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# Complexity in Technology Management: Theoretical Analysis and Case Study of Automobile Sector in Japan

KUMIKO MIYAZAKI and KYOICHI KIJIMA

ABSTRACT

In this article, a theoretical analysis on the various issues related to technology management under growing complexity is provided. We put forward a model classifying complex situations, including technology management on a two dimensional space, i.e., object-related and human-related complexity. The point on the grid depends on factors related to external and internal complexity as well as conflict of interests by the actors. By analyzing complexity involved in technology management using this framework, we may extract crucial dimensions of technology management. Finally, we provide a case study on the strategies of the Japanese automobile sector, by mainly focusing on the technological perspective. The chosen companies were Toyota, Nissan, Honda, Mitsubishi Motors, and Mazda. The factors related to the growing complexity in technology management were both technological and non-technological in nature. An analysis of the rate and direction of competence building based on patent data confirmed that the companies have been building competences in key areas related to safety, environment, and driving comfort over a decade to meet changing social expectations and environmental pressures. The analysis shows that the automobile sector has been undergoing radical changes due to growing internal and external complexity. © 2000 Elsevier Science Inc.

## Introduction

Many industries are undergoing radical transformations due to mega-competition taking place on a global scale. Technological changes are becoming primary drivers, creating ambiguity in the definition of domain of businesses. Furthermore, the speed at which changes are taking place is putting pressure on firms to act with increasing timeliness. But, growing complexity due to a variety of reasons is a major cause of concern for decision-makers in industries as well as policy makers. Technology strategy or technology management under growing complexity must be put on the agenda for decision-makers. At the firm (company) level, strategic technology management must deal with a high level of uncertainty which is not only technical in nature. It will have to take into account a range of factors, such as techno-paradigm shifts, growing socio-economic and external pressures for change, management of diverse range of knowledge

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bases, and a strong linkage with other areas of competence in the firm. In addition, consideration for global standards and intellectual properties becomes a pressing agenda. In the following section, we discuss the notion of complexity and propose a model classifying complex situations in two dimensions, taking into account various factors such as uncertainty, complexity, and conflict of interests. Finally, we discuss the case of the automobile sector in Japan, mainly focusing on complexity from the technical perspective.

## Technology Management as Complex Decision Situation

Technology management, whether it is at the firm level or national level, is certainly a complex decision/strategy-making situation involving participants associated with a variety of interests. In particular, complexity involved in technology management has been growing so rapidly recently that we are inevitably required to cope with it more adequately. On the other hand, one of disciplines that has focused on the concept of complexity is systems science which is claimed to be a discipline tackling and dealing with complexity since its emergence (see [1–2]). In this section, we will briefly discuss what we mean by complexity from a systems scientific viewpoint, since we believe that such a general but deeper understanding on complexity should provide an essential starting point for analyzing technology management. Unfortunately, there has been virtually no sufficiently comprehensive study that attempts to capture the general characteristics of complexity. Indeed, complexity is perhaps as important a concept for systems science as the concept of a system. It is also a difficult concept, because it has many kinds of interpretations and various specific meanings of complexity have been proposed and discussed on many occasions (refer to Klir [3], for example). The reason for this situation is well expressed by Casti [4]:

> The notion of system complexity is much like St. Augustine's description of time: "What then is time [complexity]? If no one asks me, I know. If I wish to explain it to someone that asks, I know not." There seems to be fairly well developed intuitive ideas about what constitutes a complex system, but attempts to axiomatize and formalize complexity all leave a vague, uneasy feeling of basic incompleteness, and a sense of failure to grasp the important aspects of the essential nature of the problem.

The concept of complexity has many facets, while at the same time it is associated with some general properties that remain invariant. According to a common dictionary, "complexity is the quality or the state of being complex" (*Webster's Third International Dictionary*). That is, complexity has the following characteristics:

1. Having many varied interrelated parts, patterns, or elements, and consequently, hard to understand fully.
2. Being marked by an involvement of many parts, aspects, data, notions, and necessitating earnest study or examination to understand and cope with.

We should notice that this basic characterization of complexity does not contain any qualification regarding the kind of entities to which it is applicable. Hence, it can be applied to any kinds of entities, material or abstract, tangible or intangible, natural or man-made, products of art or science. It is quite natural to apply the concept of complexity to decision situations.

From the basic characterization of complexity we can see that for analyzing complexity we need at least to include the idea not only of (1) the number of parts; (2) the number of relationships between the parts; but also of (3) notions/perceptions. Items 1 and 2 are concerned with the object and relations, while Item 3 may be considered

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