A CROSS-FUNCTIONAL APPROACH FOR THE FUZZY FRONT END: HIGHLIGHTS FROM A CONCEPTUAL PROJECT

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Abstract

Ideation is regarded as a critical element in the innovation process; besides, it is transversal to the different design models. Notwithstanding its fundamental characteristics for the innovation process, ideation is the least-studied phase and an ambiguous nature is sometimes assigned to it. Consequently, the Fuzzy Front End (FFE) designation was born to describe this early phase and the interest over its study has recently increased.
By means of an extensive literature review, ideation is highlighted from the design process and diverging models for the FFE are comparatively analyzed. The importance of a cross-functional approach for the FFE is underpinned with an analysis of a multidisciplinary and mainly conceptual project over the transportation sector. The innovative character and the perceived value of this project is precisely grounded in its integrated and cross-functional approach, which combines the technological possibilities with the passenger focus.

Keywords: Conceptual design, Early design phases, Fuzzy Front End, Innovation

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1 INTRODUCTION

There have been many attempts to model the design process (Cross, 2008). In general terms, the process consists in a series of activities and methods that, together, aim to solve design problems. The understanding of the design process is considered in the literature to be an initial requirement in order to achieve reliable solutions (Council, 2007, Kumar, 2013). However, and despite its vastness, we believe that literature on this subject is inconclusive; the only consensus is that there is no set best practice. In fact, many different design models are proposed, varying in the scale and nature of the problem addressed and it has been accepted that different design problems admit different design methods (Council, 2007, Crawford and Di Benedetto, 2010).

Despite the absence of a generally accepted single model, the early conceptualization or ideation phase is one of the common branches within the wide spectrum of existing design models; still, it is the least studied phase. Conversely, ideation is generally accepted as essential for the overall process; besides, it is considered to be the first stage of the innovation process as well (Bullinger, 2008). Ideation and specially the idea *per se* are fundamental to the emergence of new products. On the one hand, ideation is critical to the project management research as any new project aims to crystalize the new idea into a well-defined concept and, ultimately, a new product/service. On the other hand, due to its generative characteristics, design research has been changing its focus and efforts to this conceptual stage as well (Sanders, 2006, Sanders, 2010); a stage coined in the 1990s as the Fuzzy Front End (FFE) (Smith and Reinertsen, 1998). Some authors are now assuming that making the most in the FFE is essential to create real breakthrough products (Cagan and Vogel, 2013); furthermore, it will be critical for future designers to understand how to successfully operate in the FFE as well, given the fact that strategic options over this phase are common in large commercial enterprises (Wormald, 2011). Notwithstanding the FFE perceived importance to both the academia and industry, the FFE remains a comparatively under-examined topic (Koen et al., 2001, Koen et al., 2014a, Koen et al., 2014b); additionally, the FFE defines what will happen in the development stages (Markham, 2013).

The general motivation for this article is to study the FFE within a cross-functional context; namely, in the collaboration between industrial design and engineering teams. The study is underlined with an on-going conceptual and cross-functional project over the transportation sector. Therefore, this paper has the objective to understand whether or not cross-functional collaboration might be beneficial for the early stages of the innovation process. To achieve this goal, the paper is structured as follows: in Section 2 a literature review is carried out aiming to understand the importance of Ideation inside the Design Process and to depict the existing research over the FFE; in Section 3 the possible approaches for the FFE are compared and the importance of cross-functional work within this phase is underlined, with the findings of the project under analysis; Section 4 presents our conclusion of this brief study.

2 LITERATURE REVIEW

The objective of the literature review is to compare different design models and to highlight ideation as one of its common branches. Within the ideation step, a study on the emerging FFE issue is done.

2.1 Design Processes

Historically, the exploration of the design process began to be taken seriously in the early 20th century at Bauhaus; herein, attitudes to industrial design were radically changed and the methodological foundation for design education was established (Bayazit, 2004). This new approach revolutionized industry as well; many companies and products were redesigned according to Bauhaus' theories (Council, 2007). After the end of Bauhaus, the majority of its staff moved to the U.S., UK or Soviet Union, influencing their foster institutions. Later, the novel scientific methods and techniques used to develop the WWII war inventions' attracted many designers in the post-war period. Consequently, design work increased and it became evident that product shouldn't be the only design task core; human needs should be considered as well (Cross, 1993, Bayazit, 2004). Therefore, in 1962, the first conference on Design Methods took place in London; Bruce Archer and John Chris Jones, two engineers interested in design, were among the organizers (Cross, 1993, Margolin, 2010). In 1963 Bruce Archer published his first known model; it was the first attempt to break the design process into linear key stages (Council, 2007). The linear model was widely accepted; yet, in the 1970's Bruno Munari sustained that no model must be admitted as absolute or definitive; instead, any model should

be considered a changeable and iterative tool (Munari, 2006). Since then, revised models incorporating loops and iterative phases were developed (Council, 2007). Accordingly, the following sub-section analyses some of these more recent design models.

2.1.1 Design Processes analysis

Figure 1 integrates four different, yet related, design models. The models presented horizontally and vertically have a design thinking base (Ambrose and Harris, 2009, Milton and Rodgers, 2013), while the diagonals represent a more engineering design base (Pahl et al., 2007, Cross, 2008).

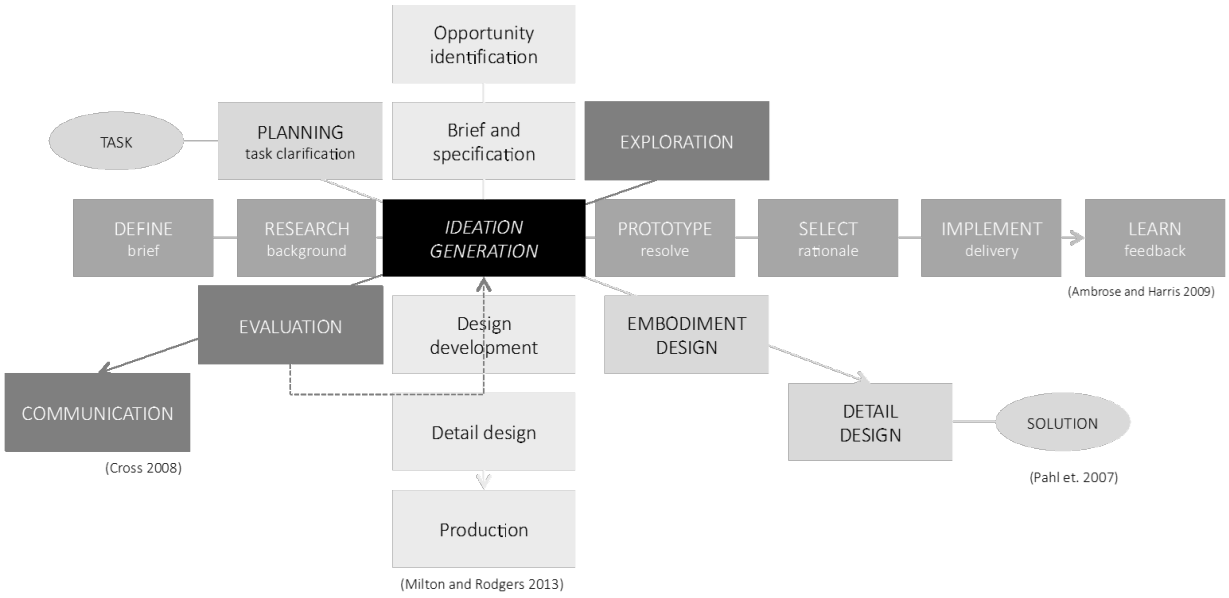

Figure 1. Design Models Mapping

Milton and Rodgers present a linear model of the design process, yet considering its intrinsic iterative characteristics (Milton and Rodgers, 2013). Ambrose and Harris admit the existence of design thinking and iterations in all the represented phases, despite modelling them in a linear path as well (Ambrose and Harris, 2009); so, these two models have the same type of linear representation and a similar iterative philosophy as well. On the other hand, Pahl et al. (2007) designed a systematic four stage model that aims to keep the iteration loops as small as possible (Pahl et al., 2007). Conversely, Cross presents a four stage model, yet considering it to have a descriptive character (with a solution early in the process) and representing an iterative loop between the evaluation and generation phases (Cross, 2008); so, these two have different philosophies towards the importance of iterations. The referred *Ideation*/*Generation* phase is one of the possible common concepts among the represented models; it is also common on the not represented ones (perhaps another common phase might be the *Brief*/*Planning* phase). In the Ideation phase, ideas are generated, ranked and selected for further development; nonetheless, idea generation *per se* is considered to be the indispensable core of the process (Smith, 1998, Harmsen, 2013). Initially, ideation was wrongly considered as a single step inside the innovation process and its study was, in somehow, disregarded; yet, it is clearly a decisive, iterative and complex phase (Koen et al., 2002). Besides, it is considered to be the first stage of any innovation process (Bullinger, 2008); consequently, the innovation process have been generally sequenced in industry along three major activity domains:

1. Fuzzy Front End (**FFE**)
2. New Product Development (**NPD**)
3. Commercialization (**COM**) (Deppe et al., 2002, Dornberger and Suvelza, 2012, Riel et al., 2013, Markham, 2013)

In this list, the FFE is the least well-known and acknowledged item. However, the difficulties to establish a best practice for the design process sustain the FFE study as the most promising way to improve the innovation process (Council, 2007). Hence, instead of focusing this study in the overall design process, this paper discusses and gives new insights in the cross-functional approach to the FFE.

2.2 Fuzzy Front End

The discipline of NPD was the first to coin the term Fuzzy Front End in the 1990s, with a recent increased use (Council, 2007, Verworn, 2009, Lucae, 2013). The FFE is a critical component in the overall innovation process, as future products are herein defined and decided (Markham, 2013); furthermore, the impact of professional design practice in the FFE is growing in significance (Wormald, 2011). Notwithstanding the FFE to be considered as the dynamic initial stage of any innovation process, its intrinsic characteristics have inhibited its detailed study (Koen et al., 2001, Koen et al., 2014a, Koen et al., 2014b). Commonly, the FFE covers the period between ideas and opportunities being generated, identified and their later approval for development (Kim and Wilemon, 2002, Verworn et al., 2008, Verworn, 2009, Eling et al., 2014). However, this stage takes place within a high degree of uncertainty and a low degree of information (Figure 2).

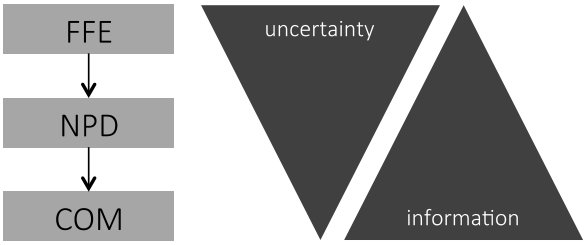

Figure 2. Uncertainty and information during the Innovation process; adapted from (Deppe et al., 2002, PMI, 2013)

During the innovation process, the uncertainty decreases as the available information increases; the FFE is clearly the least known phase (Deppe et al., 2002). The above-represented framework may be behind the referred negligence in the FFE study.
Some authors prefer to use the Front-End of Innovation (FEI) designation to detach the fuzzy character (Koen et al., 2001, Koen et al., 2014a); however, present paper uses the FFE original term.

2.2.1 FFE Relevance

The dynamic and often unstructured characteristics of the FFE assign challenges to its effective management (Kim and Wilemon, 2002). Nevertheless, FFE largely determines not only the outcome of the innovation process, as the associated costs, timeframe and required resources. Furthermore, the most important decisions for the entire innovation project are taken in the FFE; this is the phase in which the innovation process is more influenced (Figure 3) (Deppe et al., 2002, Dornberger and Suvelza, 2012, Riel et al., 2013). Still, the FFE is the least well-structured part of the innovation process (both in theory and practice); notwithstanding the greatest differences between winner and looser projects to be found in the quality of the predevelopment activities (Herstatt and Verworn, 2001).

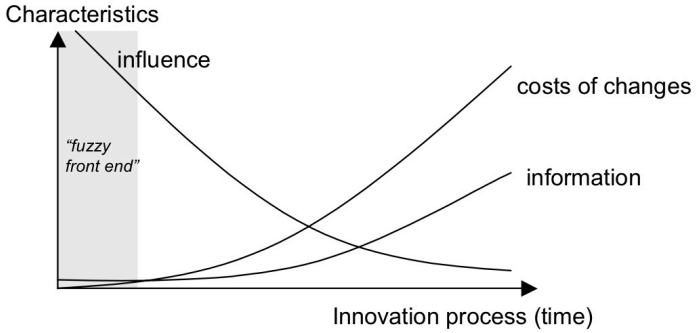

Figure 3. Information, costs of change and influence in the Innovation Process (Herstatt and Verworn, 2001, Dornberger and Suvelza, 2012)

As illustrated in Figure 3, the FFE has the highest influence in the innovation process with the lowest costs of change; the more forward into the process, more money will be needed (Cagan and Vogel, 2013). As above mentioned, the FFE starts with low levels of information, helping to explain why so many companies fail to master this initial phase, with managers stressing the practical need of acting

more systematically (Riel et al., 2013). Therefore, an exhaustive investigation aimed to structure the FFE activities is missing (Verworn, 2009, Riel et al., 2013). Furthermore, the referred highest level of uncertainty in the FFE and the lack of strategies to an effective idea management assign an increasing importance to the study of the FFE best practices (de Brentani and Reid, 2012).
As initially advanced, the FFE precedes and strongly influences the NPD; nevertheless, NPD best practices have been heavily studied and a similar research for FFE is missing (Koen et al., 2002). Furthermore, some relevant authors assume that methodologies used in NPD won't work in the FFE (Khurana and Rosenthal, 1997, Koen et al., 2002). Hence, in order to stress their major characteristics and differences a comparing table is presented (Table 1).

Table 1. General FFE and traditional NPD comparison; adapted from (Koen et al., 2001, Kim and Wilemon, 2002, Koen et al., 2002, Dewulf, 2013)

	FFE	NPD
State of an idea	Probable, fuzzy, easy to change	Clear, specific, difficult to change
Nature of work	Experimental, often chaotic	Disciplined, structured and goal oriented
Features of information	Qualitative, informal and approximate	Quantitative, formal and precise
Funding	Variable	Budgeted
Commercialization date	Unpredictable	High degree of certainty
Revenue expectations	Often uncertain	Predictable
Degree of formalization	Low	High
Activity	Both individual and team to minimize risk	Multi-functional development team
Management methods	Unstructured, experimental, creative	Structured, systematic
Damage if abandoned	Usually small	Substantial
Measure of progress	Strengthened concepts	Milestone achievement

Analysing Table 1, the experimental work, the uncertain revenues and the unstructured management methods are the highlighted points as causing the fuzzy character. According to Brentani and Reid (2002), these points stress the need for an intensive and detailed study over the FFE. Wrongly, some companies might argue that the FFE stage does not require funding, due to the conceptual nature of the work to be done (Markham, 2013). Yet, funding is a significant issue, specially in large-scale engineering FFE projects; their social, technical and organizational complexity, caused by the involvement of different companies, assign these projects several risks of schedule and cost overruns (Lucae, 2013).
On the other hand, multidisciplinary work is not solely considered as taking place in the FFE phase, individual work is stressed as well. For the FFE, the multidisciplinary work has been mainly considered in order to minimize and share risk over a cross-functional team. Conversely, Markham (2013) argues that the more interdisciplinary work conducted in the FFE the more successful this stage will be, due to the degree of concept refinement to be further developed over the NPD stage.

2.3 FFE models

The term FFE might wrongly suggest that the early stages of the innovation process have to be fuzzy; however, creative problem solving shouldn't be necessarily chaotic (Gaubinger and Rabl, 2014). The frame of reference in the FFE argues that its current descriptions aim at developing a widely accepted model to reduce the associated uncertainty (Nobelius and Trygg, 2002). The first comprehensive study on the FFE was advanced by Khurana and Rosenthal (1997), who proposed a systems view for the FFE phase (Koen et al., 2014a); as shown in Figure 4., Khurana and Rosenthal (1997) description considers simultaneously the overall strategy with relevant inputs (ideas, market analysis and technological options). Therefore, understanding the interrelationships between all the activities is equally important as the activities themselves (Khurana and Rosenthal, 1997). Accordingly, multidisciplinary and interdisciplinary relationships are particularly significant to these authors.

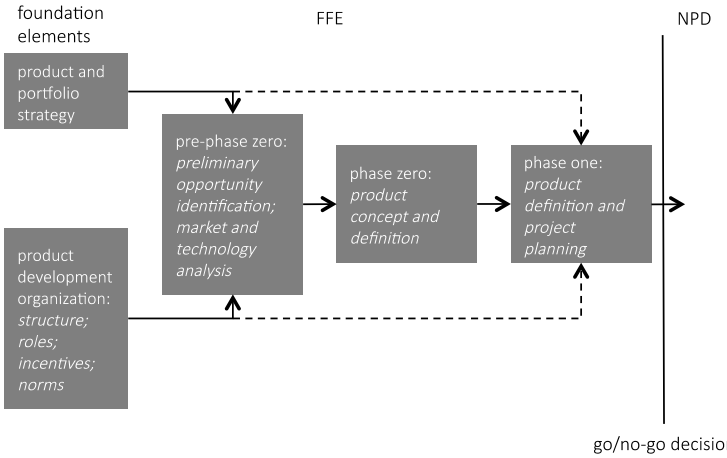

Figure 4. FFE Model; adapted from (Khurana and Rosenthal, 1997)

According to Khurana and Rosenthal (1997), companies normally start a new project when they first found an opportunity (this is the pre-phase); if the newly defined opportunity is worth exploring, a small group is assigned to work on the product concept and definition, sometimes even suppliers are included (this is phase zero). Finally, in phase one, companies assess the business and technical feasibility of the new product, confirming the product definition and planning the NPD phase as well. Despite its linear structure, this model lacked a common and applied language. Hence, in order to create a common language and a shared vocabulary for the FFE, Koen et al. (2001) developed the New Concept Development (NCD) model. This model was aimed to permit business and technology leaders to be capable of optimize the FFE activities. The NCD model consists of three main parts: the engine, the inner spoke and the influencing factors (Figure 5). The engine comprises either organizational attributes and teams or collaborations (Koen et al., 2014b); the inner part defines the so-called five controllably activity elements of the FFE; finally, the influencing factors are related to the organizational capabilities, the world and the enabling sciences involved (Koen et al., 2002). The importance of multidisciplinary teams and relationships is underpinned with the NCD, as they are considered to be the engine in this model for the FFE.

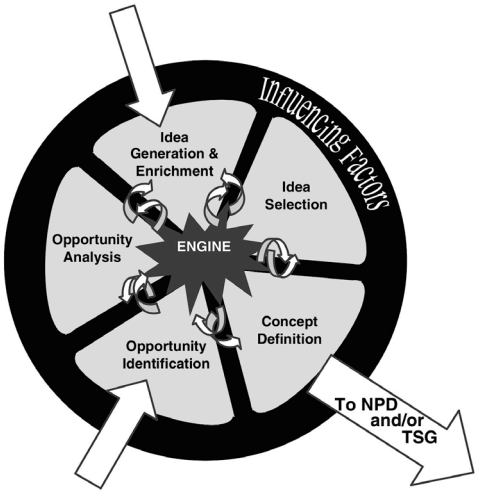

Figure 5. New Concept Development (Koen et al., 2001, Koen et al., 2002)

The arrows pointing into the model represent alternative starting points, indicating that the projects may start with either a generated idea or an identified opportunity; this is a significantly different approach. On the other hand, the exiting arrow represents how concepts leave the model and enter the NPD process (Koen et al., 2002). The circular shape means that ideas and concepts are expected to iterate across them; hence, it is an iteratively course between the referred five key elements instead of a linear process. Herein, the importance of the relationships between opportunities and ideas, as claimed by Khurana and Rosenthal (1997), is vital to elicit the innovation process.

Within the existing models for the FFE, these two represent the two major approaches; namely, sequential and iterative. Both have pros and cons, which will be detailed in the following section.

3 DISCUSSION

The FFE phase has been proved to be vital for companies involved in innovative new product development. Conversely, there is a lack of systematization regarding this early phase, with managers emphasizing its importance. The above-represented models personify the two conflicting approaches for the FFE, sequential and iterative; however, due to the pros and cons of both sequential and iterative methods, many researchers look for a combination of these two approaches in order to find a process structure (Gaubinger and Rabl, 2014). On one hand, the Khurana and Rosenthal (1997) model lacks in flexibility and iterations; on the other hand, the Koen et al. (2001) model is highly abstract which makes difficult its direct application to industry.

One of the benefits of implementing a formal FFE is to control costs and eliminate unauthorized use of resources in newly projects (Markham, 2013). Resources are challenging questions for companies; the most obvious resource is money, yet, as products are made by people and not by companies, human resources are a challenging issue as well (Cagan and Vogel, 2013). For the project under study, five different and multidisciplinary companies came together to develop new concepts that may influence future transportation. Furthermore, the integrative chosen approach, which combines better energy efficiencies with the increased focus on the passenger, was enough to convince the Portuguese Innovation Agency to apply the financially resources needed for a three-years project. Despite the studies that already consider each topic individually, it was considered that this combined approach for future transportation systems would attribute an innovative and distinguished character to the project. Both ideas from previous developed projects, the identified market and the new technological opportunities served to prompt the project; furthermore, a detailed work plan with specific timelines and deliverables was initially advanced. Nevertheless, the referred plan was holistic and flexible enough to embrace the iterations associated with a combined approach as the one taken, based on both market and technology. The model proposed by Liz Sanders (2006, 2010) for the FFE (Figure 6) helps to illustrate the experienced iterations over the project. Additionally, the perceived fuzziness for the FFE, when compared to the remaining process, can be observed as well.

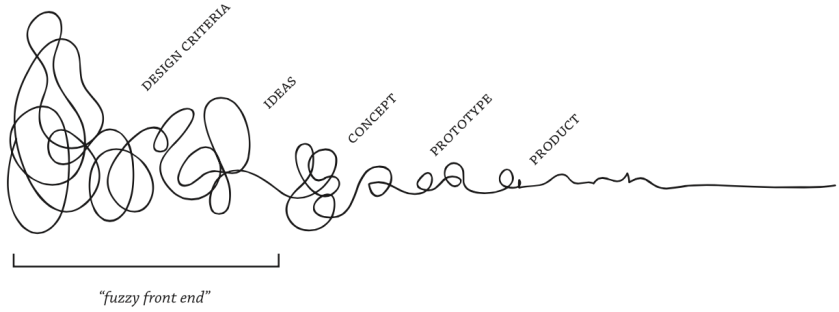

Figure 6. The front-end of the design process; adapted from (Sanders, 2010)

The project under analysis, aligned with the FFE behaviour represented in Figure 6, moved in iterative feedback loops, as ideas and opportunities were identified, analysed, merged and later selected for concept development. This iterative character of the early stages of the design process is highlighted by Cross (2008), Ambrose and Harris (2009) and Milton and Rodgers (2013) as well. Furthermore, according to Sanders (2010), half of the entire process, from ideas to market, is considered to take place in the FFE; therefore, the FFE decisive role is this way underlined.

According to the Project Management Institute (PMI), projects may vary in size, complexity and scope; yet, any project can be mapped in the generic life structure represented in Figure 7 (PMI, 2013).

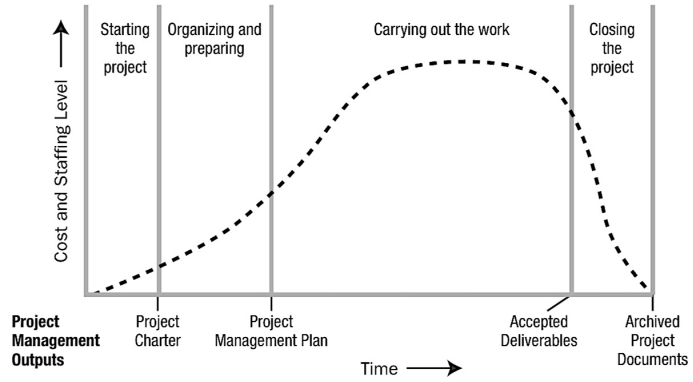

Figure 7. Cost and staffing level over time (PMI, 2013)

This generic structure is divided as follows: starting the project; organizing and preparing; carrying out the work; closing the project (Figure 7). It is the authors' opinion that the referred generic structure is applicable for conceptual projects as well, as the one under analysis. Herein, the first two steps comprised opportunities identification, technical specifications and the first generic ideation; they took roughly nine months. In the second step, the most costly and staff requiring one, the concepts were defined, developed and the three-dimensional models were created; it took half of the project, approximately eighteen months. Lastly, the on-going third step, which comprises the final detailing of the three achieved concepts, their testing and the ending reports required for approval; it is estimated to take roughly seven months. According to Cagan and Vogel (2013), a car can take thirty-six months to develop, while a software product can take months or weeks; it depends on the complexity of the product. Moreover, the project under analysis had the same thirty-six months duration, despite its final deliverable to be a set of future concepts instead of new product *per se*; hence, complexity was inherently associated with this project. Herein, the Portuguese Innovation Agency acted as a benefactor as it was focused in the results and in the value created with an intensive research project like this, instead of product development *per se*. An opinion shared with some authors, which are now asserting that much of the value of the new products is created over the FFE (Markham, 2013).

Yet, the effort over time of the project was not as simple as represented in Figure 7, due to the specific scope of each company composing the team. From the authors' point of view, the curve advanced by the PMI (2013) was five times repeated during the project, one per each company. Each company achieved a maximum effort over the project in different phases, as companies employed more human and financial resources in the phases representing their primary skills; namely, the user focus, the technology focus, the global operation, materials and fabrication processes (to highlight the expertise areas of each one). Furthermore, no company can be fully committed with one and only conceptual project; each company had other projects in development, making it difficult a full commitment of the team elements involved. Still, the coordination of this cross-functional effort is precisely one of the higher management challenges associated with any FFE stage (Markham, 2013). Therefore, one company was initially elected as project leader in order to coordinate the efforts, resources and cooperation of the remaining ones. For each previously identified phase of the project, several deliverables were identified and each company was assigned to coordinate one phase, according to their expertise areas. Roughly, it can be said that the project under analysis has a behaviour that is five times the one advanced by the PMI (2013) in Figure 7 in terms of effort over time.

This cross-functional integration is generally seen as a positively influencing factor for the new product future performance; besides, an interdisciplinary collaboration can contribute to reduce the technical and market uncertainties and the ambiguities associated with the FFE. Nevertheless, some authors assume that the complexity associated with any cross-functional collaboration makes it difficult to take broad conclusions in terms of performance and generalizations (Schweitzer and Gabriel, 2012). Yet, beyond the concepts initially considered to be the output for this project, it was possible to highlight new ideas for future projects as well; hence, the FFE importance for companies' continuous innovation strategy was also underpinned. According to Dornberger and Suvelza (2012), several tools may structure, foster and manage an innovative culture over companies, such as, TRIZ, Personas, Scenarios Technique; the last two and the mind mapping technique applied to emergent technologies were decisive for the on-going project.

4 CONCLUSION

From the performed study, it is authors' opinion that a common ideation phase might exist in all the relevant design models. Despite being the least studied phase, ideation is considered to be fundamental for the innovation process as well; consequently, ideation should represent more than a single step in the design process. Nevertheless, an ambiguous nature is commonly endorsed to this phase; the FFE designation was born this way. Even so, the FFE is increasingly being recognized as having a key role inside the innovation process, with the value of the project to be considered as being created therein.
Some authors assume that the more time spent over the FFE stage, the better the output to trigger the development process; hence, the broad innovation process will positively benefit with a compromise within the FFE. The project under analysis is a clear case of an intensive and multidisciplinary commitment over the FFE; time, money and human resources were applied to this conceptual project. Furthermore, without the referred cross-functional compromise it wouldn't be possible to get access to the needed benefactor funding. The cross-functional team was considered to have the required value to attend the demands of a complex conceptualization as future transportation is, due to the access of a diversified and integrated knowledge. Additionally, such projects might be useful for individual companies inside the team, as they will help to maintain a continued innovation strategy and this is decisive to companies remain competitive nowadays. Hence, beyond the desired and achieved outputs, new ideas, new opportunities and new knowledge can emerge and elicit new innovative projects.
Nevertheless, the complexity associated with any cross-functional methodology makes it difficult to generalize these findings. Still, the positive results of this integrated and cross-functional approach were decisive for the innovative concepts under development, for the perceived opportunities for future collaborations and to the overall created value.

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