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An integrated service-device-technology roadmap for smart city development

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ABSTRACT

Firms and other organizations use Technology Roadmapping (TRM) extensively as a framework for supporting research and development of future technologies and products that could sustain a competitive advantage. While the importance of technology strategy has received more attention in recent years, few research studies have examined how roadmapping processes are used to explore the potential convergence of products and services that may be developed in the future. The aim of this paper is to introduce an integrated roadmapping process for services, devices and technologies capable of implementing a smart city development R&D project in Korea. The paper applies a QFD (Quality Function Deployment) method to establish interconnections between services and devices, and between devices and technologies. The method is illustrated by a detailed case study, which shows how different types of roadmap can be coordinated with each other to produce a clear representation of the technological changes and uncertainties associated with the strategic planning of complex innovations.

1. Introduction

Technological innovations, and changes in globally competitive business environments, affect both firms' short-term performance and long-term sustainability. In such a context, decisions about which technology to apply are critical to many firms' competitive advantage. In particular, when future directions and options in technology are obscure and uncertain, it becomes more important to an enterprise to formulate an appropriate technology strategy to support its planning for, and response to, future technical developments [38,51,60,64]. Technology roadmapping (TRM), a strategic decision process framework that supports enterprise innovation activities, has attracted the interest of an increasing number of academics and practitioners, and has been applied in many different industrial sectors and organizations [44]. A study of U.K. manufacturing firms in 2001 indicated that at that time 10% of medium-to-large companies had implemented TRM, with 80% of those companies using the approach more than once or continuously, with exponential growth in interest in the method since the early 1990s [6]. As well as responding to market needs, roadmapping is used to support the generation of new ideas for product development, derived by predicting future technological trends and identifying potential technologies [23,45].

In recent years, a trend towards servitization has also caught the attention of academia, practitioners and governments [10,63,73,74]. This term, initially proposed by Vandemerwe and Rada [79], has grown into a distinct concept of service science, which has consolidated itself as a new academic discipline, providing impetus to developments in industry [5,53]. Service science provides a conceptual foundation for service-oriented business models, promoting the development of flexible and robust

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IT-based business models capable of responding efficiently to diverse customers' demands. In these terms, servitization is intended to enhance an organization's ability to add value to new products by strengthening their planning processes, integrating these with the delivery of services and generation of value in consumption or use [5]. For instance, the 'smartphone' and its software applications are aligned in terms of the combination of technologies, products and services they offer (and depend on) through a concept of service provision that prioritizes the creation of value to end-users [80].

Despite this emerging trend, research in technology roadmapping has tended to focus on specific examples of industrial technology deployment and product development, paying much less attention to the application of roadmapping as a paradigm to the service area [76]. This paper, therefore, highlights the importance of having an integrated roadmapping process as a holistic framework for supporting improved decision-making. Further, it proposes an integrated roadmapping process that is systematic and standardized in order to coordinate the development of integrated product and service strategies. The proposed roadmapping process has been applied to a smart city development project in order to demonstrate and validate the utility and benefits of the methodology. The process specifically aims to forecast the development of future service-oriented smart devices and technologies, and thus to propose an integrated process for roadmapping. The paper adopts the QFD (Quality Function Deployment) method to establish interconnections between services and devices for infrastructure, and between devices and technologies serving a 'smart city'. The method is particularly useful in coordinating and adjusting existing service, device and technology roadmaps and lends itself to use as a communication tool to support smart city development.

The paper contributes to broadening our understanding of the technological impact of likely future technologies and technology-based services on IT-based smart device development. The paper is organized as follows. Section 2 reviews the history of the concept of TRM with reference to the literature, establishing a conceptual foundation for roadmap development processes, and identifying different types of roadmaps. Based on this analysis, a distinct methodology is proposed in Section 3, backed up by a detailed case study. Finally, conclusions are presented in Section 4, recommending areas where further research would be beneficial.

2. Literature review

2.1. Smart city service development

The smart city concept originated from that of the 'information city', and incrementally evolved to an idea of an ICT-centered smart city. The concept of the smart city has six main dimensions: a smart economy, smart mobility, a smart environment, smart people, smart living, and smart governance. It is defined as being "*smart when investments in human and social capital and traditional* (*transport*) *and modern* (*ICT*) *communication infrastructure fuel sustainable economic development and a high quality of life*, *with a wise management of natural resources*, *through participatory governance*" [27]. The smart city concept can be distinguished from other similar ideas such as the digital city or intelligent city in that it focuses on factors such as human capital and education as drivers of urban growth, rather than singling out the role of ICT infrastructure.

Since the term 'ubiquitous' in this context is derived from 'ubiquitous computing' [82], various definitions of Ubiquitous City have been put forward by previous studies, in conjunction with terminology associated with the smart city concept. An 'early stage' smart city can be defined as one that provides combined services via integration of IT and construction industries [37]; while highly advanced future cities will apply IT infrastructure and associated technologies and services to multiple components of itself. Lee et al. [49] define a smart city in terms of the convergence of IT services within an urban space, such that the city's citizens may access smart services regardless of time or place. This will enhance the city's competitiveness and its citizens' quality of life. The Korean Ministry of Land, Transportation & Maritime Affairs have proposed a more technically-oriented definition [57], as a city that is managed by a network and which supplies its citizens with services and content via the network using both fixed and mobile smart city infrastructure, based on high-performance ICT. In summary, a smart city provides its citizens with services via its infrastructure based on ICT technologies. This definition highlights the importance of identifying and planning for future technologies that may serve future city demands, since it is almost certain that the smart city industry will grow. In this way, evolving smart city technology is a fundamental component of the infrastructure underpinning the delivery of smart city services.

Additionally, other countries such as the U.S., Europe and Japan are also driving R&D initiatives and implementing smart city technologies and applications, with the primarily aim of addressing current urban problems such as energy shortages, traffic congestion, inadequate and poor urban infrastructure, health and education. In particular, the European Union (EU) is investing in efforts to put in place smart city strategies for metropolitan city regions such as Barcelona, Amsterdam, Berlin, Manchester, Edinburgh and Bath [58]. Other international cities such as Dubai, Singapore, San Francisco, London and Hong Kong are also following a similar approach, aiming to improve quality of life for citizens and economic growth for industries within the city [49].

2.2. Technology roadmapping

Although there are various definitions of TRM, technology roadmaps may be also be defined with reference to the roadmapping *process*—the set of activities required to develop a roadmap. Roadmapping has been described as a process that contributes to the integration of business and technology, facilitating the formulation of both short- and long-term technology strategies based on the interaction between products and technologies over time [28]. Other definitions of the roadmapping process describe it as a demand-driven technology planning process serving market needs [19,22,32], a communication/knowledge management tool supporting strategic decision-making [83] and as a collective approach to developing a strategy in which the integration of science/technological considerations represents a valuable input into product and business planning [26]. In summary,