Managing Uncertainty in Innovative Design: Balancing Control and Flexibility

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Abstract

We investigate how control and flexibility can be balanced to manage uncertainty in innovative design. Emphasis is placed on two sources of uncertainty (technological and market) and two types of uncertainty (foreseen and unforeseen) that generate challenges in innovative design. After identifying project practices that cope with these uncertainties in terms of control and flexibility, a case-study sample based on five innovative design projects from an automotive company is analyzed and shows that control and flexibility can coexist. Moreover, it points out those projects that are suitable for achieving an optimal balance between control and flexibility.

Keywords: innovative design, control, flexibility, uncertainty, balance

1 Introduction

Innovative design results in high technological and market uncertainty. Moreover, greater challenges arise from the unforeseen uncertainty due to the changing or emerging information about technology or market. To handle these uncertainties, traditional models have been control-oriented, emphasizing adequate on time delivery, cost-effectiveness and technological performance. However, its drawback lies in that it prevents identification and exploration of innovative opportunities in a rapidly changing environment [1]. Thus, many authors have identified project practices that enhance flexibility [2, 3]. With these practices a design team can respond to the dramatic shift in technology and market. Thus, striking an optimal balance between them becomes paramount for innovative design. Additionally, adopting control and flexibility are contingent upon the rapidly changing environment in which innovative design operates.

Thus, this paper aims to identify the relationships between different sources and types of uncertainty and specific project practices that support control or flexibility by means of a case-study of five completed innovative design projects from an automaker.

Consequently, the sources and types of uncertainty in innovative design are defined in Section 2.1, and the identification of project practices that could cope with these uncertainties in terms of control and flexibility are detailed in Sections 2.2 and 2.3. Research methodology and empirical findings, as well as managerial insights are discussed in Sections 4-5. In section 6 we present our concluding remarks.

2 Theoretical background

2.1 Uncertainty

Innovative design often encounters two sources of uncertainty, namely, *technological uncertainty* and *market uncertainty*. The former is defined as the degree of uncertainty in respect of the design solution that will be needed in a project [4]. The latter refers to the level of uncertainty that exists in the external environment, with regard to determining the requirements that customers have of the resulting product.

Furthermore, in terms of type of uncertainty, innovative design faces not only foreseen uncertainties identified and understood at the beginning of this process, but also unforeseen ones that cannot be identified during project planning in a rapidly changing environment [5, 6]. As to foreseen uncertainty, the design team can anticipate possible risks. However, in the case of unforeseen uncertainty, the design team is unable to figure out and articulate relevant events that could impact innovative design and their functional relationships [7].

Therefore, innovative design suffers different sources and types of uncertainty. Figure 1 depicts a simple view of the issue. On the X-axis is market uncertainty evolving towards unforeseen uncertainty to the right. Here, the existing market breaks down and new ones emerge only slowly. The Y- axis depicts technological uncertainty. Similarly, we move from foreseen technological uncertainty to unforeseen uncertainty. If we map various designs depicted in Figure 1, it appears that Zone Ⅰ corresponds to routine design. Zones II, Ⅲ and Ⅳ stand for different environments of innovative design with unforeseen marker uncertainty, technological uncertainty, and both, respectively.

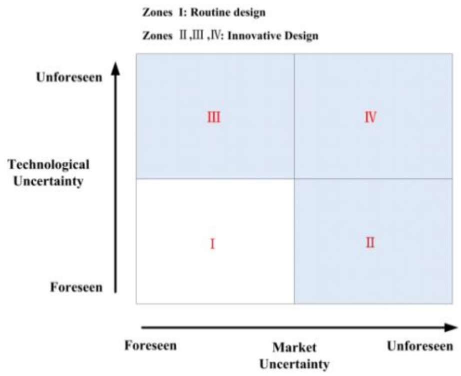

Fig. 1. Relationship between different uncertainties and designs

2.2 Control

As far as control is concerned, two types can be considered: *process control* and *output control* [1, 8]. Process control refers to a series of methods and activities adapted to design tasks; output control focuses on the result obtained relative to outputs goals and criteria. In this paper, six control practices based on these two aspects have been developed.

Process control can be represented by process structuration which refers to standardization. It consists of (i) *rigorous predefined design activities* that should be performed and (ii) *a rigorous operation sequence for these activities* [9]. Thus, a rigorous process structuration means that the design process should follow these predefined activities and their operation sequence.

Output control refers to gate evaluation whose criteria are applied to assess whether the project meets predefined goals or performance standards. Gate evaluation varies in terms of degree of rigor. Sethi and Iqbal (2008) identified the strictness, objectiveness and frequency of control as variables. Thus, we identified three control practices: (i) *strict evaluation criteria* (ii) *objective evaluation criteria* and (iii) *frequent evaluations*. Strictness is meant to ensure that all processes comply with the same criteria regardless of the nature of project. With respect to objectiveness, the evaluation criteria are not interpreted by different project managers and gate evaluators. Frequency emphasizes the number of evaluations within the whole process.

2.3 Flexibility

Flexibility is the ability to cope quickly with the environmental development by adapting to new technology and taking into account market information in order to satisfy the customer's needs with only limited penalty [2, 9]. A thorough review of the literature allows us to identify six flexible practices.

Parallel trials and iterative experiments. Parallel trials refer to several possible solutions tested simultaneously and selecting the best one *ex post*. This set of options is more likely to lead to the right solutions [10]. Additionally, iterative experimentations can generate information about how well the product functions from a technical perspective [11].

Early experiments involving customer. In addition to early experiments designed to solve a technological problem, experiments involving the customer provide the designer with information on those product features requested by customer [11].

Delaying concept freeze point. Delaying the concept freeze point probably permits the inclusion of new information fraught with technological opportunities and emerging customer requirements

Constructing a modular product architecture. Design modularity accommodates an early integration of the product design and changes in functionalities later in the process [11].

Exploitation of generation knowledge. Generation knowledge can facilitate these activities, allowing designers to find out an effective experiment strategy to match new pieces of information [2, 11]. In a highly uncertain environment, basic activities of innovative design consist in learning about new technological solutions applications.

Cross-functional and flat organization structure. When faced with the changes and requirements of possible creative product architectures, this structure can warrant openness and dynamic communication which in turn will lead to synchronized actions and greater collaboration between the different designers.

3 Research methodology

To deal with the research issues, a case-study approach is selected. A detailed and comprehensive view is needed and can be obtained by investigating ongoing projects.

(1) Sampling

To be able to compare different project practices coping with different uncertainties in a similar context, we focus on projects managed by the same company. Moreover, in order to observe the innovative design process, it is important to follow the project from beginning to end. Based on these criteria, we selected five innovative design projects carried out by a Chinese automaker from 2000 to 2010.

(2) Data collection

The method used for collecting data relies on interviews and document studies. Semi-structured and in-depth interviews were conducted with the main actors. In total, 18 interviews were made. The interviewees were asked to describe the way they coped with the uncertainties and the tools they used.

(3) Data analysis

Data analysis was in two steps. Firstly initial uncertainties in each project were assessed from the point of view of sources and types of uncertainty. The end result is given: (i) Projects 2, 3 and 4 suffered unforeseen technological uncertainty. In terms of market, the three projects supported foreseen market uncertainty. (ii) Project 1 mainly dealt with unforeseen market uncertainty. (iii) Project 5 had to deal with unforeseen technological uncertainty and market uncertainty. Secondly, the adoption of control practices and flexible practices in each project was investigated. These practices were evaluated on the basis of interviews with the main actors in each project. Table 1 summarizes data collection per interviews and document studies. The rows stand for project practices that support management control and flexibility respectively, while the right columns list the five cases. The empty circle (○) means that this case adopts this specific project practice.

Table 1. Project practices in case studies with respect to control and flexibility

	Project Practices	①	②	③	④	⑤
Control practices	• Rigorous predefined activities	○	○	○	○	○
	• Rigorous sequences of activities	○				
	• Strict evaluation criteria					
	• Objective evaluation criteria					
	• Frequent evaluation					
Flexible practices	• Parallel trial and iterative experiment		○	○	○	○
	• Early experiment involving customer	○				○
	• Delaying concept freeze point	○	○	○	○	○
	• Constructing a modular product architecture	○	○	○	○	○
	• Cross-functional and flat organization structure	○				○
	• Exploitation of generation knowledge		○	○	○	○

4 Empirical findings

4.1 Adopting control practices

The first empirical finding relates to the adoption of control practices for different kinds of uncertainties. In terms of process structuration, all projects maintained predefined design activities, but did not strictly follow the sequences of these activities except for Project 1. With respect to gate evaluation, irrespective of the kind of uncertainty, all projects avoided the strict and objective evaluation criteria and frequent evaluation.

4.2 Adopting flexible practices

The second empirical finding is that these projects adopt adequate flexible practices commensurate with the uncertainties encountered. This empirical result is listed in Table 2 and discussed below.

Table 2. Flexible practices in case studies with respect flexibility

	Technological uncertainty	Market uncertainty
Different Practices	Parallel trial and iterative experiment Exploitation of generation knowledge	Early experiment involving customer Cross-functional and flat organization structure
Common Practices	Delaying the concept freeze point Constructing a modular product architecture	

(1) Common flexible practices

According to Table 2, under any form of uncertainty, companies respond by delaying the concept freeze point and by constructing the modular product architecture. All projects prolonged the duration of the concept design stage to include information from different departments. However, constructing a modular product architecture may be the requisite for project practice with automakers. Given the high degree of sophistication of a new vehicle, even in low uncertainty projects, companies always perform design activities in accordance with the modular architecture.

(2) Technological uncertainty

All projects characterized by unforeseen technological uncertainty adopted (i) parallel trials and iterative experiments and (ii) the exploitation of generation knowledge.

Parallel trial and iterative experiment. Indeed, when exploring unknown technological terrain, multiple trials and iterative experiments do provide the best hope of getting a satisfactory solution [10], whilst allowing designers to "probe and learn" rather than invest in accurate preliminary analyses.

Exploitation of generation knowledge. We captured the amount of generation knowledge in each design team of Projects 2-5 by asking project managers to assess the proportion of designers with several generations of experience. The result shows that the proportion of designers with greater than two generations of experience exceeds the other categories.

(3) Market uncertainty

In that case, companies retained (i) early experiments with customer and (ii) cross-functional and flat organization structures.

Early experiment involving customer. When product specifications cannot be defined under unforeseen market uncertainty, innovative design should allow the evolution of customer needs to be tested continually as it rapidly evolves during the process [6].

Cross-functional and flat organization structure. Under unforeseen market uncertainty, the new information constantly provided by markets makes it impossible to define product concepts once and for all from the beginning.

5 Discussion and managerial implications

Firstly, according to these findings, all projects studied involving varying degrees of uncertainty followed the structured process, but avoided strict gate evaluation. Based on this, it is argued that by applying stricter, more objective, and frequent gate review criteria, the innovative design project will become less flexible. Thus, companies should refrain from frequently performing strict and objective gate review during this process. In addition, the result also shows that regardless of the kind of uncertainty suffered, each project still maintains similar control practices. Secondly, our empirical findings show that each project opted for not only similar control practices but also at least four flexible practices. In the event of unforeseen technological uncertainty, companies tend to rely heavily on parallel trials and iterative experiments and the exploitation of generation knowledge. In the case of unforeseen market uncertainty, the early experiment involving customers and a cross-functional and flat organization structure are much more effective.

Based on these results, it is the authors' opinion that process structuration and flexibility are compatible, and can therefore coexist within the process of innovative design. But the strict gate evaluation reinforces the inflexibility of innovative design. This has clear implications in practice. Companies should first diagnose the uncertainty profile of the innovative design project, and then simultaneously adopt adequate control practices and the corresponding flexible practices to cope with uncertainties inherent in innovative design.

6 Conclusion

This paper was to identify the relationships between different sources and types of uncertainty and particular project practices that support control or flexibility in innovative design. The first finding is that control and flexibility can coexist in this process. The second finding is about how to adjust practices to achieve an optimal balance between control and flexibility under different uncertainties.

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