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An approach to product development with scenario planning: The case of aircraft design

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ABSTRACT

Any product development process must start with a thorough analysis of the customer needs that the product is aimed at satisfying. This, however, is a challenging task, as customer needs tend to vary over time. As future is uncertain, a significant degree of uncertainty is attached to the anticipation of the future customer needs. This issue is especially relevant to manufacturers of aircraft, as extensive development costs and long product life cycles require a solid decision basis when initiating a new aircraft development program. Therefore, this paper is targeted at supporting the anticipation of future customer needs under uncertainty by proposing an approach to the derivation of robust design requirements through the consideration of alternative future scenarios. The approach is composed of several methodical steps that comprise the building of multiple scenarios, a scenario-specific analysis of the target market and customers, a description of distinct Concepts of Operations, and eventually a derivation of design requirements to form the aircraft specification. The paper ultimately portrays a case study that demonstrates the applicability and allows further evaluation of the proposed approach.

1. Introduction

Each product being offered on the market has to satisfy specific customer needs. If it cannot meet the customer needs, commercial success will be impossible, as there will be no customer willing to pay. Every product designer has to consider this fundamental law when designing a new product. Although this appears to be easily and intuitively comprehensible in theory, there are many examples of product launches that ultimately failed, as the products had not met the right customer needs.

An adequate example is the *Sonic Cruiser* of the American aircraft manufacturer Boeing. In March 2001, Boeing announced to the public that it was working on the development of this new aircraft type. With an entry-into-service planned in 2008, the Sonic Cruiser was intended to serve the long-haul air transport market by carrying between 200 and 250 passengers over 9000 nautical miles—a capability that conventional types of aircraft featured as well. However, the key benefit of the Sonic Cruiser concept was that it would be capable of traveling significantly faster than any other commercial transport aircraft. In fact, the Sonic Cruiser was planned to cruise at Mach 0.95, exceeding ordinary aircraft by around 15% in cruising speed.

Boeing argued that this capability would enable airlines to raise the number of flight rotations in their long-haul network by an even higher factor due to a higher degree of utilization of the aircraft (time in flight vs. time on the ground), while

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keeping fuel efficiency (i.e., the main driver of aircraft operating costs (Lee & Jin, 2013, p. 73; Swan & Adler, 2006, p. 106)) "comparable to today's best-performing widebody twin jets" (Gunter, 2002). Despite the promising future perspectives the Sonic Cruiser had in commercial aviation, Boeing ultimately decided to stop the entire program at the end of 2002. In fact, Boeing had not been able to attract a minimum required number of airlines that would be willing to buy the aircraft. After the 9/11 terrorist attacks, airlines struggled hard to recover from one of the worst crises ever seen in commercial aviation. As a result, they were looking for aircraft with a significantly improved fuel efficiency rather than high-speed planes. In other words, "the harsh realities of economics had killed off the fast aircraft concept in favor of low-cost efficiency" (Norris, 2003).

The example of the Sonic Cruiser reveals the high relevance of all tasks related to requirements elicitation and analysis during the initial phase of a product development process. In this context, emphasis should be on the fact that in comparison to other industries, aircraft manufacturers have to deal with a particularly challenging situation. First, because of the high degree of technical and organizational complexity involved in developing, operating, maintaining, upgrading, and scrapping aircraft, immense capital expenditures are necessary, leading to break-even points that only occur many years after the actual system development process has terminated (Altfeld, 2010). Second, the very long life spans of civil transport aircraft (see Jiang, 2013, p. 8 for a brief overview) plus extensive developing and operating periods require thoroughly prepared decisions well before the first airline actually buys and operates a new aircraft type. Third, the nature of aircraft design leads to the circumstance that the overall costs occurring during the life cycle of an aircraft are stipulated predominantly during the initial stages of aircraft development (Roskam, 1990, p. 10). In other words, if, for some reason, fundamental changes to the design of an existing aircraft become necessary, the costs for implementing these changes will be excessively high.

As a result, an aircraft designer must determine robust requirements before starting the actual design process (Strohmayer, 2001, p. 68). Although the designer may be able to identify the right design requirements of potential customers in the present, he must ensure that these requirements will be equally applicable in the future, even under varying external conditions (Kazmer & Roser, 1999, p. 22). Yet, while analyzing the status-quo situation may constitute a feasible task, uncertainty about the future makes it very difficult, if not impossible, to anticipate how the future, and with it the future customer needs, will evolve.

One option of handling future uncertainties is through Scenario Planning, i.e., by creating multiple, equally plausible pictures of the future (*scenarios*) in order to "characterize the range within which the future is likely to evolve" (Schoemaker, 1991, p. 550). Scenarios enable the consideration of a broad horizon of potential futures, which, in this way, capture future uncertainty, and may thus form the basis for the elicitation of robust design requirements. In this sense, unlike forecasts or trend extrapolations, scenarios neither represent states of nature nor predictions (Wack, 1985, p. 140), but stipulate possible future worlds within which the system under scrutiny will have to operate (O'Brien, Meadows, & Murtland, 2007, p. 211). In fact, for a few decades, various aerospace companies have been using Scenario Planning as a method to handle future uncertainty (Linneman & Klein, 1983, p. 98).

2. Scenario planning: Origins and techniques

2.1. Historical evolution

In the 19th century, German military strategists first employed the modern approach of handling uncertainty through the development of multiple future scenarios (Reibnitz, 1988). This reveals the original purpose of scenarios, which is to support strategic decision-making by preparing an organization (and especially its leaders) for a broad range of future eventualities. The actual beginning of the emergence of what is today known as *Scenario Planning* was only in the 1960s when two "geographical centers," one in the USA and the other one in France, fostered the development and use of the scenario methodology (Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005, p. 797). After more than 50 years of evolution, Scenario Planning has become today one of the most popular methods to handle future uncertainty. It is still being discussed intensely in the literature (van Notten, Rotmans, van Asselt, & Rothman, 2003, p. 423; Varum & Melo, 2010, p. 356).

In the aftermath of World War II, the US center of Scenario Planning evolved out of two particular needs of the US Department of Defense (DoD) (Raubitschek, 1988). It required (1) a method to "capture the reliable consensus of opinion of a large and diverse group of experts" and (2) "simulation models of future environments which would permit various policy alternatives and their consequences to be investigated" (Bradfield et al., 2005, p. 798). In the 1950s, the RAND Corporation developed and delivered techniques to address these two needs (Cooke, 1991). The circumstance that the development of both computers and game theory was at its initial stage at those times, and that the US military required the capability of war game simulation models, actually formed the basis for the creation of scenario techniques at RAND (Schoemaker, 1993, p. 195).

Initially, Herman Kahn, a leading researcher at RAND who focused on national defense and strategic planning, elaborated future scenarios for the US Air Defense System Missile Command, and, by doing so, actively contradicted the leading US military strategists who had a clearly different vision of the decades following World War II (Bruce-Briggs, 2005). By forming the well-known phrase *Thinking about the unthinkable*, he "demonstrated through a combination of facts and logic, that military planning tended to be based on wishful thinking rather than 'reasonable expectations.'" With his scenario-based approach, Kahn created a way of broadly exploring the future horizon, which is why scenarios that were created using Kahn's approach are sometimes referred to as "exploratory" (Godet, 2000, p. 11) or "explorative" (Börjeson, Höjer, Dreborg, Ekvall, & Finnveden, 2006, p. 727) (as opposed to "normative" scenarios (Godet, 2000, p. 11)). In this sense, Kahn employed the