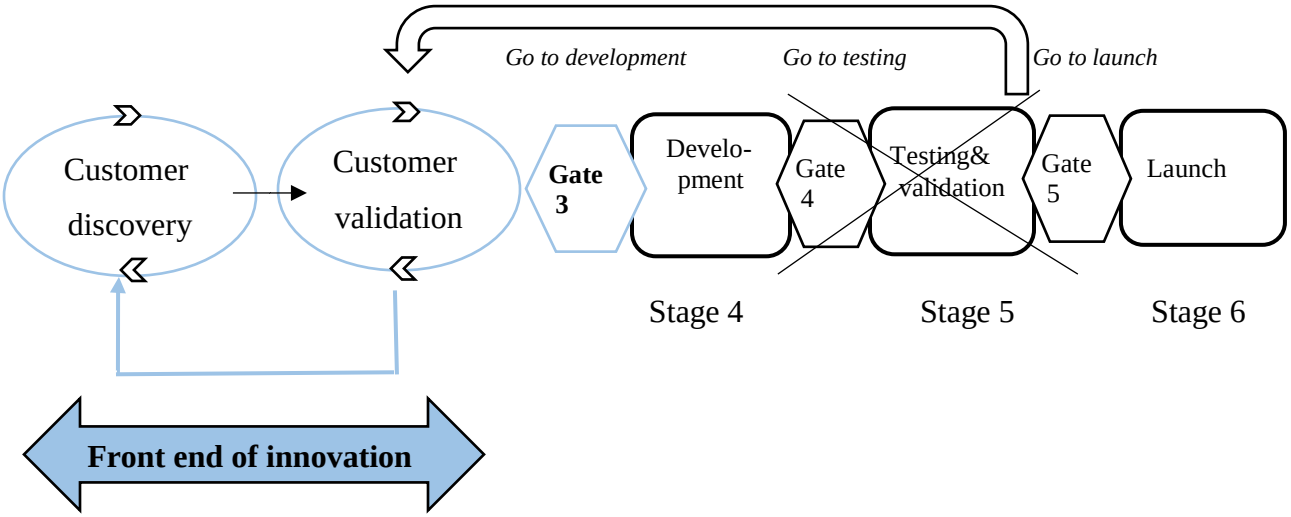
Recently, a new approach regarding the new product development process has emerged within the startup environment: the Customer Development process (CD process) developed by Blank (2006) which is depicted in the figure 5.

Instead of taking part in planning and research activities for a certain period of time- what traditional NPD approach requires- entrepreneurs list a series of hypotheses that they will test “outside of the building” through the customer development process (Danes & York, 2014).

The Customer Development is an entrepreneurial practice placed within the theoretical context of earlier product development models such as the SG model or the NCD model (Danes & York, 2014).

In the entrepreneurial approach of new product development process, the front end of innovation is identified in the two steps of the customer development process, Customer Discovery and Customer Validation.

Figure 5: The customer development process (Blank, 2006)



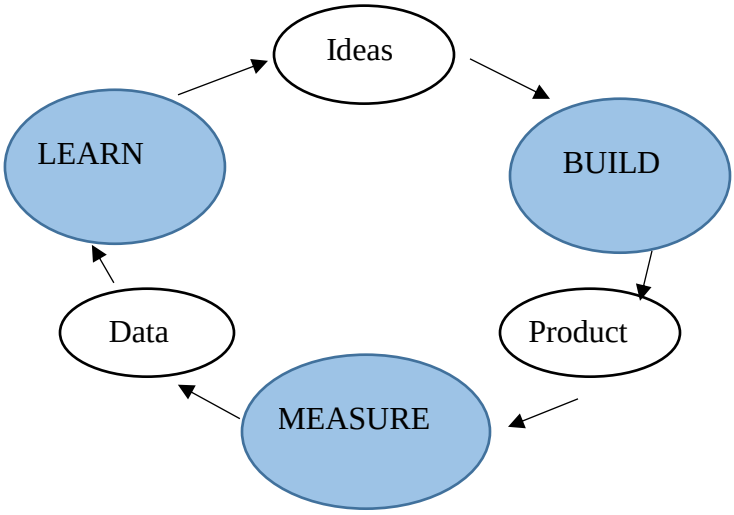
In the Customer Discovery, entrepreneurs test whether the hypothesis regarding the problem, the customer and the product of the business plan are correct. The purpose of this step is to find out the customers of the product and whether the problem they have really matters (Blank, 2006).

The objective during the Customer Validation is to build a repeatable and scalable sales model (Blank, 2006; Danes & York, 2014). Customer Validation acts like a quality checkpoint that verifies whether there is a product with customer willing to pay for it and a roadmap to describe how to sell it. Only when customers validate the hypotheses, the company can move to the execution phase and create a full business case (Blank, 2006). Completing these two stages permits to confirm the company business model (Maurya, 2012).

Later on, Eric Ries (2008), a former student of Steve Blank, builds the *lean startup process*, based on the customer development model – see figure 6. The lean startup is a recent method by which new businesses and products are developed (Hussein, 2015).

Therefore, in the lean startup process, the CD describes the parallel process of building continuous customer feedback through the product development process and occurring during the Build-Measure-Learn loop (Maurya, 2012).

Figure 6: The lean startup process advocated by Eric Ries (2008)



To sum up, authors agree to state that the front end of innovation is everything that comes before to formal go/no go decision to move the project forward in the development stage of the innovation process. The front end of innovation does not require much investments, its purpose is rather on reducing the uncertainties related to the project. The final outcome of the front end is a business case which contains the financial and business analysis of the project and gathers the product definition, the project justification and an action plan for further steps (Khurana & Rosenthal, 1997). The front end of innovation ends when the business case is handed to the Management who takes the decision to either commit to larger investments for development, either kill the project.

For a long time, companies have used the traditional Stage-gate model, keeping the whole innovation process inside of the company until the launch of the product on the market (Cooper,

2008). This approach, criticized by the potential gaps with market reality (Cooper, 2014a), gradually left room for a more customer-oriented approach. Today, companies reinvent their innovation process making it easier, faster and more effective by integrating voice-of-customer techniques (Cooper, 2008).

In the entrepreneurial approach, companies consult the market in the very first steps of the innovation process, integrating customer feedback in the earliest stages. Even though this approach has emerged from startups, large organizations such as General Electric, Qualcomm and Intuit began adopting the lean startup approach, integrating customer development early in the innovation process (Blank, 2013).

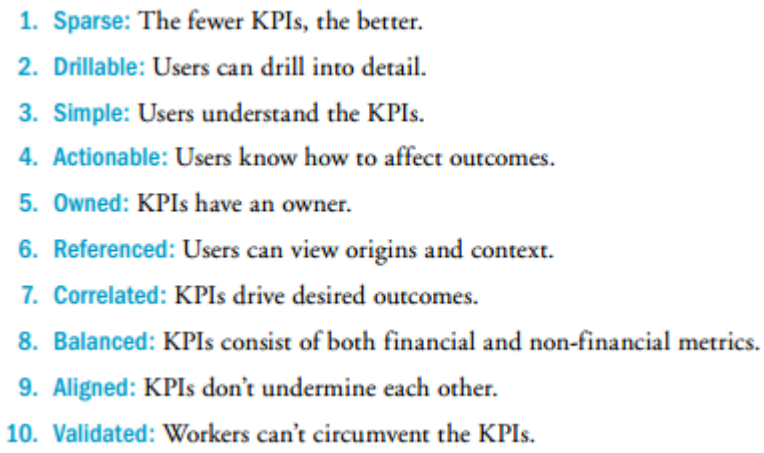
4. Performance indicators

This section raises the issue about the indicators that assess the progress and the performance along the front end process.
The present part starts with the characteristics of "good' indicators and their objectives. At the end, the section presents a literature review on previous researches carried out in the performance indicators specific to the front end of innovation.

4.1 Characteristics of good indicators

Wayne W. Eckerson (2009) develops ten characteristics that indicators should comply with for the organizations to be likely to deliver high-impact performance indicators- see figure 7.

Figure 7: Characteristics of good indicators



Source: Eckerson, W. W. (2009). Performance management strategies. *Business Intelligence Journal*, *14*(1), 24-27.

1. Most people focus on a maximum of five to seven indicators, therefore the number of performance indicators should be limited to this number.
2. The performance dashboard should analyze performance indicators and data which are based on role, level and task.
3. The simplicity of the indicators comes from the ability of the employees to understand what is being evaluated and how this is calculated.
4. In addition, indicators ought to be actionable meaning that employees know how to affect the outcome of the indicators in a positive way.
5. Each performance indicators must have a "business owner" and a "data owner". The former is in charge of the meaning and the value of the indicators whereas the second takes care of generating data to the indicators.
6. For the data to be trusted, it must be referenced in the sense that it is clean, accurate and especially perceived as accurate.
7. Indicators should be statistically correlated with desired outcomes in order to verify whether they impact performance in the good direction.
8. The set of performance indicators must be balanced and therefore evaluate the performance in accordance with multiple dimensions and not to be restricted to the financial dimension.
9. The indicators should not be challenged between them to ensure the alignment.

10. The validation of the indicators results from the guarantee that employees cannot manipulate them.

4.2 Objectives

In spite of the plethora of previous researches confirming the impact of the FEI in the NPD performance (Cooper 1988; Cooper & Kleinschmidt, 1991, 1994; Herstatt & Verworn, 2001; Khurana & Rosenthal, 1998; Langerak et al., 2004), there remains some questions about how the front end performance can be measured and its dimensions evaluated (Kim & Wilemon, 2002a).

Measuring the front-end performance is particularly challenging due to its uncertain and non-routine nature (Frishammar & Florén, 2008). As a consequence, financial measures of NPD performances such as profits, market shares or sales do not often apply.
In addition, there is no universal common measures of FEI performance (Kleinschmidt, Koen & Reilly, 2005). Therefore, subjective criteria through perception-based criteria are usually applied (Poskela and Martinsuo, 2009).
Doll & Zhang (2001) state that the principal goal of the performance indicators is to give an opportunity to monitor and measure the performance of the project in the front end of innovation. Chiesa, Frattini, Lazzarotti & Manzini (2009) add that the evaluation criteria of the performance helps monitoring the progress of the process along critical dimensions i.e. cost, time, profitability etc. Some authors stress that with performance goals established, there is an opportunity to point out the weaknesses and to improve the front end practice (Poskela, 2009).

For Berg et al. (2009), a system of performance measurement in the front end of innovation gives to those responsible of the innovation process, information about the efficiency of the front end process and the effectiveness of its outcomes.
Moreover, the information derived from the performance measurement can be used to provide support in the decision-making process by offering to the decision-makers sufficient knowledge about alternative ideas and consequently by promoting the current choices (Poskela & Martinsuo,

2011). Besides, managers are provided with necessary information to undertake actions in order to improve the performance of the process (Skin & Tuttle, 1989[2] cited in Cedergren, 2011). Information collected through performance measurement also contributes to reducing technical and commercial uncertainty and the risk of the project (Chiesa et al., 2009).

Koen et al. (2002) add that performance appraisal is a means to stimulate the generation and enrichment of ideas. In addition, it provides incentives and motivation to the teams to meet the objectives (Chiesa et al., 2009)

To summarize the authors 'thoughts, the performance measurement in the front end of innovation in the new product development process can help to:

- ✓ Monitor the progress of the project and eventually point out weaknesses
- ✓ Provide information for supporting decision-making, for reducing risk and uncertainties and for enhancing the performance of the process
- ✓ Give incentives, motivation and stimulation to the teams
- ✓ Avoid future complications, time delays, increased costs, failures etc.

4.3 How to define performance indicators

Berg et al. (2006) and Brenner & Uebernickel (2016) have developed the Balanced Innovation Front end Method also named Balanced Design Front end Method aiming at evaluating the front end of innovation. This method comprises four stages:

- Selection of measurement criteria
- Selection of data sources
- Data collection
- Data analysis

[2] Sink, D. S., & Tuttle, T. C. (1989). Planning and measurement in your organization of the future. Industrial Engineering and Management.

Although this model presents the whole process of setting indicators, the paper focuses on the selection of measurement criteria in the front end of innovation, the first step of the procedure.

When it comes to set performance indicators, the first step consists in establishing the objectives to attain related to the performance. When objectives are clearly identified, discussions and workshops should take place between teams and managements in order to agree on the indicators that will point out whether the objectives are met or not. Only then, the data to track the measurements must be collected and analyzed (Brooks, 2005).

Data can come from many sources: customers, employees, management systems, management reports are examples (Berg et al., 2006; Brenner & Uebernickel, 2016).

Berg et al. (2009) resume the process in the selection of measurement criteria in two principal questions:

- What are the performance objectives of measurements?
- How can the objectives be measurable?

4.4 Classification of indicators

Performance indicators can be classified by their nature in multiple ways i.e. financial and non-financial, quantitative and qualitative, process and output, tactical and strategic, corporate-level and project-level measures are examples of common classification (Tatikonda, 2008).

Regarding the elements to assess in the front end of innovation, Berg et al. (2006) state that the front end process and its outcomes should be measured. Performance indicators related to the outcomes assess the actual outputs of the FEI such as product definition, project or business-case while the process performance indicators rather assess the inputs, the work effort itself during the FEI (Tatikonda, 2008).

Kim & Wilemon (2002a) state that the FE project should be assessed by the means of evaluating its outcomes, but they contend that the front end team is of major significance in the FE performance and thus should be gauged in a similar extent.

For this purpose, the following literature review on performance indicators is related to the evaluation of the individual project (including the outcomes) and the innovation process (including the team dynamics-related indicators), in line with the work of Kim & Wilemon (2002a) and Berg et al. (2006).

4.5 Individual project and innovation process performance indicators

This section describes the measures of front end performance from the academic literature regarding the individual project and the innovation process itself.

4.5.1 Efficiency and effectiveness

Efficiency and effectiveness are common performance measures of the FEI in the literature and authors have been using them intensively in order to demystify the FEI and to identify the critical success factors in the FEI (Herstatt, Nagahira and Verworn, 2008; Ho & Tsai, 2011; Kim & Wilemon, 2002a; Wagner, 2010).

Herstatt et al. (2008), in their large study of NPD projects in Japanese firms, use effectiveness and efficiency as the two principal measures of performance in the FEI. In their research, efficiency compares the results with the expectations made during the predevelopment phase.

In that sense, they build up two reliability indicators related to efficiency:

- Degree of agreement between planned personnel resources during the FEI and those actually required to reach the milestones.
- The project had come in budget.

Still based on Herstatt and al. (2008)' work, effectiveness evaluates the outcomes of the FEI and is decomposed into five indicators.
The extent to which the product meets:

- Profit expectations
- Sales expectations
- Market expectations
- Customer expectations
- The product achieves a competitive advantage.

Ho & Tsai (2011) base their research on the similar definitions of efficiency and effectiveness. However, they construct different performance indicators. From the efficiency measure they build two indicators:

- The project was one of the fastest undertaken in the company
- In the FEI, actual development costs overtook the budget dedicated to the development

Regarding the effectiveness, two performance indicators are constructed:

- The project plan is explicit and stable
- The product concept is clear and in line with customer needs

4.5.2 Future business potential

In 2009, Poskela & Martinsuo publish an article aiming at measuring front-end performance and identifying the success drivers. The measure of performance they define is the future business potential of the product generated in the FEI, meaning the ability of the FEI to define a product which has the potential to create opportunity windows for new market entries and NPD activities (Poskela & Martinsuo, 2009).
Poskela & Martinsuo (2009; 2011) propose four performance indicators that enable to evaluate whether the product has future business potential:

- The product gives access to new markets

- The product opens up new NPD possibilities
- The product creates new market know-how
- The product creates new technical know-how

Poskela & Martinsuo (2011) found out from their econometric model that using strategic and technical criteria in the idea and concept evaluation was increasing the probability of future business potential of the product. However, surprisingly, market criteria was not associated with the strategic renewal variable. The authors explain this statement by the fact that market and technology information belong to two different types of uncertainty. While market information relies more often on speculation or guesses, technology-related information is tangible and based on research reports.

4.5.3 Team composition and team dynamics

Former researches were carried out about the importance of a quality team in the creation of a superior concept at the end of the front end (Frishammar & Florén, 2008; Herstatt et al., 2008; Langerak et al., 2004; Moenaert et al., 1995, Reid, Hultink & Barczak., 2013). A quality team helps reducing the uncertainties in the front end of innovation (Herstatt, Nagahira and Verworn, 2003). Therefore, these authors suggest it to be a suitable measure of performance.

Regarding the characteristics of good team dynamics, Hoegl & Gemuenden (2001) identify six indicators of performance: communication, coordination, balance of member contributions, mutual support, effort and cohesion.

Doll & Zhang (2001) emphasize the need of a clear team vision in a successful team. Team vision includes a shared purpose for all team members and a plan of actions that clarifies the strategic fit and sets project targets and priorities (Wheelwright & Clark, 19943 cited in Doll & Zhang, 2001).

[3] Wheelwright, S. C., & Clark, K. B. (1994). Accelerating the design-build-test cycle for effective product development. *International Marketing Review*, *11*(1), 32-46.

Ho & Tsai (2011) argue that a rapid emergence of team vision helps to create commonality which improves the communication between team members so that it reduces the eventual conflicts during the project execution.

In addition to these elements, the team composition is of major importance. The involvement of cross-functional expertise in the front end team has been largely promoted as a driver of performance. Researches by Moenaert et al. (1995) found out that the integration of multi-disciplinal backgrounds in a team had a positive impact in the reduction of uncertainties during the front end stage and helped to achieve competitive advantages.

Following this, Kim & Wilemon (2002a) claim the advantages of building cross-functional teams in four points: it facilitates mutual understanding and communication, it enhances idea and technology transfer, it minimizes resistance to new ideas and finally, it reduces the ambiguity via an early understand of other function's capabilities and limitations.

Based on the previous authors' work, Ho & Tsai (2011) summarize these thoughts in four principal indicators of performance:

- The team involves cross-functional experts
- The team has sufficient knowledge and capabilities to perform specific activities.
- The team communicates and coordinates well
- The team has a vision and a shared purpose

For the purpose of the present research, and based on the studies presented above (Ho & Tsai, 2011; Hoegl & Gemuenden, 2001; Moenaert et al., 1995; Doll & Zhang, 2001), the indicators related to the team composition and team dynamics are resumed in six measures:

- The team is composed of cross-functional experts
- The team has sufficient knowledge and capabilities to perform specialized roles
- The project quickly develops team vision, shared purpose and creates a team spirit
- The team communicates and coordinates well

- All team members are able to bring in their expertise to their full potential

4.5.4 Competitive advantage

The competitive advantage expresses itself in terms of product superiority compared to competing products on the market (Poskela, 2009).
As the product concept resulting from the FEI will be judged to decide whether the project moves to the development phase, Frishammar & Florén (2008) suggest to focus on the quality of the product definition in order to assess the FE performance.

Moreover, due to its explorative nature, the front end phase participates significantly in building a superior validated product concept (Kleinschmidt, Koen and Reilly, 2005). Therefore, scholars (Aura, 2007; Bacon et al., 1994; Koen, Bertels & Kleinschmidt, 2014a, 2014b; Poskela, & Martinsuo, 2011) consider the competitive advantage achieved by the product as a measure of performance.

Poskela & Martinsuo (2009) decompose the competitive advantage in four indicators:

- The product offers uniqueness to consumers, unique features compared to competing products
- The product solves important customer problems
- The product has superior price/performance ratio compared to competitors
- The product reaches high customer satisfaction

In order to achieve a competitive advantage, Poskela & Martinsuo (2009; 2011) recommend to use market and technical criteria in the idea and concept evaluation.

According to Cooper & Kleinschmidt (1991), market and technical conditions represent the biggest uncertainties in the NPD. Hence, it is reasonable that the product concept requires a careful evaluation in these two areas.

Although it still can be improved along the process, the product concept provides an appropriate reference point to evaluate the competitive potential (Poskela & Martinsuo, 2011).

The competitive potential is able to be monitored as soon as the product concept is defined. Because competitive potential is an excellent source of future product success, it is a good measure of front end performance (Poskela & Martinsuo 2009, 2011).

4.5.5 Strategic fit

In her work, Aura (2007) measures the front end performance based on the strategic fit dimension. It appears that the strategic fit is an appropriate measure of performance since it has the ability to predict the future financial performance of the project and hence its success (Cooper & Kleinschmidt, 1987[4] cited in Aura, 2007).

Aura (2007) decomposes the strategic fit criteria into three indicators of performance:

- The project fits with the portfolio of products of the company
- The project fits with the business strategy
- The projects fits with the existing resources

Carbonell-Foulquié et al. (2004) interpret the strategic fit in a different way: it refers to the alignment between the project and the business strategy and a window of opportunity. The latter dimension denotes the ability of the project to adapt to new business requests.

Finally, considering Ebner, Leimeister & Krcmar (2009)'s work, strategic fit encompasses two indicators related to the product portfolio and the development potential fits:

- The expected fit of the project into the company's product portfolio
- The project is adaptable to new business requirements

For the purpose of the research, the dimension strategic fit is in line with the work of Aura (2007) and is defined as the extent to which the project developed through the front end of innovation

[4] Cooper, R.G., Kleinschmidt, E. J. (1987) New products: What separates winners from losers. *Journal of Product Innovation management, 4(*3):169-184

fits with the business strategy of the company, with the portfolio of products and the existing resources

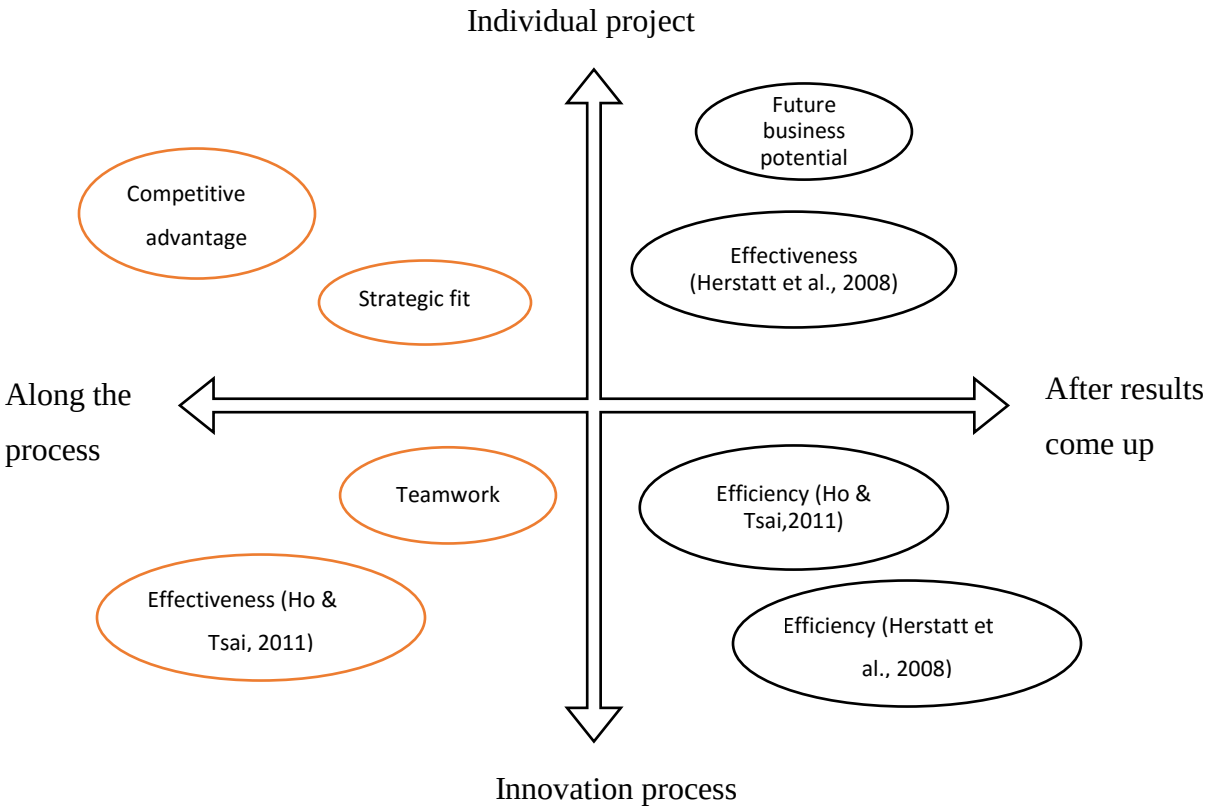
4.5.6 Selection of performance indicators

In order to deliver a set of quality criteria able to monitor the performance all along the front end process, indicators verifiable only after results come up are excluded from the scope of the study. This includes the indicators based on future estimations and the “reliability” indicators that compare expectations with results.

As a consequence, the efficiency dimension defined by Herstatt et al. (2008) as well as by Ho & Tsai (2011) are both excluded. The former compares the estimations made in the innovation process with the results coming up after the process has ended while the second is measurable only when results on the process are delivered.

Following the same reasoning, the indicators of effectiveness settled by Herstatt et al. (2008) as well as the future business potential developed by Poskela & Martinsuo (2009; 2011) are excluded.

Figure 8: Selection of performance indicators



In conclusion, authors have used different measures in order to evaluate the front end performance. In this fourth section, a literature review dealing with performance indicators in the front end of innovation was presented.

Based on the studies mentioned earlier, authors have developed sets of indicators relative to specific area of analysis, namely the effectiveness of the process, the competitive advantage, the team composition and team dynamics as well as the strategic fit. The indicators considered have the ability to measure the performance all along the front end process and to provide immediate feedback about whether the team is taking the good direction or if it should undertake modifications.

It should be noted that the indicators do not constitute an exhaustive set of performance measures. The research is based on specific previous authors' works i.e. Aura (2007); Doll & Zhang (2001); Herstatt et al. (2008), Ho & Tsai (2011); Hoegl & Gemuenden (2001); Poskela & Martinsuo (2009, 2011); and the scope is restricted to the indicators measuring the performance all along the process.

From now, the next purpose is to study and highlight the potential gaps between the theory-defined indicators and the indicators applicable in an institution performing the front end process. For this, a case study is undertaken about an accelerator of technology commercialization named Cohitec.

5. Summary of the literature review

In the first part of the thesis, the purpose was to become familiar with the concepts of innovation and front end of innovation. The innovation journey was defined as the whole process through which ideas are generated, developed and commercialized in the market. Although innovation concerns a wide range of areas, the research was restricted to product innovation – the development of new and improved products and services.

As a result, the NPD process that represents the complete innovation process through which product ideas go with the objective of being launched on the market was introduced by two very well-known models: the BAH and the SG model. The SG model is further considered in the research as the performance indicators work similarly than the quality criteria implemented in the management gates in the Stage-gate model. However, the scope of the study is on the upstream part of the NPD process known as "front-end" of innovation.

The front end of innovation is everything that comes before the formal decision "go / not go" prior the development stage. Amongst diverse activities, the activities in the front end of

innovation include idea generation and enrichment, concept development and definition, idea/concept evaluation and selection (Cooper, 1988).

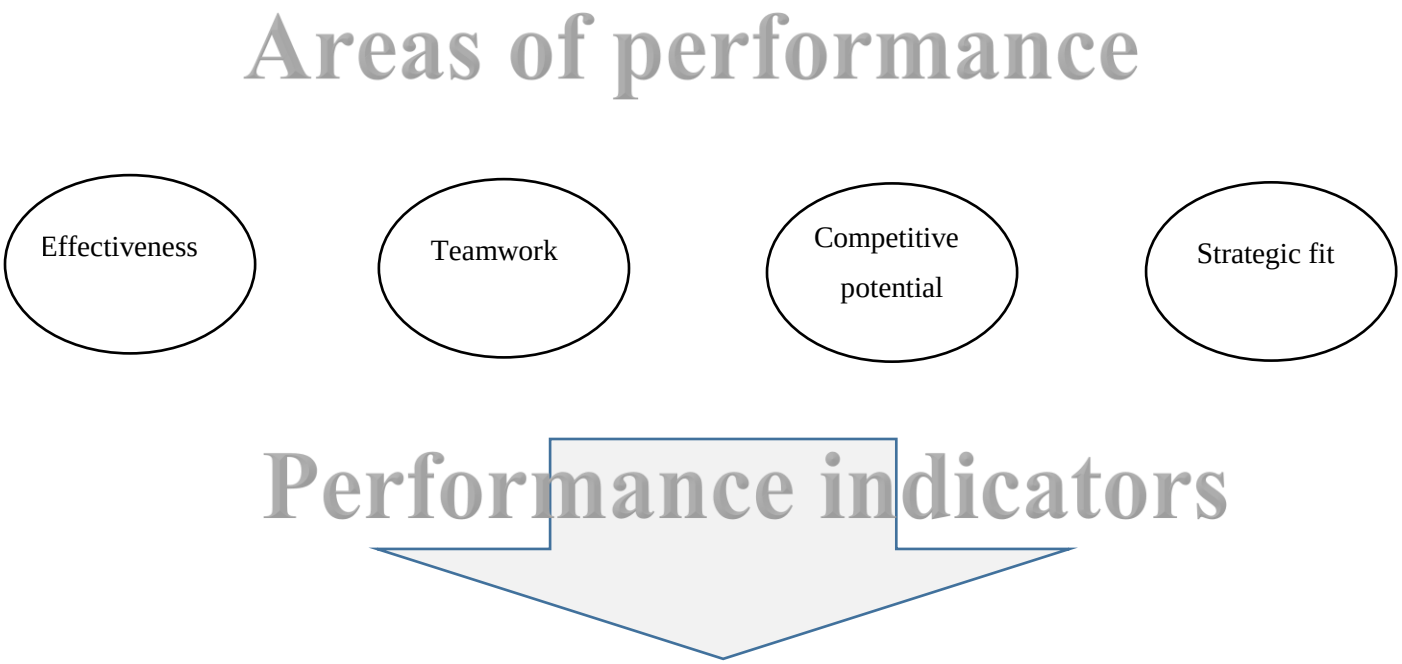
The FEI was illustrated in three different approaches based on works produced by Cooper (1988), Koen et al. (2001) and Blank (2006). It should be noted that the three models presented are only illustrations of the FEI. There does not exist any model of FEI that can be implemented without any modification in any company.

Thereafter, the focus was on identifying, from previous works, indicators able to assess the performance in the FEI. Based on previous researches, some specific area of performance analysis were identified: effectiveness of the process, team composition and dynamics, competitive advantage and strategic fit- see figure 9. Each of these measures of performance was decayed in several performance indicators capable of displaying whether the objectives are being met or not.

The purpose of monitoring the progress in the front end of innovation is to allow teams to operate modifications and observe whether results are not satisfying and thus avoid future potential costs of a not-well managed front end such as time delays, loose of launch opportunities, excessive development costs etc. (Gassmann & Schweitzer, 2014; Ho & Tsai, 2011).

The following exercise is to apply the indicators identified previously in the academic theory within a practical context. The purpose of this is to highlight the eventual gaps between theory and business usages.
From this, it will be possible to verify the relevance of the indicators, make conclusions and write recommendations.

Figure 9: Summary of the performance indicators from the literature review



PRACTICAL PART: THE CASE STUDY

6. Methodology

The objective of the present section is to present the research methods and the research strategy applied through the study with the view to addressing the research questions of this thesis.

6.1 Research questions

The purpose of this thesis is to give an opportunity to monitor the front end of innovation by defining relevant performance indicators with the aim of helping and guiding front end teams to succeed in the process. In addition, it enables teams to operate modifications and prevent from future complications. For this end, the research questions we tend to give an answer to is:

- What are the relevant performance indicators when monitoring the front end of innovation?

To respond to this question, a research strategy based on diverse research methods is carried out and described in the two next points.

6.2 Research methods and strategy

Two main types of method researches are regularly used in the collection of data namely quantitative and qualitative research.

Quantitative research is a research strategy that prefers quantification in the collection and analysis of data, consisting in empirical studies involving mathematics and statistics (Bryman & Bell, 2007). A quantitative approach is often likely to be linked with a deductive approach whose purpose is to test hypothesis (Greener, 2008).

In the opposite, the qualitative approach includes data collection techniques such as interviews or questionnaires that generate and use non-numerical data (Saunders et al., 2012). The qualitative research method is likely to be associated with inductive approach in order to generate theory (Greener, 2008).

For the purpose of the present thesis, the qualitative method is selected. The ambition in this paper is to define indicators that permit to monitor the front end performance along the process and confront the results with a case study.

Following this intention, it was primordial to consult several stakeholders in Cohitec such as the managers, coordinators and participants about the relevant indicators needed within the program. Hence, in order to define indicators of performance, quantitative data are not required. As a matter of fact, people's opinions, feelings and experiences are necessary and privileged to quantitative data.

In the business research methods, one finds two natures of relationship between theory and research depending on whether data are collected in order to test or to build theories (Bryman & Bell, 2007).

In the deductive approach, theory and hypothesis (or hypotheses) are developed and tested by collecting data which either validate or reject them. In the contrary, in the inductive approach, theory is developed as a result of the data collection and analysis (Saunders, Lewis & Thornhill, 2012).

The present research follows a deductive reasoning meaning that the process starts with an established theory or generalization and seeks to see whether the theory applies to specific instances (Hyde, 2000: 90).

The case study was the most appropriate instrument in the study of performance indicators in the front end of innovation. According to Yin (2003), the case study is preferred when the investigator has few control on the events and when the focus is on a contemporary phenomenon

in a real-life context. Moreover, the single case study was selected as it is an opportunity to observe a phenomenon that few authors have considered (Saunders et al., 2012). In addition, Cohitec appears to have weaknesses in the area of monitoring the front end performance but more importantly it shows the willingness to address this issue.

Concerning the importance of setting a research approach, it appears that it enables to define a general orientation of the business research. The research strategy was chosen in alignment to the objective of defining front end performance indicators and confront it with the findings coming from the case study.

The research strategy started with the collect of background information about innovation, front end of innovation and performance management in the front end. Early in the beginning of the thesis, informal exploratory interviews took place with the coordinators of Cohitec in order to have a better overview of the functioning of Cohitec.

Thereafter, the problematic **"How to monitor the front end of innovation in the new product development process: Defining performance indicators – *the case study of an accelerator of technology commercialization*"** was chosen and a literature review was carried out.

In order to build the framework, primary data was collected through semi-directed interviews with Director, coordinators and participants at Cohitec. The purpose of the interviews was to define, together with interviewees, valuable and relevant performance criteria. Also, secondary information was collected on front end performance indicators through a literature review.

Thereafter, a confrontation between the indicators studied in the academic literature and those needed in the practical case study of Cohitec was made in order to start the discussions of the results, write conclusions and recommendations.

The findings of the thesis were illustrated through a set of performance indicators specially designed for the Cohitec and made available to the Management of Cohitec.

6.3 Data collection and analysis

In order to fulfill the objective of this paper and answer the research question, primary and secondary data were necessary to gather.

Multiple options to collect primary data are presented to the researcher who decides on the qualitative research approach. Amongst other, action research, case study, focus group, participant observation and different types of interviews are common qualitative methods (Greener, 2008).

It is the researcher's choice to select one method or a mix of several methods in order to gather qualitative data. Triangulation of data, which is the combination of methodologies in the study of the same phenomenon (Denzin, 1970) is usually preferred as it achieves more reliable and robust results. Analyzing data collected through different research methods allows the researcher to corroborate the findings and reduce the probability of the potential biases (Bowen, 2009).

With the aim of following the triangulation strategy and integrate different perspectives in the collection of data, three research methods were undertaken:

- Unstructured and semi-structured interviews
- Participant observation
- Document analysis

Unstructured interviews were undertaken in the very beginning of the study. Unstructured interviews are informal and used to explore in depth a general area of interest (Saunders et al., 2012). Saunders et al., (2012) state that there is no predetermined list of questions to ask, however the researcher must have a clear idea of the aspects to explore. Informal interviews were undertaken with the main coordinator of Cohitec Lisbon and the Director of the program. The interviewees were able to talk freely about their experiences at Cohitec and the initiative of this paper.

The objectives of these exploratory interviews were for the researcher to have a better overview of the situation at Cohitec and the problematic itself. Also it served to ensure to connect the academic theory on the front end of innovation with the usages of the institution.

Once the problematic was clearly defined, the focus was set on collecting secondary data with an in-depth literature in the areas of innovation, front end of innovation and performance measurement in the FEI.

The literature review on the different concepts were necessary in order to prepare the future formal interviews, have a better knowledge in these fields and prepare the discussion between academic theory and the findings from the case study. The main sources to collect secondary data were scientific publications issued from databases such as Google Scholar, ProQuest, ScienceDirect, CAIRNS and numerous additional sources accessible from universities and libraries.

Thereafter, semi-directed interviews were conducted as one of the several sources of qualitative data collection. Semi-structured interviews were preferred to structured interviews as it is directed in the form of a general discussion and allows the interviewer to adapt the questions according to the answers given by the interviewee (Bryman and Bell, 2007). The flexibility of semi-structured interviews permits the researcher and interviewees to open up new subjects that would have been excluded with close questions.

To ensure that all the important points were addressed with success during the interviews, interview guides were prepared formerly (they can be consulted in appendix 1 and 2). In addition, some personal notes were collected right after each interviews in order to highlight the most important aspects that were treated during the interviews.

The individuals being interviewed were directly involved in the training program proposed by Cohitec. The two coordinators of the program, in Lisbon and in Porto, were interviewed as they are deeply involved in the front end of innovation process. They designed the process and they provide to front end teams the business classes. Moreover, they have a direct contact with teams such that they are aware of the challenges that teams face during the process.

Also, the Director of ACT and Cohitec program was interviewed due to its strong experience in this accelerator of technology commercialization. He is one of the founders of Cohitec and his knowledge and involvement in the program were valuable for the present research.

In addition, current participants of Cohitec Edition 2016 were interviewed in order to make sure to include all the different points of view and to have diverse data to build robust analysis. Participants are the ones going through the front end process and thus are the most aware about the difficulties and in which ways performance indicators could help. All the interviews were made within three weeks, between the 19th of May and the 10th of June 2016.

In addition to formal and informal individual interviews, the participant observation method was undertaken as an additional source of primary data. Participant observation allows the researcher a total immersion in the research setting (Saunders et al., 2012) and obtain direct experience of a specific situation.

Having participated myself to the Cohitec program in Lisbon, I was able to observe the mechanisms in the front end of innovation and analyze the strengths and weaknesses of the process. Furthermore, as a member of one of the front end team, I had the opportunity to observe and live the challenges that most teams are facing in the front end of innovation.

During the four-month program, I kept records of personal notes about the front end activities, the weaknesses of the program whose teams were subject to and the need of indicators of performance in order to bring direct experiences to this thesis.

Finally, document analysis is the third type of qualitative research method that was carried out. With the collaboration of the Cohitec Staff, I was able to have access to different documents able to nourish the practical part. The documents provided valuable information about the assessments of projects, criteria used by the jury during the mid-term presentation and the content of slides presented during the educational classes.

Once the primary data were collected, it is the researcher's role to analyze it. Regarding the semi-directed interviews, the data analysis method was separated in three steps.

First, all the interviews were recorded and transcribed on paper for the data to be examined (the transcription are available in the appendices 3, 4, 5 and 6). During the second step, data reduction was performed by summarizing the different main aspects treated during each interview as primary qualitative data. The third step was consisting of connecting the primary data and

practical discoveries with the literature review in order to prepare the result discussions and subsequently, make a general conclusion and write recommendations.

Documents issued from Cohitec and personal notes were subject to a similar method of analysis. First, a data reduction with the objective to resume the main facets was undertaken prior to linking qualitative primary data with the theoretical part.

7. Case study: Cohitec

Since the research is based on a case study Cohitec, the institution as well as the program proposed are described in the present section.

7.1 Presentation of Cohitec

Cohitec is a training program in technology commercialization, part of the Accelerator of Commercialization Technology (ACT) initiative developed by Cotec Portugal.

Cotec Portugal - Associação Empresarial para a Inovação is a non for profit organization that was created in 2003 with the support of the President of Portugal and the Prime-Minister. It has the mission of promoting the competitiveness of companies established in Portugal through the development and the diffusion of a culture and a practice of innovation. One of the initiatives undertaken by Cotec Portugal to encourage the development of innovation from Portuguese institutions is the program ACT which aims at accelerating the commercialization of new technologies in Portugal.

Cohitec is part of the ACT unit and was founded in 2004. Its purpose it to support the knowledge produced in Portuguese R&D institutions. The program lasts four months and presents two main objectives. The first aims is to assess the commercial viability of the products or services that can

be developed from the technologies proposed by the participants. The second objective is to induce entrepreneurial and technology commercialization skills in the participants. Participants are researchers or technologists issued from Portuguese institutions (universities, R&D, research centers, etc.) who have one or more technologies that present uniqueness and that are capable to answer clear market needs.
So far, Cohitec has supported more than 151 projects reuniting 700 participants. From these projects, 26 ventures were created and all together collected more than 35 million euros.

7.2 Accelerators

Cohitec presents itself as an accelerator which is defined in the literature as a sort of business incubation program that supports the entrepreneurial teams and their (future) ventures to connect with investors and additional important stakeholders as well as to have access to their resources (Malek, Maine and McCarthy, 2014).

In addition to link ventures with important stakeholders, accelerators help ventures define their products and identify potential customer segments. Being part of an accelerator program is an experience with intense, rapid, and immersive education whose aim is to accelerate the life cycle of undeveloped inventive enterprises (Hathaway, 2016a).

Accelerators are regularly mistaken with business incubators. However, accelerators distinguished themselves with particular features not shared with the incubators.
Accelerators offer a time-limited support –from 1 to 3 months- and propose, amongst other, a plethora of contacts to develop networking, intensive mentoring with peer startups and mentors, and educational program through seminars to help with the new venture process (Cohen & Hochberg, 2014).

In addition, accelerators focus on classes of startups, independent with each other, that start and finish the program together and interact along the process.

Most accelerator programs ends with a final event retitled “demo day” or “pitch day “ during which entrepreneurs pitch their project to an audience composed principally by a jury and experienced investors such as business angels and venture capitalists.

7.2.1 Missions

Business accelerators give support to early-stage entrepreneurs and growth-driven companies by providing education, networking, mentorship, financing and sometimes office spaces (Hathaway, 2016a).
Their main objective is to support the development of early-stage ventures that have a growth potential (Hathaway, 2016b). Nonetheless, it is not the only reason of their existence.

Accelerators tend to provide entrepreneurial skills or the enhancement of business skills to the future founders of startups (Kuppers, 2014). The reason is that entrepreneurship involves more than launching a startup, it comprises also the development of skills to grow a venture and the development of personal competencies necessary to make the venture a success (Cooney, 2012).

The ambition of entrepreneurship education behind this is indeed to develop entrepreneurial capacities and mindsets that can encourage creativity, innovation, and the creation of employments which profit to economies (European Commission, 2008).

Accelerators accept ventures at different stages of development. Some of the ventures may have a finished product and may have been already financed while other venture participants may have only an idea or just the technology itself (Fallon, 2015).

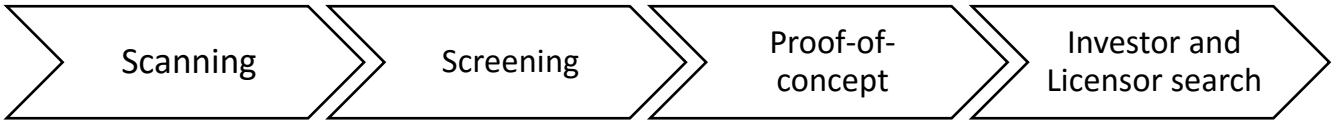
7.3 Cohitec as an accelerator of technology commercialization

Cohitec proposes to help determine if a sustainable business can be launched from a business idea inspired from one or several technologies. If so, Cohitec offers assistance to get the

idea on the market by providing training, mentoring and access to funding for all stages of the idea development from the proof-of-concept to the business plan development. In addition, Cohitec actively looks for investors or licensors for the well going of the project.

The accelerator program is a process defined in four steps:

Figure 10: The four stages of the acceleration program of Cohitec



Source: https://www.actbycotec.com/en/about.70/process.72/process.a63.html

1. The process starts with the sourcing of ideas from universities, companies, research centers, R&D institutions and individual inventors. During the scanning phase, Cohitec looks for innovative ideas:
    - Based on one or several technologies
    - Based on world-class sciences
    - Competitive in global markets
    - Ideas led by committed and enthusiastic promoters.

    Anyone having an idea that meets these criteria is welcome to apply to the Cohitec Program. Cohitec targets projects belonging to four specific technological areas: Biotechnology, Life Sciences, Industrial technologies and Clean technologies.

2. The second phase, screening, assesses the potential of the idea in order to identify the best products or services generated by the technology-ies- and to analyze market needs and the competition. In addition, Cohitec offers assistance regarding the regulatory and Intellectual Property issues.

    Before the third phase starts, Cohitec attracts venture capital companies, business angels and additional appropriate investors who may be interested in the projects supported by Cohitec.

3. The third phase is about validating the product or service idea through the proof-of-concept. The validation is made in two different fields. There is a technical validation which is about the technology proof-of-concept. It includes the construction of a prototype, preliminary clinical trials, laboratory tests and other. In addition, there is a business validation for which an investment ready business plan must be developed and approved.
   Each team is supported by the help of experienced and qualified mentors who bring their expertise, experience and advice.

4. Finally, when the proof-of-concept is accomplished with success, Cohitec continues to support the participants of the program in the further valuation of the project in two different ways: either by identifying potential investors with the aim to develop the startup (second round of investment), either by identifying potential licensees and negotiating the terms of the contract, the conditions and the fee structure.

8. Observations

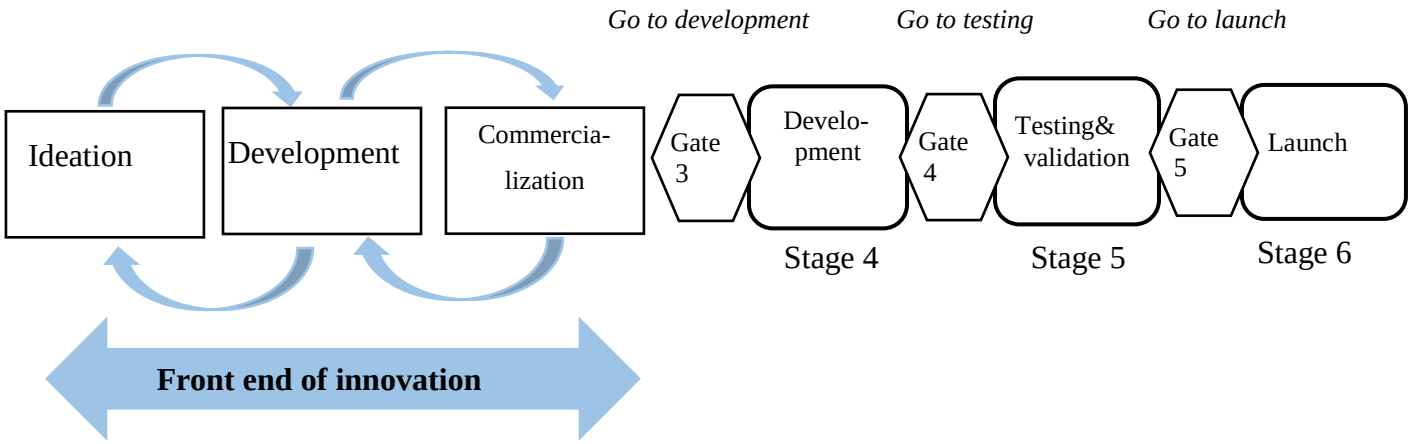
Here are presented the observations resulting from the analysis of the data collection.

8.1 The front end of innovation at Cohitec

In this section, the aim is to describe the structure of the front end of innovation at Cohitec. The front end takes place in the screening phase; when it comes to evaluate the best products or services that can be generated from unique technologies.

The front end of Cohitec is designed in three sequential stages: ideation, development and commercialization and is illustrated in figure 11. It follows the technology entrepreneurship commercialization methodology[5].

Figure 11: The front end of innovation at Cohitec



The arrows note that the front end approach is highly iterative. Throughout the program, teams amass information from the market and may be forced to come back to previous stages in order to improve preceding decisions or findings (Vilarinho, 2015).

In order to guide the teams throughout the front end of innovation, Cohitec prepares educational activities. Classes and seminars, taking place once a week, address diverse topics relevant for the development of valuable skills for the elaboration of a startup such as intellectual property, financials, business development, tax law and venture funding amongst other. Every week, all along the process, teams must provide deliverables that aim at shepherding them through the three phases.

[5] Find more information: Vilarinho, P. M. (2015). COTEC's Technology Commercialization Accelerator (Act®). *Competitive Strategies for Academic Entrepreneurship: Commercialization of Research-Based Products: Commercialization of Research-Based Products,* 188.

IDEATION

Ideation is the earliest stage in the FEI and starts from the technology characteristics. The objective is to generate multiple product concepts and thus multiple value propositions based on the technology developed by the participant(s). For this purpose, team must search for linkages between the uniqueness of their technologies and the eventual customer/market needs (Technology-Product-Market linkages).

At the end of the phase, must be delivered a set of clearly defined product concepts prioritized according to the linkages between the unique capabilities of the technologies and the market needs. The ideation phase lasts five weeks.

DEVELOPMENT

The goals of the development phase are to refine and improve the product concepts generated in the ideation phase and to select among them, the ones for further evaluation. The development phase challenges and sustains each of the T-P-M linkages produced in the ideation phase.

The selection and validation of product concepts is supported by a set of analytical and management tools (e.g., 5 forces of Porter, SWOT analysis, industry mapping, voice of the customer, etc.) from which participants get a better understanding of the market reality (Vilanriho, 2015). At the end, participants are expected to select a product with the best potential to move onto next phase. The development phase lasts seven weeks.

COMMERCIALIZATION

The last stage of the FEI shaped by Cohitec has the purpose to end up with a business proposal which is the final outcome of the program. Along the process, participants generate value propositions for their products which must follow a typical format:

- Clearly define the product
- Connect market needs with the customer benefits of using the product
- Differentiate the product from the competitors according to the unique features of the products

In addition, participants develop business models, financial projections and respond to strategic questions about when and where the venture operates and launches its products which build the commercialization strategy. Typically, the third stage of the front end builds the development strategy of the chosen product concept. The business proposal (or business case) reunites all the previous outputs and gathers the information collected so far throughout the program. This last stage is estimated to last six weeks.

8.2 Methods of assessments

In this section, the different methods used in the program to assess the projects developed by teams are presented.

The two program coordinators have designed Cohitec in such a way that it provides at certain moments feedbacks and evaluations about the progression of teams along the front end of innovation. According to the information obtained during the interviews and the information coming from documents and personal notes, two types of assessments are distinguished: formal and informal evaluations.

8.2.1 Formal assessments

Formally, teams are given feedbacks about their projects in three different ways: during the Hitec meetings, the mid-term presentation and the final presentation.

HITEC MEETINGS

Nearly every seven weeks, teams are being challenged about their projects by professors from North Carolina in the United States qualified in entrepreneurship. The American professors test the teams about the technology itself and its uniqueness in the first meetings (ideation phase). Later on, they test the choices that teams have made in terms of products, applications, market targeted and the business models (development phase). Then, it is the turn to the development and commercialization strategies to be challenged.

These moments of assessments named “Hitec meetings” enable teams to be given feedbacks from outside sources about the choices they have made so far and about the rational they build to explain their decisions. American professors do not use a specific evaluation grid, the assessment rather follows a discussion between the individuals.

MID-TERM PRESENTATION

During the training program, teams must present their project twice to external audiences. This happens for the mid-term and the final presentations. For the mid-term presentation, teams have four minutes to present their work in front of a panel of entrepreneurs and professors before answering questions during three minutes. The jury uses an evaluation grid (see figure 12) to judge the project. Then, the jury provides feedbacks on the work and bring some suggestions in order to further improve the project.

Figure 12: The mid-term evaluation grid.

1. Clarity of the problem statement	1 -2 -3 -4 -5
2. Clarity of the value proposition	1 -2 -3 -4 -5
3. Fit of the product features and benefits answering to the stated needs	1 -2 -3 -4 -5
4. Strength of the need identified	1 -2 -3 -4 -5
5. Potential of the opportunity	1 -2 -3 -4 -5
6. Knowledge of the market	1 -2 -3 -4 -5
7. Knowledge of the competition	1 -2 -3 -4 -5
8. Advantage regarding the competition	1 -2 -3 -4 -5

1- Very low
2- Low
3- Average
4- High
5- Very high

The mid-term presentation takes place when ideation phase is finished and the development stage has just begun. From the grid, two types of criteria are presented. The first three criteria assess the product itself and the fit with the market while the last five ones rather evaluate the market conditions in which the product will be launched. It should be noted that teams do not have access to the criteria employed to assess their work.

FINAL PRESENTATION

For the closing session, teams present their business proposal in seven minutes before answering Q&A for three minutes. The jury gives feedbacks and interact with teams to give them some suggestions for the enhancement of their work.

The audience mainly includes researchers, management students, executives, government officials and investors (Vilarinho, 2015). Only a minority part of the teams participating have access to the next stage of the accelerator namely the proof-of-concept. For this, teams must provide the business proposal resulted from the Cohitec training with a proof-of-concept development roadmap. They must present these formalities to a group of entrepreneurs and executives coming from various businesses during a due diligence meeting. The jury evaluates

the business potential of the proposition and the potential value that can be created from the project if the proof-of-concept stage is successfully accomplished.

Although Cohitec has developed different means to provide assessments and feedbacks to the teams, participants regret the lack of proper evaluation with comparison to standards. Moreover, four months is a very short time to turn projects into real business opportunities such that the training program is going very fast. One assessment in a month does not seem enough for participants.

8.2.2 Informal assessments

Beside formal moments of assessment, informal evaluation provides some sort of feedbacks to teams. Informally, during each TEC session (educational classes taking place once a week), some of the teams present their deliverables in front of the other participants and the coordinator of the program. By doing so, they receive some comments or questions coming from their colleagues and the coordinator that they can use to enhance their business project. Also, mentors have an important role to play to guide teams. Mentors meet the teams once a week and provide their experience and their knowledge to help progress in their work.

8.3 Indicators of performance

The establishment of performance indicators is a formal assessment which judges the work of the teams in the front end of innovation and delivers feedback on the performance. This section describes the objectives of such an initiative.

8.3.1 Objectives

Although formal and informal moments of assessments take place along the process, it appears that teams do not always feel confident about the path they take through the development of new products.

The coordinator of Cohitec Lisbon declares that this represents a big issue regarding the proper assessment of teams. Every year, teams complain about not being properly evaluated and not being given the right directions to progress. They expected support from mentors, coordinators and American professors to tell explicitly how well they are doing. However it does not happen.

According to Cristina Simões, coordinator of Cohitec Lisbon, the set of performance indicators has then the objective to help teams, “at least psychologically and emotionally”, by providing proper feedbacks on their performance. By having access to a set of performance criteria, they have clear objectives to attain and they can feel more comfortable in their work as they have something to compare with.

Furthermore, from the assessment with criteria, they can judge immediately whether they are on the good path or whether they must undertake some modifications. Unfortunately, coordinators of Cohitec programs find some difficulties in choosing the relevant tasks and points to be evaluated due to their deep involvement in the training.

8.4 What are the relevant performance indicators

In this section, the findings on the indicators resulting from the case study of Cohitec are being presented. The indicators are defined in accordance to the three stages coined by Cohitec namely ideation, development and commercialization.

In order to properly define the performance indicators, a look at the structure of the front end of innovation was suggested by the interviewees. According to them, the best way to define relevant

performance indicators is to separate the front end process in multiple stages given the nature of each stage.

The advantage of setting quality criteria that follows the sequence of activities is that it does not create additional noise for the teams. Participants are indeed aware of each stage and can clearly bear in mind the objectives they have to reach.

8.4.1 Ideation

The starting point of the process is to connect the technology with the product ideas. At the end of the ideation phase, the front end teams should deliver a wide list of product concepts developed from the technologies. The aim of this stage is to identify products with an abundant potential that can be produced from the uniqueness of the technology.

Therefore, before even starting generating ideas, one should ensure the business potential of the technology and assess whether the technology meets specific performance criteria.

Based on the interviews, the technology must meet the following three criteria:

- The technology is protectable,
- The technology is scalable
- The technology is unique.

The technology must be able to be protected from the competitors in order to limit the risk of imitation. The protection can come from intellectual property (patents are common in the technology area), trade secrecy or other means.

Also, the technology must permit the scalability of the process by which products are made. The scalability allows to answer the market needs by producing industrial quantities whether it is needed.

Finally, the uniqueness of the technology surely matters as it is the uniqueness of the technology that provides the unique features to the product. Uniqueness of the technology can be found in the components, in the way the technology works or by the professional skills needed to control the technology.

In the ideation phase, the most important outcomes delivered are the value propositions (VP) related to the product concepts. The value proposition is a statement made by company that explains why customers should buy the products or services and convinces of the uniqueness of the offer compared to competitors (Skok, 2013).

In order to be effective, the VP must clearly identify problems in a market and in addition, it must bring solutions by answering the market needs. Moreover, the product concept must be clear in such a way that it is easy to understand from a customer's perspective.

- The VP identifies market problems
- The VP solves market needs
- Clear product concept

The product idea must also follow a performance assessment. In order to be have a competitive potential and thus a significant potential on the market, the product must:

- Have a superior performance/price ratio compared to competitors
- Have unique features
- Be able to satisfy customers
- Have a different proposition from competitors

The product must be able to achieve a competitive advantage to the entrepreneur in the sense that it either offers better prices either better performance, or both, compared to competitors. Unique features of the product are not shared with competitors' product. The product must solve customer needs or wants such that it reaches customer satisfaction. Finally, based on the

competitive advantage and the unique features, the product must be differentiated from the competitor's product on the market.

Finally, the quality of the team work must also be taken into account in the set of quality criteria. The Director of ACT believes "it is better to have an outstanding team with a not so good project than the opposite because if the team does not work out, indeed good results cannot be produced".

At Cohitec, teams are cross-functional and reunite researchers, management students and mentors. However, the challenge is to overcome the multi-disciplinary nature which can drive members apart. For this, the coordinators of Cohitec claim that teams should meet specific criteria:

- Cross-functional experts in the team
- Sufficient capabilities and knowledge within the team to develop the project
- Communication and coordination within the team
- Integration of team members for them to provide their best expertise

Interviewees state that team criteria are not specific to the idea phase and the team performance should be guaranteed all along the process.

8.4.2 Development

The concern in the development phase lies in the validation of the potential of product concepts formed in the prior stage. The development stage's main activity is the collect of information about the market and the competition in such a way that it confirms or refutes the potential of each product concept.

Whether the product concepts are validated or not depends on their suitability to the market targeted. Hence, one should use market criteria to evaluate and select the product concepts with the best potential.

In order to ensure the suitability of the products with the market, indicators should be able to display the market information.
According to the interviewees, the relevant information concerning the market targeted by the new products includes amongst other the market share, market growth, market size, access to market (depending on the barriers to entry such as channels, market competition, entry investment etc.).
In addition, the assessment of the competition, the differentiation with competitors, the potential of the product within the market and the establishment of contacts who provide primary information should take place.

To amass primary information, teams should be able to establish contacts who are either able to help them by providing figures about the market, either helping for the launch of a startup. The objective is for the teams to create a business network able to leverage more skills and more information. The more information collected and the more uncertainty and risk are reduced.

- Significant market size/growth/share
- Easy access to market
- Big strength of the need in the market
- Fit of the product with market needs
- Establishment of a networking of contacts
- Sufficient knowledge of the competition
- Differentiation from competitors

8.4.3 Commercialization

The purpose of the last stage focuses on what must be done to get the product on the market. This phase has a major importance since it significantly contributes in building a convincing business case that will be presented to the investors. The business case is the final outcome of the training program and is the element on which investors decide to put money on or not.
The commercialization stage contributes in elaborating a development strategy. For this, teams must elaborate a plan for development.

The plan of development reunites the set of activities that must be undertaken in order to further develop the project until the commercialization. It is a stable roadmap which is understood by all. It contains clear and realistic project targets. In addition, it shows the time-to-market, defined as the length of time from the product concept until it is made available on the market. In order to have the biggest chance on the market, it is suggested to have a short time-to-market.
The plan should display whether the team has sufficient materials and human resources to perform the project.

- Stable and explicit plan
- Milestones are clear and realistic
- Short time-to-market
- Sufficient materials and human resources to perform the project

9. Discussions

9.1 Front end of innovation

The case study of Cohitec put in light three specific periods that typically constitute the front end of innovation. In this thesis, these will be called exploration, validation and business case.

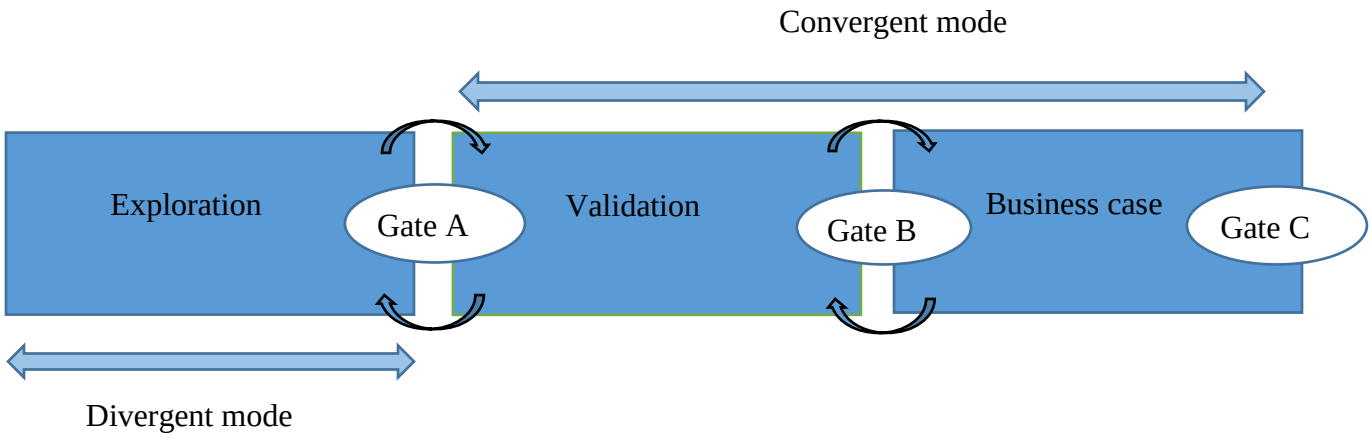
The first period taking place in the very beginning of the front end is exploration. This stage involves the exploration of opportunities and generation of ideas. This is the creative part of the process and belongs to the divergent mode which includes discovery and exploration activities (Palmer & Kaplan, 2007).

In the validation, the stage deals with the development of product concepts and the validation of the findings. Product ideas generated are being evaluated and a minor part of them is selected for deeper researches and evaluations. In order to corroborate the product ideas, information specific about the market, the competition and the technology must be collected (Doll & Zhang, 2001).

Finally, during the last period, team must elaborate a business case for the product idea with the best potential. The business case incorporates a business plan (including financial and business analysis), a product definition, a project justification and a plan for further development and commercialization (Khurana & Rosenthal, 1997).

The two last stages described, conversely to the first one, are part of the convergent mode which uses the traditional business techniques with the aim of evaluating and refining the potential of the opportunities until the implementation (Palmer & Kaplan, 2007).

Figure 13: Practical model of front end of innovation based on literature review and case study



This model has similarities with the three approaches of front end reviewed in the literature review.

Similarly to the Stage-gate model of Cooper (1988), the present models proposes gates during which the individual project and the innovation process are judged against a set of performance indicators. It enables teams to verify whether they can continue the process or should undertake changes before going further.

However, unlike the 1988' SG model it is not a linear process. The process is rather dynamic just as the new concept development model of Koen et al. (2001) meaning that activities are not performed in a sequential way and loop back can occur.

The practical model of front end tries to enter in contact with market experts and customers for the validation of findings as soon as the exploration period has ended. Likewise the customer development process developed by Blank (2006), the purpose is to check whether there is a market and customers willing to pay for the product.

The sequence of these three periods in the innovation process were not pointed out in the models presented in the literature review i.e. the Stage gate model, the New Concept Development model and the Customer development model.

The figure 14 applies the practical model of the front end of innovation to the three models developed in the literature review. Activities in each model are classified in accordance to the three periods identified in the case study i.e. exploration, validation, business case.

Figure 14: Practical model of front end of innovation applied to the models in the literature review

Models	Exploration	Validation	Business case
Stage-gate model Cooper (1988)	Discovery or idea	Scoping	Build the business case
NCD process Koen et al. (2001)	Opportunity identification Opportunity analysis Idea generation & Enrichment	Idea selection	Concept definition
Customer development Blank (2006)	Customer discovery	Customer validation	

9.2 Indicators of performance

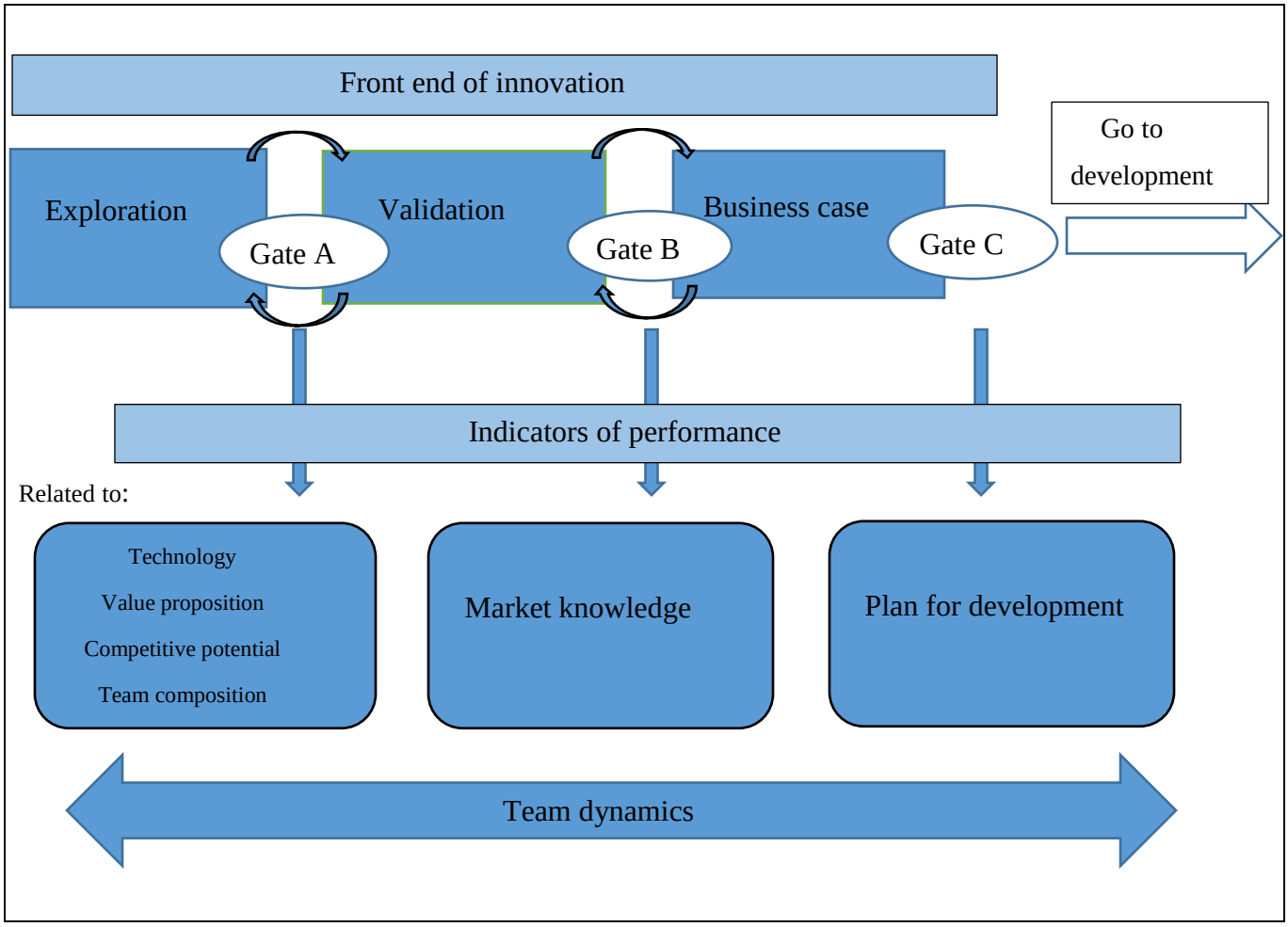
The research question tends to define the relevant performance indicators in order to monitor the performance all along the process of front end of innovation.

The literature review presented on the indicators of performance in the thesis suggested to develop criteria according to specific areas of analysis. The indicators were classified in four areas: effectiveness, competitive potential, team composition and team dynamics, and strategic fit without taking into account the sequential aspect in which they should intervene.

The case study revealed the importance of the time dimension when utilizing the indicators of performance. Specific indicators should be set at specific time during the innovation process.

Therefore, the indicators developed within the case study follow the sequential aspect in the front end of innovation and are then classified whether they should intervene during the exploration, validation or business case stage.

Figure 15: Summary of findings in the case study



When applying the indicators of performance developed in the literature review, it appears that all of them were found relevant in the case study with the exception of the strategic fit dimension. The absence of strategic alignment criteria can be explained by the nature of the case study.

Cohitec is an organization helping multiple independent entrepreneurial teams to develop a product and eventually a startup. Therefore, ventures do not exist yet and this may be the reason why strategic criteria were irrelevant within the case study.

In the contrary, indicators belonging to the area of effectiveness, competitive potential and team dimension were applicable and relevant in the case study. However, they were not classified in line with the moments during which they should intervene.

The assessment of the competitive potential of the product was found pertinent in the exploration, while the effectiveness is more likely to take place in the business case stage as it refers mostly to the plan of development.

Concerning the team dimension, it was split into team composition which is applicable at the very beginning of the innovation process i.e. exploration, while team dynamics is suggested to be evaluated through the whole innovation process.

In addition to the indicators presented in the literature review, the case study enhanced the set of indicators by adding criteria related to the potential of the technology, the value proposition, the market knowledge and the plan for development.

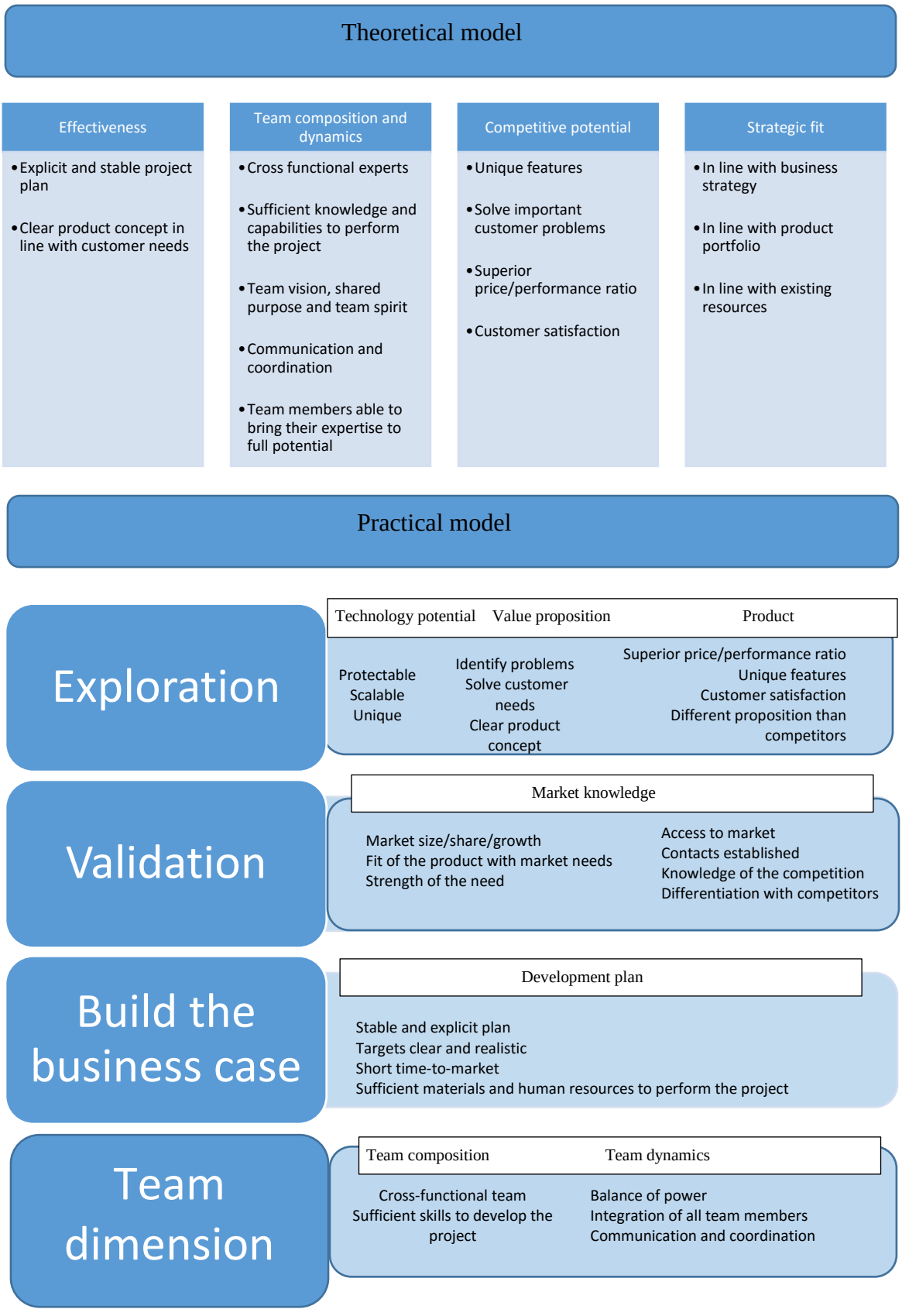
The technology potential assessment can take place in the exploration period, at the very beginning of the innovation process. The literature review did not mention the importance of setting technology-related criteria whilst it was revealed to be necessary in the case study.

Market criteria was found relevant in the validation stage in order to ensure the suitability of the product within the targeted market. According to the literature review, the front end faces three types of uncertainties: technical, market and competition (Doll & Zhang, 2001). In the case study, technical uncertainty is being solved in the exploration stage whilst market and competition uncertainties are resolved in the validation stage through the information collected.

Finally, the case study highlights the need of setting indicators related to the plan for development. The literature review contains very few information about indicators for the development plan. However, it is just as important as the other indicators in order to bring a product with potential to the market in the best manner.

Therefore, the figure 16 confronts the theoretical model of performance indicators developed in the literature review with the practical model resulting from the observations made within the case study of Cohitec.

Figure 16: Summary of the findings of the literature review and the case study



To sum up, the thesis has studied the indicators that monitor the performance all along the front end process. It confronted the model developed from the literature review with a practical model resulted from a case study of an accelerator.

Following Poskela & Martinsuo (2011)'s point of view, most criteria are subjective and do not rely on mathematical or statistical methods. It is up to the team or the Management to judge of the performance in accordance with the set of criteria.

9.3 Illustration

In the present section, the indicators are illustrated through the definition of a set of criteria especially for the purpose of Cohitec. It must be noted that the set of criteria cannot be implemented in another company or institution without modification. This is exclusively designed for the Cohitec training program. However, it can inspire management of companies and serve as a foundation for further modifications.

The indicators are based on formal interviews, discussions with Cohitec employees and document analysis which have allowed the researcher to define a set of performance indicators customized for the case of Cohitec.

The coordinators of the program explicitly ask for indicators in line with the Cohitec structure of front end of innovation i.e. ideation, validation and commercialization, and not to exceed more than three to five indicators per stage.

Based on the results from the discussion and the interviews, the figure 17 presents the set of indicators designed for the acceleration training program of Cohitec.
Green areas mean that the objective is being met and should be maintained. White areas suggest teams to make efforts and improvements.

Figure 17: The performance indicators proposed for Cohitec

	Strongly disagree	disagree	No opinion	agree	Strongly agree
IDEATION (EXPLORATION)					
1. The technology presents unique characteristics able to provide a competitive advantage					
2. The value proposition identifies a real problem and solves markets needs					
3. Each member of the team feels fully integrated in the team and is able to bring his/her full potential of expertise					
4. The technology is protected or currently in progress to be protected					
DEVELOPMENT (VALIDATION)					
1. The number of established contacts is able to provide the team enough primary information on the market					
2. The access to the market is relatively difficult (high barriers to entry, monopoly, etc.)					
3. The need of the market is significant					
4. The market size is sufficient and the market is growing					
5. The product features and benefits can answer market needs and provide a differentiation given the competitors					
COMMERCIALIZATION (BUSINESS CASE)					
1.The roadmap presents clear and realistic milestones					
2. The time-to-market is significant					
3. The investment required to market the products can without difficulty be funded by investors					
4. The team has the required skills to execute the project (technical, financial, marketing etc.)					

While studying the case of Cohitec, some weaknesses were discovered.

The first weakness identified is the absence of performance indicators in the program. Cohitec proposes a plethora of types of assessments to evaluate team's projects. However, participants feel frustrated in not being able to compare their project with given standards. Although they have the opportunity to compare the advancement of the project between teams, the future ventures do not belong to the same technological areas and usually target different markets.

The second weakness stems from the first one: because Cohitec has never implemented indicators of performance, it does not possess formal quantitative data relative to the technological area of the project. Hence, it is unfortunately not possible to propose a mix of quantitative and qualitative measures of performance. Therefore, the figure 17 includes mostly or exclusively qualitative measures.

The third weakness identified through the case study is the absence of team performance assessment. Every formal or informal assessment that Cohitec provides is about the project and its outcomes. The team performance is never evaluated even if it is known as a key driver of performance.

10. General conclusion

The aim of the paper is to study the indicators of performance that allow to monitor the performance throughout the front end of innovation. As a matter of fact, literature is very scarce in this area and the front end of innovation stands as the uncertain and ambiguous part of the new product development process. This thesis has the ambition to address this issue and to propose a set of performance indicators applicable along the process.

Multiple models of front end of innovation and especially three specific models were approached: linear, dynamic and entrepreneurial. Although they contended dissimilar frameworks, they also presented similarities. All of them agree to define the front end of innovation as a process reuniting all the activities until a business case is built and presented to the Management who takes the decision to move the project forward or to kill it.

The final outcome of the front end of innovation is the business case. It presents the product definition with all its specificities, the financial and business analysis, the plan of development and the commercialization strategy. On the basis of the business case, companies and investors will decide to either move the project forward in the development stage, either to terminate it. This is the moment when the front end of innovation ends.

In the study of the indicators of performance, the literature review explicitly claimed the importance of monitoring the front end of innovation. A performant front end is particularly crucial as the consequences of a not well-managed process can be significant.
It can result in time delays, heavier costs, the loss of launch opportunities, failures to achieve a competitive advantage and additional loops in the further steps of the process (Gassmann & Schweitzer, 2014; Ho & Tsai, 2011).

The paper had the purpose to answer the following question of research:

- What are the relevant performance indicators when monitoring the front end of innovation?

The case study brought to light the importance of the dynamic nature in the front end of innovation when setting indicators of performance.

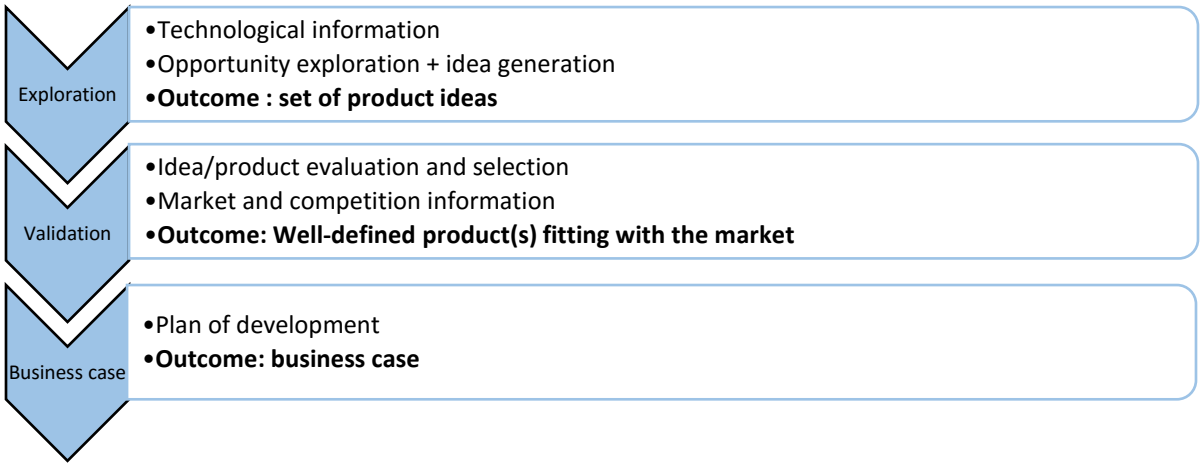
Based on the observations made in the case study and the literature review, the practical model of front end of innovation was split into three specific moments named exploration, validation and business case.

Exploration moment is taking place at the beginning of the process and aims at exploring opportunities and generating ideas. During this period, the technology-related information must be collected in order to reduce the technical uncertainty. The outcome of the stage is a list of product ideas generated from the technology.

Validation moment aims at developing the product ideas and either validate them, either refute them. The selection of ideas is based on information collected about the market and the competition mostly.

Finally, the business case moment is when the team elaborates the whole business case which contains all the elements in order to launch the product on the market i.e. product and project definitions, plan justification and plan for development (Garcia, 2014).
The figure 18 illustrates the main activities in the practical model of front end of innovation.

Figure 18: The activities in the practical model of front end of innovation



The case study suggested to define indicators of performance by respecting the sequence of moments. In addition, the practical case of Cohitec enhanced the set of indicators developed in the literature review by proposing extra indicators related to the technology itself, the value proposition of the product, the market knowledge and the plan of development.

However, the literature review did not take into account the moments during which indicators should be presented and rather identified indicators related to four areas of analysis: effectiveness, competitive potential, team composition and dynamics and strategic fit- see figure 9.

The four dimensions of performance developed in the literature review were confirmed in the case study apart from the strategic dimension which was found irrelevant in the case study. This was explained by the purpose of Cohitec which trains independent entrepreneurial teams to launch a product and eventually a startup. Therefore, ventures do not exist yet and strategic criteria are not pertinent.

Indicators related to the effectiveness were placed in the business case stage as it is mostly related to criteria for the plan of development while competitive potential was found more relevant in the exploration stage to assess the product generated. Team composition is more likely to be assessed

at the beginning of the innovation process i.e. exploration, however team dynamics should be guaranteed all along the process.

Ho & Tsai (2011) note that criteria regarding the development plan is usually not given heavy weight in the front end performance. However, it appears that it is just as important as the quality of the product concept and should not be ignored.

To end, the paper has studied the indicators of performance relevant along the front end of innovation process as the theory is not exhaustive in this area.
It had the ambition to intend a formal means to monitor the performance throughout the front end. The case study of Cohitec allowed to define extra indicators which were not developed in the literature review and thus enhanced the set of criteria.

It should be reminded that the indicators presented are flexible and should adapt to all types of projects. It serves as an inspiration for institutions willing to implement performance control in their process.

10.1 Managerial implications

Cohitec is a successful accelerator of technology commercialization. Founded in 2004 in Portugal, it has been promoting innovation since then by helping entrepreneurs launching their startup. So far, more than 650 people have participated to the experience, beyond 150 projects were supported by Cohitec which led to the creation of 26 technology-based companies.

For its training program, Cohitec proposes a front end of innovation process divided in three main phases: ideation, development and commercialization. The front end of the innovation process is crucial as it can significantly impact the further development of the product. In order to prevent from consequences of a not well-managed process, the implementation of a set of quality criteria along the process is a solution.

Therefore, the first recommendation to make to the Cohitec Management is to define a set of indicators of performance that follows the front end structure in order to help their participants to monitor their project. When discussing with Cohitec members, they expressed the keen interest in developing performance criteria. For this end, a set of indicators was developed for the specific case of Cohitec – see figure 17 and was made available to the Management.

The second recommendation concerns the nature of the indicators. As Cohitec has not implemented any indicators in the past, it does not possess numerical data which would allow to provide quantitative indicators. Therefore, it is advised to Cohitec to start tracking data related to the four technological fields in which it develops projects namely biotechnology, life sciences, industrial technologies and clean technologies in order to have a better knowledge of these industries.

The third recommendation concerns the assessment of the team performance. Cohitec Management seems aware of the importance of a quality team within a project but it does not give it evaluations. Therefore, it is strongly recommended to Cohitec to undertake team assessment either in the formal moments of assessments, either informally.

10.2 Limits and suggestions for further researches

There is a couple of limitations regarding the reliability of the study that should be carefully considered.

The first limitation concerns the research method. As explained in the methodology, the thesis treats a single case study –Cohitec- which makes difficult to generalize the findings. Case studies are subject to number of criticisms whose the most common ones are the absence of the generalization of results and the absence of external validity (Reis, 2011). Therefore, the study of performance indicators should be extended to multiple case studies which would allow to corroborate the findings or refute them. However, the results can be taken as a basis for improvements and can represent a source of inspiration for the readers.

In addition, the case study was about an accelerator of technology commercialization helping independent entrepreneurial teams to go on the market. Hence, it was pointed out that some criteria can be irrelevant within the context as it was the case concerning the strategic criteria. To counteract this, the further researches should carry out multiple case studies, including the case study of established companies.

Secondly, the research was limited to the study of indicators which can evaluate the current situation in the front end process. Indicators about future estimations or comparison between estimations and results were explicitly excluded from the research. As a consequence, the set of indicators presented is not exhaustive and further researches should include the study of the omitted indicators of performance in order to enlarge the panel of indicators.

Thirdly, the scope of the thesis was restricted to the NPD innovation process which brings products and services to the market. Therefore, the indicators were defined for the case of a product innovation (including products and services) and may not be applicable for all types of innovation (i.e. process, production, organizational forms, etc.). Further researches should extent the type of innovation and define indicators for various innovations.

Finally, the fourth limitation of the study is related to the nature of the research method. It was decided to take on a qualitative research method. Data coming from qualitative researches are subject to individual opinions and personal perceptions which makes it common weaknesses of such a method. Future studies should consider to carry out quantitative research method in the area of performance indicators in the front end of innovation.

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