# Architecting Absorptive Capacity: Systems Framework for Open Innovation in Japanese Enterprises

by

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ABSTRACT

As Japan faces challenges in maintaining its global innovation leadership, this thesis explores the potential of collaborative R&D between large Japanese firms and external actors to drive innovation through open innovation practices. The research focuses on absorptive capacity - defined as an organization's ability to recognize, assimilate, and utilize external knowledge - as a critical factor in successfully implementing outside-in open innovation. To address the gaps between academic research and real-world implementation of open innovation, the thesis develops a systems framework for understanding and designing absorptive capacity in the context of large Japanese firms. Using a systems architecture approach and conducting case studies of five Japanese companies recognized as high-performing innovators, the research identifies four main capabilities constituting absorptive capacity: management, recognition, assimilation, and exploitation. The framework maps these capabilities to specific architectural decisions and options, linking the theoretical understanding of absorptive capacity as a system to practical choices in designing a firm's absorptive capability. The significant influence of management capability on recognition and assimilation capabilities, as well as organizational structure and needs assessment in driving absorptive capacity as architectural decisions, are also revealed. This thesis is expected to contribute to both academic discourse and practical implementation, extending previous perspectives on absorptive capacity and providing actionable guidance for designing and managing open innovation initiatives for large Japanese firms and policymakers. While limitations of this research include the potential lack of comprehensiveness in architectural decisions and the subjectivity in case study selection, this thesis will serve as a foundation for future studies on establishing Japan's competitive innovation ecosystem on a global scale.

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DISCLAIMERS

This thesis is intended for academic purposes. The views and opinions expressed are those of the author and do not represent any organization's opinions, intentions, or other information. The author is not responsible for using the information in this thesis.

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# 1. Introduction

## 1.1. Status Quo of Japan's Innovation

More than twenty years ago, Japan stood at the forefront of global innovation, leading on various technological and economic fronts. However, many Japanese companies have recently faced severe challenges in overcoming the "Innovation Dilemma." As they focused on meeting existing customer needs with increasingly advanced products and services, they often failed to adapt to disruptive market changes led by emerging competitors. As a result, despite continuous innovation efforts, Japan has struggled to maintain a dominant position in significant global markets. This has resulted in a reduced global presence, challenging its status as a leader in innovation.

The Global Innovation Index (GII), one of the most authoritative indicators for assessing a nation's innovation published by the World Intellectual Property Organization, has proven this trend. In 2007, Japan debuted impressively at the 4th position, but this high standing was not sustained, as it witnessed a gradual decline, eventually falling to 13th among 132 economies in 2023[1], [2]. The GII considers a wide range of factors based on two dimensions: innovation inputs and innovation outputs. Innovation inputs refer to institutions, human capital and research, infrastructure, market sophistication, and business sophistication. These factors provide an understanding of the elements that facilitate innovative activities within a country. Innovation outputs measure the actual results of innovation activities within a country, including knowledge and technology outputs as well as creative outputs. In 2023, Japan ranks highest in market sophistication (8th), business sophistication (11th), and infrastructure (13th) but lowest in creative outputs (25th), institutions (21st), and human capital and research (18th)[1].

As the other indicator, the World Economic Forum measures the Global Competitiveness Index (GCI) to determine each country's productivity factors, and a vital subcategory of the GCI is the innovation score, which assesses a nation's capacity for innovation. Japan's ranking in the innovation score has seen a notable shift over the years: From 2010 to 2016, Japan consistently ranked between 4th and 5th place, but since 2017, Japan has experienced a decline, falling to 7th or lower[3], [4], [5], [6], [7], [8], [9].

In addition, Boston Consulting Group, which has published annual reports since 2003 to identify the world's most innovative companies by examining how innovative companies drive innovation engines based on total shareholder return values, shows that only three Japanese companies (SONY Group Corporation, Hitachi, Ltd., and Nippon Telegraph and

Telephone (NTT) Corporation) are ranked among the top 50 in 2023[10]. This survey corresponds with the decrement in the total market value of Japanese companies. While more than half of the top 50 valuable companies in the world were Japanese in 1989, Toyota Motor Corporation is the only Japanese one in 2023[11].

In summary, all of these rankings suggest the necessity of studying measures to revitalize the Japanese economy through innovation creation, leading to the motivation of the thesis.

## 1.2. Innovation and R&D

The Organisation for Economic Co-operation and Development (OECD) Oslo Manual 2018 provides comprehensive guidelines for understanding and measuring innovation and related activities[12]. According to the manual, "innovation" and "innovation activities" are defined as follows: An "innovation" is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). "Innovation activities" include all developmental, financial, and commercial activities undertaken by a firm that is intended to result in innovation for the firm. On the contrary, the OECD's Frascati Manual 2015 defines research and development as follows: "Research and development (R&D)" comprises creative and systematic work undertaken in order to increase the stock of knowledge and to devise new applications of available knowledge[13].

Based on these definitions, it seems reasonable enough to assume that R&D provides the crucial foundation for innovation in companies and organizations of all kinds. The new knowledge, groundbreaking technologies, and powerful capabilities produced through meticulous and sustained R&D efforts enable the development of innovative new products, services, and business methods that can disrupt and transform entire industries. In other words, R&D could play a critical role in innovation activities by focusing on inventing new technologies and processes.

## 1.3. Critical Players for Innovation and R&D in Japan

Who are the key players in creating innovation in Japan? It is generally accepted that small companies, including startups, are generally regarded as the more innovative ones due to their agility and lack of constraints, but Boston Consulting Group's report on innovative companies shows some data that the innovation success rates for small companies are not statistically higher than those for large firms. Adversely, they imply that since larger companies can fund investments internally, they have an innovation advantage, and company size is not necessarily a barrier to innovation[14].

The same is true for R&D: According to the OECD Research and Development Statistics, in major countries such as the United States, the United Kingdom, France, Germany, and China, firms spend much more on R&D than government institutions and academia (firms spend 65-80%). Japanese trends are the same as those of these countries, where the proportions spent by business, academia, and government institutions are 70%, 20%, and 10%, respectively[15]. Furthermore, compared with the other countries, large companies in Japan account for a high share of the private sector R&D expenditures, and small and medium-sized enterprises (SMEs) and start-ups account for a low share of R&D expenses, as summarized in Table 1-1[16]. Therefore, it seems plausible that large Japanese companies and their R&D capabilities are essential to stimulate innovation in Japan.

**Table 1-1 Share of total R&D expenditures depending on company sizes**
(from OECD Research and Development Statistics[16])

| Country | Year | Large Companies Share (%) (more than 500 employees) | SMEs Share (%) (less than 250 employees) |
|---|---|---|---|
| Japan | 2020 | 90.1% | 5.5% |
| Germany | 2019 | 86.7% | 8.8% |
| US | 2020 | 84.4% | 11.7% |
| Korea | 2020 | 71.1% | 24.7% |
| UK | 2013 | 66.5% | 22.9% |
| France | 2017 | 64.8% | 27.0% |

## 1.4. Problems of Japanese Large Companies

Several types of research suggest critical differences between large firms that can generate innovation and others. The Bank of Japan's 2018 report indicates that R&D in Japan does not boost productivity growth for the following reasons: Japanese companies' R&D investments do not meet consumers' needs, and R&D in Japan is likely to focus on incremental improvements rather than creating innovative products. They also point out that Japanese companies are fixated on their internal R&D and do not collaborate with other companies and universities to innovate[17].

In 2019, McKinsey and Company conducted a questionnaire-based survey to identify the factors that contribute to the R&D performance of Japanese companies[18]. The results suggest that Japanese R&D organizations face five challenges: digitalization, agility, talent acquisition, effective portfolio, and leveraging external sources. Despite global efforts, few have seen sustained improvements from digital initiatives due to legacy systems and resistance to new processes. Agility is limited, with a slow adoption of agile methodologies potentially caused by cultural and hardware project complexities. Japan is also experiencing a talent crisis, struggling to attract and retain top engineering talent amidst demographic shifts and increasing demand for digital skills. Regarding R&D effectiveness, only a third of companies manage their project portfolios efficiently, often prioritizing short-term performance. Moreover, less than half of the companies effectively build innovation ecosystems, hindering collaborative innovation efforts. They suggest that these challenges underscore the need for Japanese companies to adapt and modernize their strategies to maintain global competitiveness.

In 2020, the Japan Management Association's "CTO Survey 2020" also lists the challenges facing the R&D department as perceived by each company's Chief Technology Officer (CTO). The most common response is establishing R&D topics in line with management strategy (54.1%), followed by increasing the commercialization rate of R&D results (45.5%), promoting open innovation (35.7%), coordinating R&D and marketing (31.1%), and narrowing R&D topics (28.3%)[19]. Based on all three surveys, it seems notable that collaborative innovation and external partnerships are indispensable for improving R&D performance.

## 1.5. Public Treatments for Innovation

In general, as described, innovation drives economic growth, which is one of the significant indicators for measuring a country's competitiveness in the world. It is simply why governments have enough incentives to encourage innovation through public policies. Neubig et al. (2016) argue more in detail that innovation is inherently uncertain, leading to the following reasons why public policy is essential for fostering innovation[20]: First, the concept of market failure can justify government intervention in business R&D. The knowledge generated through R&D is often non-rival and partially non-excludable, leading to spillovers where other firms or the broader society benefit without contributing to the costs. This phenomenon typically results in underinvestment in R&D from a societal perspective, as firms are reluctant to invest in activities where they cannot fully capture the resulting benefits. Public policy interventions, therefore, aim to correct this imbalance by providing financial incentives, ensuring that firms' investment in innovation is closer to the socially optimal level. Second, the role of government support in encouraging firms to invest in knowledge creation is crucial. Businesses, especially in research-intensive industries, often rely on fundamental science and ideas originating from government or publicly-funded institutions. However, the leap from basic research to marketable innovation necessitates additional support. Public support could be incentives designed to make innovation financially feasible and attractive for businesses, countering the inherent risks and uncertainties associated with R&D. Thus, government incentives can address market failures and financial challenges faced by firms engaged in R&D by mitigating inherent risks and barriers in the innovation creation process.

## 1.6. Research Motivation

To summarize the previous sections, the motivation for this research stems from the current state of innovation in Japan, its challenges, and the potential role of collaborative R&D in large Japanese firms as critical actors for innovation, as well as public policy perspectives. Schaede (2020) examines Japan's transformation and how the country has adapted to new business architectures and corporate strategies. She discusses the restructuring of Japanese companies for the adoption of modern economic challenges and opportunities and explores the potential of the openness of large Japanese companies to adopt new technologies from startups, demonstrating a shift from traditional business models to more dynamic and innovative approaches[21]. Therefore, this research aims to explore the main research question:

*Q. What are the critical levers to activate collaborative R&D activities in large Japanese enterprises?*

Understanding these aspects will be essential for proposing solutions to revitalize the Japanese economy through enhanced innovation and R&D efforts. Regarding the public policy perspective, the findings from the analysis based on this research question will provide insights that can inform implications. It is important to note that the subsequent literature review will also investigate the public policy perspective, which is expected to be a crucial element in considering policy implications. These policy implications will be summarized after obtaining the answers to the primary research question.

## 1.7. Thesis Structure

The thesis is organized as follows: Chapter 1 presents the research background and motivation with the main research question that forms the core of the thesis. Chapter 2 provides an unbiased literature review to introduce the concept of open innovation, as well as its history and examples of implementation. This chapter also provides an overview of innovation policy from an open innovation perspective. Chapter 3 narrows the research question with narratives of research approaches based on the results of Chapter 2 to clarify the novelty and significance of the thesis. Chapter 4 defines the research methods and processes to address the research question and validate the results of the analysis. Chapter 5 presents the analysis and findings through system architecture and systemic case studies to address the research question. It explores the critical levers that activate collaborative R&D activities and open innovation in large Japanese companies. Chapter 6 provides a discussion of the findings, focusing on the validation of the hypotheses. It also includes implications for enterprises and policymakers, research limitations, and future work based on the findings of the previous chapters. Finally, Chapter 7 concludes this thesis by providing a concise summary of the entire research, highlighting the key findings, contributions, and overall significance of the study in the context of revitalizing the Japanese economy through enhanced innovation and R&D efforts.

# 2. Literature Review

## 2.1. Overview

This chapter provides a brief overview of the evolution of innovation theory and practice, focusing on the significant shifts from closed to open innovation models and the role of policy in fostering innovation in the 20th and 21st centuries. Section 2.2 outlines the foundational theories of innovation, emphasizing the role of innovation in economic change, the importance of customer creation in business management, and the concept of disruptive innovation. Section 2.3 introduces Chesbrough's concept of open innovation and contrasts it with the closed innovation model that dominated the 20th century. It shows how the changing business environment, characterized by shorter product life cycles and increased development costs, necessitated a more collaborative approach to innovation. Section 2.4 delves into the academic exploration of open innovation, detailing various typologies, phases, and performance metrics associated with open innovation. It also discusses the challenges and trade-offs of open innovation and the critical concept of absorptive capacity, which is essential for effectively leveraging external innovation. Section 2.5, which focuses on practical applications, presents case studies from companies such as Procter & Gamble and General Electric that illustrate the implementation and results of open innovation strategies. It also examines the diffusion of open innovation practices through questionnaire-based surveys, highlighting organizational and strategic barriers to adoption. Section 2.6 examines the role of policy in fostering innovation, detailing instruments such as R&D subsidies, tax incentives, and platform strategies that governments have used to promote open innovation. In summary, this chapter aims to provide a structured understanding of the major developments in open innovation theory, its practical application by firms, and the instrumental role of policy in open innovation through literature reviews.

## 2.2. History of Innovation Theory in the 20th Century

Schumpeter (original work published in 1912) identifies "innovation" as the critical dimension of economic change and defines it as the discontinuous combination of production factors such as product, production method, distribution channel, source, and organization[22]. Then, Drucker (original work published in 1954) applies the theory of innovation to business management, explaining that the primary objective of a business is not the pursuit of profit but the creation of customers who will pay for products and services and that "innovation" is the most fundamental activity of a business in creating customers[23]. He also outlined seven sources as opportunities for innovation creation: unexpected events, incongruities, process needs, changes in industry or market structure, demographic changes, changes in human perception, new knowledge based on scientific or non-scientific advances, explaining that companies that cannot adapt to these factors will decline[24], [25]. Christensen (original work published in 1997) discusses how emerging companies can displace market leaders through an innovation dilemma; that is, focusing on sustaining innovation and responding to customer feedback, an established company often falls into the trap of over-engineering[26]. Startups, on the other hand, introduce disruptive innovations that, while initially inferior, gain widespread market recognition due to their unique features[26]. This concept of the "Innovator's Dilemma" shows worldwide changes in the industry and market and problems with the mechanisms of innovation creation in companies and organizations in the 21st century.

## 2.3. Rise of Open Innovation

At the beginning of the 21st century, Chesbrough (original work published in 2003) defined the new concept of "open innovation" as the intentional and proactive use of the flow of internal and external technology, ideas, and other resources to foster innovation within the organization, thereby increasing the market opportunities for the deployment of internally generated innovations outside the organization[27]. It was contrasted with the concept of "closed innovation," which was an entire process, including R&D and commercialization, vertically integrated within an organization with only limited external interactions[27], [28]. The concept of "closed innovation" worked well enough in many leading industrial companies in the 20th century because it was considered the most efficient way to invest heavily in internal R&D and skilled human resources, such as General Electric's drastic growth and Dupont's establishment of centralized research labs. However, by the end of the twentieth century, product lifecycles were becoming shorter, the cost of technical development in the marketplace was increasing, and the flow of knowledge was being activated by the growth of knowledge workers and the activities of private venture capital, all of which affected the internal innovation cycles within a firm. These external factors allowed companies to "commercialize external (as well as) internal ideas by deploying outside (as well as in-house) pathways to the market," which was the rise of "open innovation." Table 2-1 shows the contrasting principles of closed and open innovation[28].

**Table 2-1 Contrasting principles of closed and open innovation** (from Chesbrough[28])

| Closed Innovation Principles | Open Innovation Principles |
|---|---|
| The smart people in our field work for us. | Not all of the smart people work for us so we must find and tap into the knowledge and expertise of bright individuals outside our company. |
| To profit from R&D, we must discover, develop and ship it ourselves. | External R&D can create significant value; internal R&D is needed to claim some portion of that value. |
| If we discover it ourselves, we will get it to market first. | We don't have to originate the research in order to profit from it. |
| If we are the first to commercialize an innovation, we will win. | Building a better business model is better than getting to market first. |
| If we create the most and best ideas in the industry, we will win. | If we make the best use of internal and external ideas, we will win. |
| We should control our intellectual property (IP) so that our competitors don't profit from our ideas. | We should profit from others' use of our IP, and we should buy others' IP whenever it advances our own business model. |

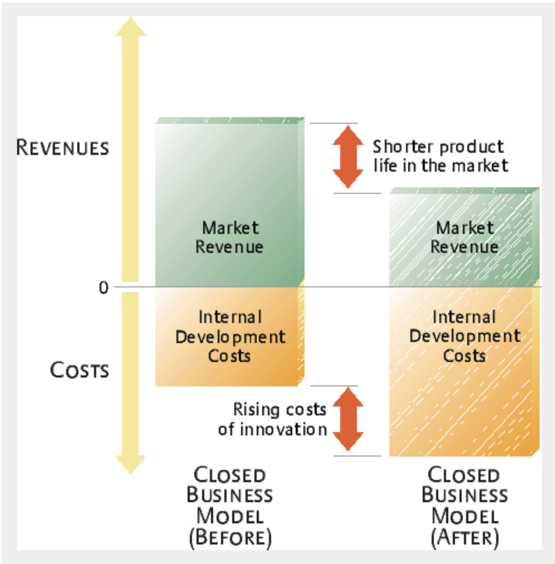


**Figure 2-1 New business model of open innovation** (from Chesbrough[29])

Chesbrough (2006) reported the concept of openness in a business model whose function is to create value and capture a portion of that value across a range of activities from production to customer delivery and to establish a competitive advantage in those activities. Open business models leverage external ideas and allow companies to use their essential resources not only in their own operations but also in other companies' businesses[30]. In addition, as technology development costs rise and product life cycles shorten, openness between different companies can better commercialize specific ideas and technologies, thereby addressing inefficiencies in the market for innovation. Figure 2-1 shows that the bar chart depicting the open business model can increase revenues and reduce costs by using external ideas and technologies in internal product development and allowing internal intellectual property to be commercialized externally[29].

O'Reilly and Tushman (original work published in 2016) proposed the concept of organizational "ambidexterity" as the key to resolving the innovator's dilemma: how companies can maintain competitiveness in their core markets while also succeeding in new domains[31]. In ambidexterity management, it is necessary to advance both the "deepening of knowledge" in existing core businesses and the "exploration of knowledge" in developing new businesses simultaneously. Companies that improve performance generally tend to advance the exploration of knowledge, while typical companies, as their performance matures, tend to lean towards deepening knowledge to strengthen existing businesses. The reason is that deepening knowledge in existing businesses has a higher probability of success than exploring knowledge through research and investigation for new business ventures. However, the more successful a company is in its existing business, the more it tends to lean towards deepening knowledge, leading to a situation where innovation does not occur[31]. The concept of "ambidexterity" management could be regarded as another perspective of the open innovation concept.

## 2.4. Open Innovation History in Academic Research

For around thirty years since Chesbrough defined open innovation, many articles have contributed to deepening our understanding of the concept. This section provides an overview of major open innovation empirical research mainly based on academic journals. First, it outlines the three types of open innovation processes (2.4.1): (outside-in, inside-out, and coupled), and the four-phase model (2.4.2): (obtaining innovations, integrating them through building capabilities, commercializing resulting products/services, and interacting via co-creation). Next, it highlights the performance metrics of open innovation effects (2.4.3) and tradeoffs between openness and performance (2.4.4). Also, it summarizes the absorptive capacity concept, the ability to recognize and assimilate external knowledge, which is critical for a firm to benefit from open innovation. The absorptive capacity involves capacities to recognize, assimilate, and exploit external innovations (2.4.5). Finally, it notes the research on open innovation failures, such as deficiencies in strategy, organizational structure, intellectual property management, resources, collaboration skills, and external alignment cause failures (2.4.6).

### 2.4.1. Typology of Open Innovation

Gassmann and Enkel (2004) identified three principle open innovation processes as follows based on their empirical analysis of more than one hundred companies[32]:

- **Outside-in Process:** To augment a company's knowledge by incorporating inputs from suppliers, customers, and external sources, thereby enhancing its capacity for innovation.
- **Inside-in Process:** To leverage ideas in various markets by selling intellectual property and expanding technology reach, achieved by transferring ideas externally.
- **Coupled Process:** To intertwine the outside-in and inside-out methods, engaging in partnerships with synergistic companies where reciprocal exchange is vital for success. This approach necessitates continuous consideration across the entire value chain and adopting novel business models to support this fundamental process.

Moreover, they identified the detailed work typologies for each innovation process, including their characteristics, as summarized in Table 2-2. The "Outside-in Process" can be accomplished through methods such as customer and supplier integration, innovation clusters, cross-industry innovation, purchasing intellectual property, and global knowledge creation. In particular, suppliers can contribute to product and project success by adding their innovation capabilities, and successful supplier involvement offers benefits ranging from the early identification of technical problems to better resource utilization, reduced risks, improved product features, and shorter time-to-market as shown in the example of IBM and DaimlerChrysler. As for the "Inside-out Process," licensing intellectual property (IP) and transferring technology to other companies, aiming to generate profits outside the company's traditional boundaries, are the key components. Outsourcing and licensing allow access to new knowledge areas, flexibility, concentration on core competencies, faster market entry, and cost-sharing. This process is exemplified in pharmaceutical industries, where drugs developed for one purpose succeed in other applications, like Botox. The "Coupled Process" combines the outside-in and inside-out processes, focusing on gaining external knowledge and bringing ideas to market through strategic networks and cooperation with other companies. This approach requires a balanced exchange of knowledge between parties. It often involves joint ventures, suppliers, customers, and research institutes. These collaborations result in mutual learning context-specific knowledge and can improve competitive positions and minimize risks. It is particularly effective for companies seeking to set industry standards or achieve increasing returns by exploiting their innovations across various sectors, as shown in the examples of Canon and Hewlett-Packard's partnership in printer development and Boeing's collaborative approach in seven countries[32].

**Table 2-2 Characteristics and company examples of each innovation process**
(from Gassman and Enkel[32])

| Process | Characteristics | Examples |
|---|---|---|
| Outside-in Process | - low tech industry for similar technology acquisition<br>- act as knowledge brokers and/or knowledge creators<br>- highly modular products<br>- high knowledge intensity | - Earlier supplier integration<br>- Customer co-development<br>- External knowledge sourcing and integration<br>- In-licensing and buying patents |
| Inside-out Process | - (basic) research-driven company<br>- Objectives like decreasing the fixed costs of R&D, branding, setting standards via spillovers | - Bringing ideas to market<br>- Out-licensing and/or selling IP<br>- Multiplying technology through different applications |
| Coupled Process | - standard setting (pre dominant design)<br>- increasing returns (mobile industry through multiplying technology<br>- alliance with complementary partners<br>- complementary products with critical interfaces<br>- relational view of the firm | - combining outside-in and inside-out processes<br>- integrating external knowledge and competencies and externalising own knowledge and competencies |

Chesbrough and Brunswicker (2014) refined the typology into modes of open innovation based on a survey of 125 large companies in the United States and Europe with annual revenues of more than $ 250 million. They distinguished between inbound (Outside-in) and outbound (Inside-out) open innovation, depending on whether the knowledge flow was inbound or outbound and whether or not some form of compensation was involved. The categorization created a four-part matrix for classifying open innovation based on inbound or outbound and monetary or nonmonetary, and they found that inbound open innovation was much more common than outbound open innovation by an average of 27 percent[33].

### 2.4.2. Four Phases of Open Innovation

As described in the previous section, inbound (outside-in) open innovation is more embedded in organizations than outbound (inside-out) innovation, and the scope of research also tends to focus more on outside-in and coupled processes than on inside-out open innovation. For example, Mazzola et al. (2012) found from a literature review on open innovation published from 2003 to 2012 that less than 10% of the studies addressed outbound activities[34].

Regarding "outside-in" and "coupling" open innovation, while various researchers have made models to identify their overview of how companies obtain benefits from external functions through open innovation, West and Bogers (2014) conducted the overall analysis of 291 articles from the top 25 innovation journals and proposed the four phases: obtaining, integrating, commercializing, and the interaction between firms and their collaborators as shown in Figure 2-2[35].

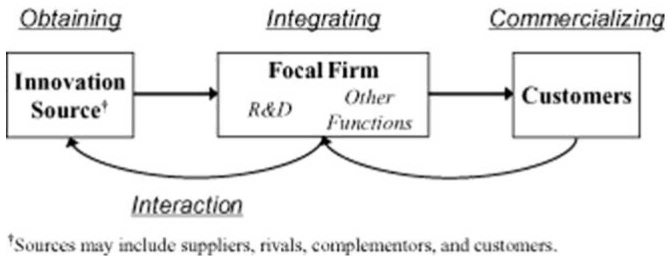


**Figure 2-2 Process model for leveraging external sources of innovation**
(from West and Bogers[35])

"Obtaining" innovation from external entities involves searching for, sourcing, enabling, incentivizing, and formalizing agreements or contracts. This phase is the initial stage of open innovation. "Integrating" innovations involves several aspects, such as facilitating or hindering integration, which may affect organizational capabilities and structure. "Commercializing" is the act of bringing innovations to market. The model could be extended to the fourth phase, "Interaction," which refers to the feedback for the feedback mechanism or reciprocal innovation processes such as co-creation. They also pointed out the tendency that much more empirical research has been done on the first two phases, obtaining and integrating, than on the remaining phases, commercializing and interaction[35].

### 2.4.3. Open Innovation and Companies' Performance

Many studies have suggested that open innovation leads to increasing companies' performance through quantification of the benefits from value creation through open innovation[36]. The metrics of innovation performance are highly diverse depending on research, such as profitability, R&D performance, customer satisfaction, product innovativeness, and new product success[37], [38], [39], [40], [41]. In contrast, some articles find that it is difficult to isolate precisely the impact of open innovation on firm performance because it is intertwined with other strategic choices made by competent managers; that is, firms that pursue open innovation are often already innovative with the necessary resources and capabilities[42].

### 2.4.4. Tradeoffs of Open Innovation

Chesbrough's main argument (original work published in 2003) is that it is strategically advantageous to use external knowledge rather than just internal knowledge for creating innovation effectively[27], and it is supported by many articles to demonstrate the positive relationships between open innovation and firm performance. However, many researchers have also pointed out that too much openness can lead to loss of control, increased complexity, increased coordination burden, etc., which implies tradeoffs of open innovation. By examining the impact of a firm's external knowledge search strategy on innovation performance, Laursen and Salter (2006) found a threshold above which the effectiveness of the return on open innovation diminishes or becomes negative. They explained that although managerial focus, a vital but limited internal resource, is critical to firms' adaptability and innovation, excessive management search for external knowledge leads to inadequate or excessive engagement in both external and internal communication channels, ruining innovation performance. That is, there are some trade-offs between external search and collaboration benefits, and searching broadly and deeply takes an inverted U-shape with respect to performance, as shown in Figure 2-3[43].

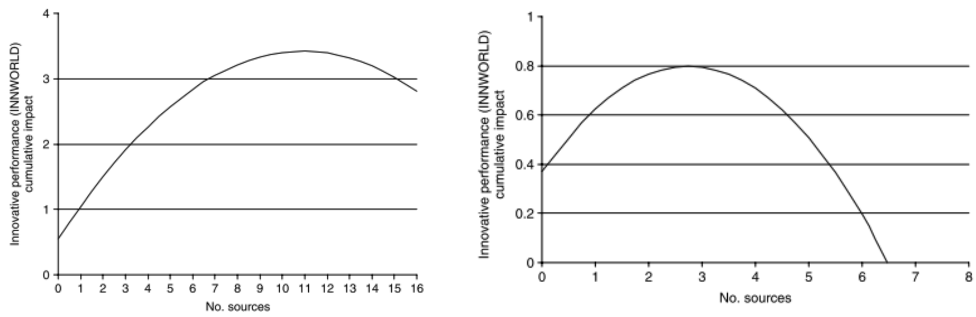


**Figure 2-3 Predicted relationship between innovative performance and the breadth/depth (left/right) of search through external sources of innovation**
(from Laursen and Salter[43])

Laursen and Salter introduced the external search "width" and "depth" as critical constructs. Based on that, Keupp and Gassmann categorized the archetype users of open innovation as shown in Figure 2-4: "Professionals" show high scores in both breadth and depth, indicating that they engage with a wide range of external knowledge sources with high intensity. "Explorers" show medium to high scores in breadth but only average scores in depth, indicating that while they engage with various sources, their level of engagement is not as intense as that of professionals. On the other hand, "Scouts" have low depth scores but medium to high breath scores, suggesting that they initially scan the environment for suitable parties without committing to intensive collaborations. "Isolationists" score low on both scales, suggesting that they either rely on a limited number of external sources for innovation without deep collaboration or prefer to keep their innovation activities relatively closed. One of their prominent findings is that no companies in the panel data fall into the combination of "low OI breadth" and "medium" or "high OI," suggesting that all companies need to have some relationship with a significant number of external entities before intensifying their open innovation partnership[44].

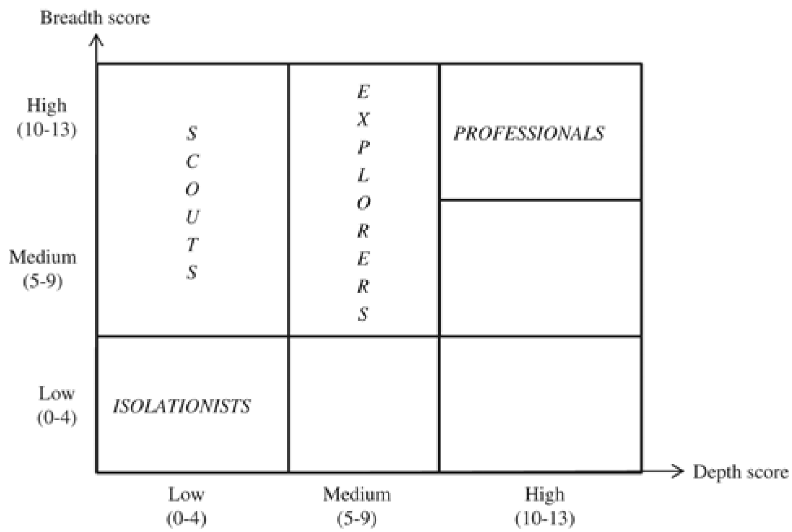


**Figure 2-4 Archetype users of open innovation** (from Keupp and Gassman[44])

Garriga et al. (2013) also expanded Laursen and Salter's model (2006) to evaluate whether the companies' context factors, such as constraints on resource application, could have any impact on the search strategy itself. They found that barriers against innovation could mediate the effect of external search; that is, resource shortage positively affects search breadth but negatively affects depth. If companies have abundant external knowledge, both search breadth and depth have U-shaped relationships[45].

In addition, implementing open innovation requires companies to reveal parts of their proprietary knowledge, which leads to some knowledge leakage. Managers need to be more vigilant in protecting themselves from being imitated by competitors during the open innovation process, and this tension points to an apparent paradox that openness requires much more attention to knowledge protection. This is the openness paradox, which has been studied from different angles to identify the nature of the tradeoffs.

Arora et al. (2016) scoped two conflicting theories, "spillover prevention" and "organizational openness," to elucidate the relationship between openness and patenting. The first theory predicts a positive relationship because firms are inclined to seek external collaborators if they can protect their innovations through patents and minimize unintended knowledge spillovers. The other theory implies a negative relationship based on the fact that patenting may hinder a firm's ability to develop collaborative innovations, making it a less attractive partner. Using an empirical model, their results suggest that the balance between openness and patenting varies among different types of firms. Leaders, more vulnerable to unintended knowledge spillovers in collaborations than their counterparts, tend to increase patenting in response to greater openness. On the other hand, follower firms, which typically engage in incremental innovation and have less proprietary technology, may be reluctant to patent because it could reduce their attractiveness as open partners and potentially reduce the benefits they derive from collaboration[46]. In a related study, Zobel et al. (2016) found that while patenting increases openness in a company that has a vigorous technology intensity, the positive relationships become weaker as the intensity decreases[47].

### 2.4.5. Absorptive Capacity

To benefit from external sources of innovation, identifying and acquiring external innovations is only half the story; it is necessary to integrate them into the firm's activities[35]. This leads to the necessity of understanding how companies can translate their openness into innovation outcomes through an open innovation process. It is related to the concept of "absorptive capacity," the organization's ability to recognize the value of new external knowledge and assimilate it to apply its collaborative projects to drive innovation, which is the most discussed in the research on the integration phase of open innovation. Absorptive capacity, as well as the open innovation concept, focus on how innovating firms obtain benefits from external knowledge resources.

The concept of "absorptive capacity" was first defined by Cohen and Levinthal (1990) before the birth of open innovation. They view the concept as a function of the source of knowledge and the level of prior related knowledge, arguing that a firm can recognize the value of external knowledge and assimilate it for its commercial purposes. They suggest that building absorptive capacity requires internal R&D capability, using R&D investment or total R&D expenditure as a rough proxy for the firm's prior knowledge stock[48]. Then, in the context of open innovation, other research has developed the concept of absorptive capacity by adding other factors, such as the proportion of employees with a university degree or a scientific-technical degree, implying that the learning environment in a firm has a positive impact on absorptive capacity[49], [50].

Although absorptive capacity is well understood conceptually, its measures and detailed components are not well defined. Many articles discuss the absorptive capacity of a firm implementing open innovation, implying that it is critical to the success of open innovation because it can amplify the benefits of using external innovation and improve financial performance[50], [51], [52]. However, very few articles precisely describe the multiple components of absorptive capacity for open innovation[53].

Based on Cohen and Levinthal's model, Zobel (2017) proposes a multidimensional model of absorptive capacity with three subcomponents: recognition, assimilation, and exploitation. He implies that firms change from closed to open as absorptive capacity is built and the processes of recognition, assimilation, and exploitation of external knowledge resources become more prominent. Recognition capacity consists of exploring, identifying, and evaluating external knowledge resources. Assimilation capacity refers to the analysis, processing, and dissemination of external knowledge within the organization based on knowledge management. Exploitation capacity determines the ability to apply the assimilated knowledge resources and leverage the existing competencies of the organization[53]. He then examines the relationships between these three subcomponents of absorptive capacity and three constructs for driving competitive advantage in product innovation, as summarized in Figure 2-5. That is, he demonstrates that absorptive capacity is critical for firms to leverage external resources to achieve competitive advantage in product innovation: Firms with robust capabilities to identify external technologies through scanning and evaluation are likely to have better access to these technologies. Moreover, the effectiveness of this access in enhancing technological capabilities depends on the firm's ability to assimilate these technologies. Finally, the extent to which these technological capabilities lead to competitive advantage in product innovation depends on the firm's ability to exploit them[53].

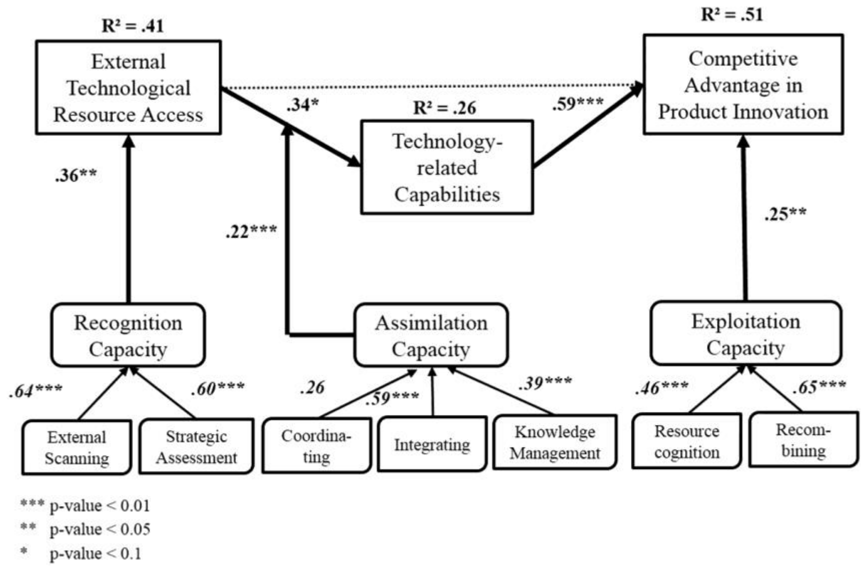


**Figure 2-5 Structural model of absorptive capacity for open innovation**
(from Zobel[53])

Although many articles provide insights into the relationship between absorptive capacity and open innovation, there is no consensus on how much absorptive capacity is necessary to implement open innovation in a firm. As described in the previous section, there are some trade-offs between open innovation performance and openness, and higher absorptive capacity does not necessarily increase open innovation performance, leading to the unresolved question of what kind of subcomponent of absorptive capacity is needed to benefit from open innovation[42].

### 2.4.6. Failure Causes of Open Innovation

As described in previous sections, articles focus more on successful cases of open innovation than failures and research on the causes of open innovation failures is limited and fragmented. Criceli (2023) analyzed such failures based on literature reviews and proposed a framework to organize the types of failures. He summarized that, in terms of internal elements, the main failures are due to deficiencies in firms' strategy, business organization, knowledge and IP management, management, and resources. Since strategy sets the direction and purpose of entire firms, strategic alignment with open innovation is critical, affecting inter-firm collaboration and internal management decisions. Organizational structures, which include formal hierarchy, division of labor, communication, coordination mechanisms, and reward systems, must align the organization's strategy with its open innovation goals. IP management highlights the importance of managing shared information and resources in open innovation projects, and companies need to balance protecting their competitive advantage with sharing resources in the project. Managers should have appropriate ownership to frame open innovation projects within the organizational strategy and decide on allocating resources, such as financial and human resources, which are the project's foundation. In addition, from an external perspective, inter-firm collaboration and the influence of environmental factors can affect whether an open innovation project can be successful. The open innovation project may fail if the interaction with external partners to share goals, resources, and knowledge through effective communication and coordination does not work well enough. Similarly, external environmental factors such as alignment with market trends, regulations, and government policies can significantly influence the outcome of open innovation[54].

## 2.5. Open Innovation in the Real World

The previous section describes the history of academic research on open innovation, including the definition of its typology, phases of its implementation in the firm, and the concept of absorptive capacity. However, such empirical research is not sufficient to understand the concrete and real mechanism for the firm to adopt and exploit the open innovation system. This section presents prominent examples of companies that have been able to reap the benefits of open innovation (2.5.1), as well as some questionnaire-based surveys that identify the factors of success or failure of open innovation in U.S. and Japanese companies (2.5.2).

### 2.5.1. Individual Cases

(1) Procter & Gamble (P&G)

In the early 2000s, Procter & Gamble (P&G) realized that relying solely on internal R&D was insufficient to drive the company's growth and innovation. R&D productivity was declining and stagnating, leading P&G to embrace open innovation strategies in 2003 under the leadership of newly appointed CEO A.G. Lafley. He spearheaded the Connect + Develop (C+D) program to identify new ideas, solutions, and technologies from outside the company, setting a goal of sourcing 50% of its innovations from outside the company. This marked a strategic shift for P&G, which had previously relied heavily on its internal capabilities. He also believed that this program, or open innovation, could save significant cost and time. As a result, by 2006, more than 35% of new products introduced to the market included elements from external sources, up from 15% in 2000, and 45% of product development initiatives included some external discovery. In addition, their R&D productivity increased by nearly 60% in 2006, even though R&D spending as a percentage of sales decreased from 4.8% in 2000 to 3.4% in 2006[55].

Based on this remarkable experience, P&G actively continued the C+D approach and pursued open innovation partnerships and collaborations to drive innovation in the 2000s and 2010s. They actively partnered with companies of all sizes, from start-ups to large multinationals, to co-develop new products and technologies, leading to the market success of many products, such as Olay Regenerist, Swiffer Dusters, and Crest SpinBrush. To expand its open innovation collaborations, P&G also launched a new website for its C+D program in 2013, creating direct connections between innovators and the company's top needs, as well as between business leaders and external innovation proposals. This approach contributed significantly to the company's status as the top innovator in the 2013 New Product Pacesetters list, with seven of the year's most successful non-food products, including Tide Pods and Vidal Sassoon Pro Series[56].

However, after Lafley stepped down as P&G's CEO in 2009, the company's revenues declined due to the severe recession despite having an established open innovation process with numerous satisfied external collaborators. Even after Lafley's return in 2013, P&G couldn't reignite growth, leading to his second departure in 2015. Chesbrough (2019) suggests that P&G's focus on open innovation has diminished due to organizational changes, such as the merger of the C+D team in 2016, as well as the market impact of the Great Recession. Competitors have begun adopting similar open innovation strategies, another trigger for P&G's decline. These episodes suggest the importance of having the right open innovation mindset as a company[57].

(2) General Electric

In the early 2000s, General Electric (GE), like many large companies at the time, was experiencing declining productivity from its closed innovation model. While GE already had a large billion-dollar energy business, it lacked a presence in the emerging green and renewable sectors that were generating innovation at smaller kilowatt scales. This led GE, under the leadership of CEO Jeffrey Immelt, to launch the Ecomagination project in 2003, a major corporate initiative focused on open innovation in clean technology and sustainable solutions. The project focused on attracting entrepreneurs to develop new energy businesses and represented a strategic shift for GE to look externally for new ideas and technologies that could drive future growth. First, GE offered a $100 million fund to invest in the most promising ventures. They then partnered with four experienced venture capitalists (VCs) who invested another $100 million, creating a $200 million pooled fund. This allowed them to leverage the VCs' extensive experience in supporting renewable energy startups. Ultimately, GE funded 17 companies, and its VC partners invested in several others, for a total of 23 new startups. Recognizing the value of an engaged community, GE created a new position, Community Engagement Manager, to sustain engagement. This example shows that by embracing open innovation, GE was able to access external knowledge beyond its own R&D team and gain the ability to expand into new businesses that require different innovation capabilities[57], [58].

(3) Pharmaceutical companies – Shire, Bayer and Roche

The pharmaceutical industry is widely regarded as the most technology-intensive industry, and R&D is the primary driver of growth and innovation. It is challenged by high R&D costs and the need for accelerated innovation, which drives each company to adopt collaboration between internal and external knowledge. Schuhmacher et al. (2013) explored the evolving R&D landscape in the pharmaceutical sector, highlighting the transition to an open innovation model that can foster technological development. Analyzing 13 large pharmaceutical companies, they find that the current industry standard is for approximately 50% of late-stage R&D pipelines to consist of externally sourced projects, whether through licensing deals, acquisitions, or partnerships. Companies that acquire over 50% of their projects externally tend to have better financial performance and share price growth. One of the most important examples is Shire, which is more aggressive in acquiring external innovation and uses a mix of internal and external resources. Shire's model contributes to lower R&D costs and faster time-to-market because it can increase R&D productivity through avenues such as licensing, crowdsourcing, early-stage alliances, and virtual R&D[59].

Chesbrough (2019) pointed out that by professionalizing its open innovation management and aligning its practices with its goals, Bayer, the traditional pharmaceutical company, is achieving valuable innovation outcomes from this diversity of internal R&D, external partnerships, and collaboration models. Today, Bayer uses an "all of the above" open innovation strategy, which includes maintaining strong internal R&D capabilities, collaborating extensively with universities, partnering with startups and venture capital firms, organizing hackathons, licensing external technologies, and acquiring entrepreneurial biotech companies. Specifically, Bayer uses four main types of open collaboration models, each with increasing levels of risk and organizational involvement, as shown in Figure 2-6: Insight activities such as crowdsourcing have low integration. Workbench, where parts of development are outsourced, is more involved. Licensing and IP access modes require knowledge, rights, and money transfers. Co-development represents the most intensive collaboration to create new drugs together[57].

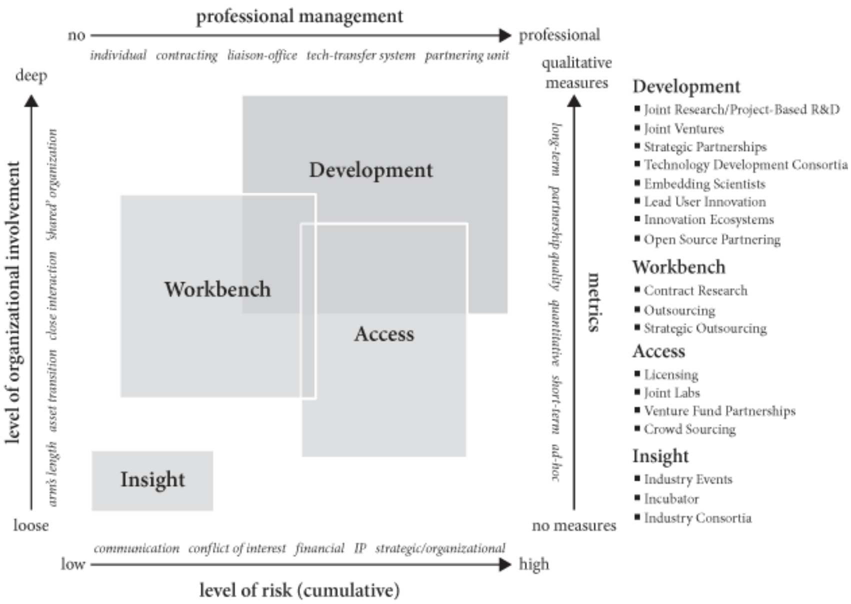


**Figure 2-6 Mapping objectives to research activities at Bayer** (from Chesbrough[57])

In contrast, Nakagaki et al. (2012) from Roche Diagnostics and Pharma divisions showed that although Roche recognizes the potential of open innovation, it experiences significant hurdles in transitioning large, established companies from closed to more open models. The main reasons are the long timelines in the pharmaceutical industry, high project failure rates, and the complexity of systems that combine many components. Although the company has moved to an incremental approach focused on small wins that demonstrate collective value, senior management disagreements and cultural challenges have hindered the adoption of an open mindset. Internal scientists resisted external solutions, seeing their role as problem-solving, and the lack of incentives for open innovation also hindered progress. Roche seeks out willing leaders and champions to promote open innovation and selects projects demonstrating value. However, fully embedding open innovation into Roche's culture remains challenging, given ingrained mindsets and incentives aligned with closed innovation[60].

## 2.5.2. Questionnaire-Based Survey Results

(1) United States and Europe

Chesbrough and Brunswicker (2014) surveyed 125 large American or European firms on adopting open innovation practices by sampling more than 2800 companies whose annual sales were in excess of 250 million USD. It targeted senior executives such as CEOs and CTOs at company headquarters. The questionnaire contained 23 items, including the challenges or barriers to the adoption of open innovation. As shown in Figure 2-7, the survey results revealed that organizational change poses the most significant barrier to implementing open innovation. At the outset of adopting open innovation, respondents rated organizational change as the top challenge, with an average importance score of 5.6 out of 7. Today, it remains the top challenge, scoring 5.26. This indicates that the difficulties of organizational change persist over time. Managing relationships with external innovation partners was also rated as an important ongoing challenge, scoring 4.97 in importance at the start of open innovation efforts and 4.89 today. In contrast, minimizing Not-Invented-Here syndrome among employees was viewed as a less critical barrier, with scores of just 3.61 at the start and 3.69 today. This suggests that large firms are less concerned about employees disregarding external knowledge. Other challenges perceived as moderately important were protecting intellectual property, finding appropriate partners, and identifying truly promising ideas from external sources. In summary, the survey highlights the need for companies to focus on organizational change management as they seek to incorporate open innovation practices[33].

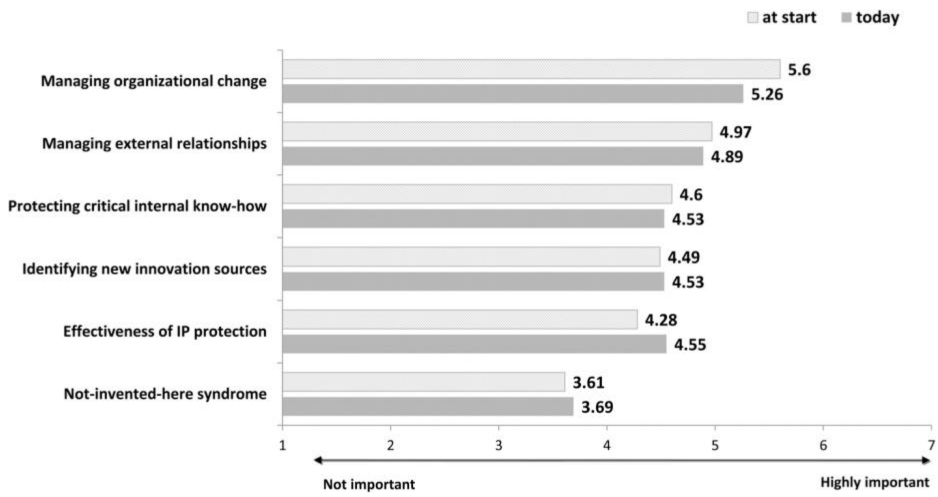


**Figure 2-7 Importance of challenges to open innovation at start and today**
(from Chesbrough and Brunswicker[33])

(2) Japan

The Japanese government has conducted several large-scale questionnaire-based surveys on open innovation among major companies listed on the Tokyo Stock Exchange First Section. The 2015 survey results showed that 52.3% of companies have become more active in open innovation compared to 10 years ago, and furthermore, 74.5% of companies have taken some steps to build the necessary organizational systems for promoting open innovation. When collaborating externally, Japanese companies prioritize several factors: comparing their technological strengths with potential partners, evaluating differences in R&D speed and cost between internal and collaborative efforts, and having high predictability around the division of roles and IP rights post-collaboration. As for problems and challenges, as shown in Figure 2-8, shortage of personnel was most frequently cited, followed by difficulty finding suitable external partners, limited impact due to lack of authority, lack of budget, and lack of understanding of R&D staff and units. The government periodically checks the status of open innovation adoption through these comprehensive surveys of major Japanese firms[61].

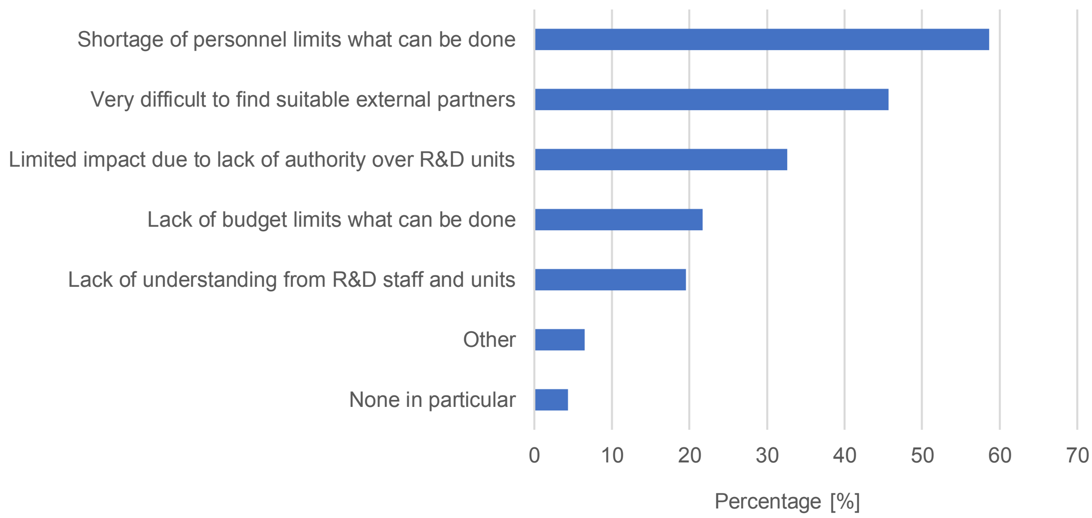


**Figure 2-8 Challenges for promoting open innovation**
(from Ministry of Economy, Trade and Industry of Japan[61])

In addition, Yoneyama et al. (2017) conducted a survey on Japanese firms that was exactly the same as the one conducted by Chesbrough and Brunswicker (2014) on American and European firms to compare the implementation of open innovation practices in large firms across continents. The results show that open innovation has become quite mainstream, especially among Western companies, which is suggested by the fact that about 78% of

European and American companies reported adopting open innovation, compared to 61% of Japanese companies. This is consistent with the findings that 61% of European and US companies are increasing their investment in open innovation, while only 30% of Japanese companies are doing so. On average, companies allocated 10-20% of their total innovation budget and 1-5 employees explicitly to open innovation initiatives.

However, companies face several persistent challenges and difficulties when adopting open innovation practices, as shown in this article. Figure 2-9 shows that organizational change, human resource shortage, and lack of direct benefit are the most common barriers. Other sticking points include managing relationships with external partners and protecting IP and core internal assets. Finding appropriate partners, establishing ways to work together, and creating successful knowledge management collaborations seem hard for many companies to get right[62].

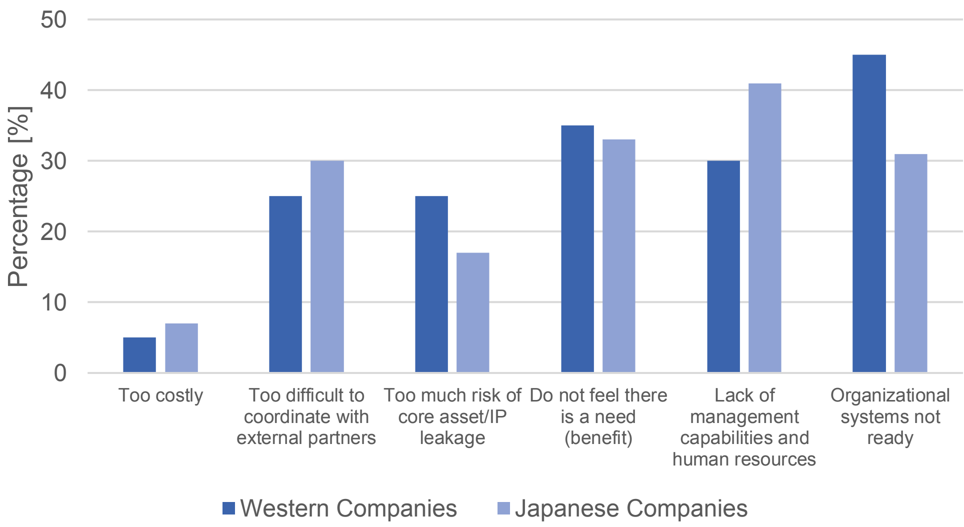


**Figure 2-9 Reasons for not implementing open innovation** (from Yoneyama, et.al.[62])

## 2.6. Open Innovation and Public Policy

This section provides an overview of innovation policy instruments that promote open innovation. It first summarizes the main individual innovation policy instruments, including R&D subsidies (2.6.1) and tax incentives (2.6.2), noting that evidence on their impact is mixed but that they can stimulate additional private R&D spending and partnerships if well targeted. It emphasizes that governments use a policy mix, combining instruments across the innovation cycle rather than single policies (2.6.4). For open innovation, it outlines examples such as the EU's Horizon program, which funds cross-border, cross-sector collaboration; Japan's tax deductions for joint R&D projects; and platform strategies in the EU and the US to connect innovators (2.6.5). Limited research suggests that subsidies can increase firms' propensity to partner and improve the efficiency of open innovation when aligned with firms' strengths (2.6.6). Overall, this section provides an overview of different policy instruments, from subsidies to platforms, that aim to promote open innovation across borders and sectors systematically.

### 2.6.1. Individual Instrument (1) R&D Subsidies/Grants

R&D subsidies or grants are direct funding from public authorities to companies to finance their innovative projects. While this is the most popular policy instrument, there are many variations in terms of grant size, funding duration, target industries, project types, etc. In theory, R&D subsidies can correct R&D market failures and enable firms to innovate. This is basically because some market failures lead private firms to underinvest in R&D compared to the socially optimal level. Positive knowledge spillovers mean that firms cannot fully capture the returns of their R&D investments. In addition, financing constraints, especially for SMEs, limit access to the capital needed for risky R&D projects. By lowering the cost of realizing desired firm benefits and innovations, R&D subsidies aim to increase private R&D spending closer to the socially optimal level[63].

However, empirical evidence on the impact of R&D subsidies is mixed[64]. Many articles suggest subsidies stimulate additional private R&D spending above what would have occurred without the subsidies. For example, Moretti et al. (2023) found that a 10 percent rise in publicly funded R&D granted to private companies led to a 3 percent increase in private R&D investment, leading to their productivity growth[65]. This trend is more apparent for SMEs, which are more likely to be financially constrained. Howell (2017) found that receiving an early-stage Small Business Innovation Research (SBIR) grant approximately doubles a firm's chances of obtaining follow-on venture capital financing and that receipt of an SBIR grant positively affects the grantee's revenues and patent activity[66]. In contrast, Görg (2007) suggests that a subsidy that is too big cannot serve to increase private R&D spending[67].

Bloom et al. (2019) pointed out that part of the difficulty in getting clear evidence is the challenge of constructing a valid counterfactual - what would the firm's R&D spending have been absent the subsidy? Subsidies often target the most promising firms or projects, so finding an appropriate comparison group is hard. It is widely accepted that spillovers are hard to quantify. There is also debate about whether metrics such as the number of patents are sufficient to assess the impact on innovation[68].

### 2.6.2. Individual Instrument (2) R&D Tax Incentives

R&D tax incentives are the indirect innovation policy instruments to stimulate private R&D by reducing the tax burden on firms investing in eligible R&D activities to support investment in R&D. The choice of R&D tax incentive structures depends on macro (country-level) variables such as innovation performance, industrial structure, firm size and the nature of the corporate tax system[69].

The OECD reports (2005, 2020) provide a comparative analysis of R&D tax incentives across OECD countries using the "B-index formula," based on the pre-tax income required to break even on a dollar of R&D expenditure. They reported that the use of R&D tax incentives has proliferated, accounting for 50% of public support for business R&D in OECD countries in 2017, up from 30% in 2000. Evidence suggests that R&D tax incentives are effective in stimulating additional private R&D spending, with each unit of tax subsidy translating into 1.4 additional units of R&D, and that they have greater effects for SMEs than for large firms but minimal effects for R&D-intensive sectors such as pharmaceuticals, computer manufacturing, and scientific R&D. They increase both R&D expenditures and human resources devoted to R&D without increasing R&D labor costs[69], [70].

Although it is generally accepted that R&D tax credits are less heterogeneous than R&D subsidies[71], some articles still point out that the additional R&D expenditure achieved by R&D tax incentives does not directly translate into additional innovation. For example, the OECD report (2022) summarizes that in the short run, R&D tax credits may have inflationary effects on researchers' wages if supply is limited, and they may primarily be actively shifted across borders rather than actually increasing R&D expenditures in the case of multinational firms[64].

In addition, to encourage business R&D and innovation, which leads to economic growth, OECD and EU countries are increasingly using income-based tax incentives that offer reduced tax rates or exemptions on income from a firm's innovation output, such as IP regimes for eligible IP assets and dual-category regimes for broader business income from R&D or innovation activities[64]. The OECD report (2023) suggests that their benefits are concentrated in a limited number of firms, with large firms receiving a disproportionate share, reflecting the concentration of IP in these firms. They also note that, given the scarcity of evidence, policymakers should carefully assess the effectiveness, costs, and distributional effects of income-based tax incentives to stimulate R&D and innovation[72].

### 2.6.3. Other Individual Innovation Policy Instruments

As described above, innovation or R&D-specific policies such as R&D subsidies and R&D tax incentives effectively encourage firms to innovate and improve productivity. However, these instruments are not the only elements of innovation policy. It is widely accepted that other individual policy instruments, such as IP policies and demand-side instruments, can provide important incentives as complementary instruments to such tax and subsidy measures[64].

IP rights like patents, designs, and trademarks provide a temporary monopoly on technologies to increase incentives to innovate at the expense of a temporary reduction in competition, and IP policies are as broad as definitions of patentable technologies, application costs, transparency of the system, and litigation costs and procedures[64]. Determining the effectiveness of individual IP policies on private innovation is difficult. In terms of demand-side instruments complementing supply-side instruments, greater demand demonstrated by the government can create more incentives for private R&D investment based on the expectation of a larger market. Guerzoni and Raiteri (2013) summarize that the public sector is an early buyer in technology-intensive industries, and private innovation activities are influenced by public demand. They find that public procurement positively impacts private spending in innovation activities and is more effective than subsidies in stimulating private investment in innovation activities[73].

### 2.6.4. Innovation Policy Mix and Development

While individual policies have been discussed in the previous section, governments do not adopt a single innovation policy but rather a combination of policies simultaneously. In this sense, the OECD report (2013) expands the scope of innovation policy by highlighting the crucial role of combining policies that promote innovation or technology adoption with effectively formulated framework policies that enable the widespread diffusion of knowledge. Specifically, the configuration of framework policies related to product market regulation and trade openness are identified as key factors in facilitating the diffusion of new technologies[74].

These trends are then developed conceptually as a "Mission-Oriented Innovation Policy (MOIP)". It is defined as a high-level policy mix aimed at addressing complex socio-economic and environmental challenges through innovation, involving the definition of a concrete problem-solving mission with measurable goals and multiple stakeholders to achieve the mission. The policy mix encompasses different stages of the innovation cycle, combines supply-push and demand-pull instruments, and cuts across different policy areas, sectors, and disciplines[75]. The most prominent example of the recent MOIP is carbon neutrality, which consists of environmental regulations, subsidiary incentives for green technologies, and tax reductions based on carbon pricing. The OECD report (2021) analyzed and categorized forty MOIPs in the world, including notable examples such as the DARPA project of the United States and the Horizon project of the EU, by defining the multiple capabilities in three dimensions: strategic orientation (including legitimacy, directionality, intentionality, flexibility), policy coordination (horizontality, verticality, intensity, novelty), and policy implementation (consistency, financeability, evaluability, reflexivity)[75].

### 2.6.5. Policy Instruments for Open Innovation

(1) R&D Subsidies

As described in the previous section, R&D subsidies are financial assistance or support mechanisms provided by governments or other public institutions to encourage and support organizations, such as companies or research institutions, in their research and development activities in order to promote innovation, technological progress, and economic growth. While some R&D subsidies in major countries are seen as tools to promote open innovation, collaboration itself is not a necessary and sufficient condition for direct funding in most countries. Openness is only one element of the requirements for the adoption of subsidies.

One of the most prominent examples of symbolic subsidies for open innovation is the Horizon program in the EU, which funds collaborative R&D and innovation projects between commercial and research partners across borders and sectors. Horizon is the EU's flagship research and innovation funding program, with €80 billion from 2014 to 2020 and €96 billion from 2021 to 2027. The latest Horizon program aims to achieve this by promoting scientific excellence, fostering cross-border research collaborations, and supporting the development of innovative technologies and solutions to societal challenges, which are defined as its three pillars. The program is characterized by its emphasis on open science, requiring open access to publications and encouraging data sharing. This approach is intended to foster collaboration that can lead to open innovation. Based on these values, the European Innovation Council provides funding and support for start-ups and SMEs to develop innovations. Some consortia must include a mix of commercial companies (especially SMEs) and academic research organizations from several EU countries, and calls for proposals are designed to encourage multidisciplinary projects that facilitate knowledge sharing between researchers, entrepreneurs, companies, and end-users. As a result, Horizon 2020 has succeeded in creating more than one hundred partnerships, activating the financial commitment of the European industry to the program[76].

(2) R&D Tax Incentives

As described in the previous section, R&D tax incentives allow companies to receive a tax credit for a percentage of qualifying R&D expenditures. This applies to R&D activities performed internally by a company or outsourced to other for-profit entities, with the aim of encouraging private sector innovation by reducing tax costs.

In Japan, R&D tax incentives were first introduced in 2003, and the government has gradually increased the tax credit rate. The government expanded the R&D tax incentive system to promote open innovation between companies and external research institutions in 2011. Under this scheme, companies can deduct a percentage of the expenses for collaborative R&D projects with designated partners, such as universities, public research institutes, and startups, from their corporate income tax liability. The deduction rates vary depending on the partner: 30% for projects with universities, 25% for startups, and 20% for large corporations. To qualify, the contracted research must correspond to the company's basic or applied R&D activities, and simple outsourcing contracts are excluded - the external partner must actively contribute expertise and intellectual property. Initially, there were strict requirements to document collaborative projects through formal contracts. Figure 2-10 shows the use of this scheme as measured by the total value of deductions claimed. The sharp increase in 2015 was largely due to procedural improvements, which streamlined the requirements for validating collaborative agreements and expenses, making the system easier to use. Specifically, the reforms allowed for simplified contract documentation and expense validation for open innovation partnerships. This significantly improved the system's operational efficiency and user-friendliness. By reducing the administrative burden, the authorities aimed to encourage greater uptake by companies to promote open innovation activities. This type of R&D tax incentive specifically targeting open innovation collaborations appears to be relatively unique globally and demonstrates Japan's focus on promoting this open innovation paradigm[77][78]. In addition, Japan also has a tax incentive that allows companies or corporate venture capital firms to deduct 25% of the acquisition cost from taxable income when they acquire shares in a startup company or engage in a merger or acquisition to acquire a controlling interest in a startup company for open innovation purposes[79].

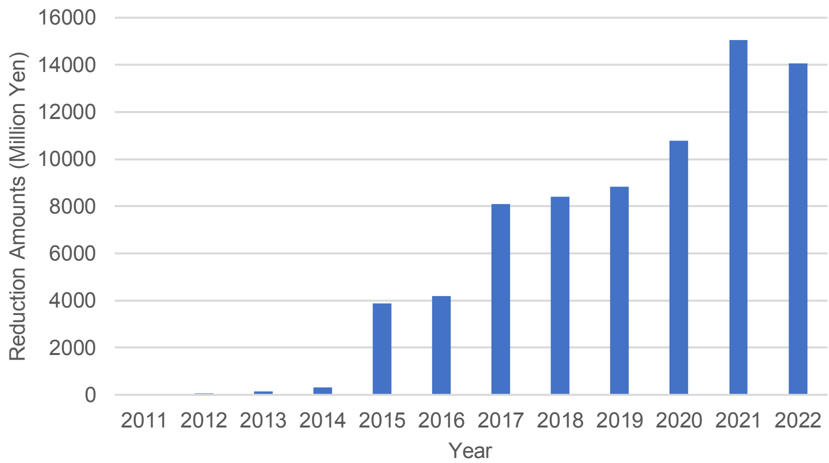


**Figure 2-10 Total reduction amounts based on the open innovation type of R&D tax credits** (from Ministry of Finance of Japan[78])

(3) Platform Strategy

Platform strategies refer to efforts by governments or industry associations to create common platforms that facilitate collaboration and knowledge sharing among companies and research institutions. Platforms provide a foundation where different actors can interact, exchange ideas, access resources, and develop new innovations through partnerships. Platforms reduce transaction costs for open innovation, provide infrastructure for matchmaking and networking, and help overcome challenges such as intellectual property management. Effective platform design and governance are key to attracting participants and facilitating valuable interactions.

For example, as described above, Horizon Europe has developed an open platform called "Open Research Europe," an innovative open-access publishing platform that provides rapid publication and open peer review of research projects funded by Horizon Europe. It is a legal requirement to have open access to projects funded by Horizon Europe, which means that European countries intend to promote linkages between multiple stakeholders, including companies, universities, and research laboratories for technology transfer and commercialization of new inventions[76]. Similarly, the U.S. government has established several online platforms to facilitate open innovation. One prominent example is "Needipedia," a website developed by the Defense Intelligence Agency where defense and intelligence end-users can post and share current mission needs that require innovative solutions. It has both a public version and a classified version that contains sensitive information. "Challenge.gov" is also an open government platform where various federal agencies can post innovation challenges and competitions. The platform allows agencies to post problems or needs, set a timeframe for submissions (typically around 3 months), and offer financial rewards of up to $500,000 for successful solutions. In this way, platform policies are one approach that governments and industry are taking to promote open innovation on a broader scale systematically[80].

### 2.6.6. Impacts of Innovation Policies on Open Innovation

Literature about the impacts of public policies on open innovation is limited except for the following articles: Busom and Fernández-Ribas (2008) empirically investigated whether participation in public R&D subsidies increases the propensity of firms to enter into research partnerships, using data on Spanish manufacturing firms from 1990-2002 and found that subsidies program participation positively impacts the probability of engaging in R&D cooperation agreements, increasing partnerships with other firms by 7-8 percentage points and with research centers/universities by 4-5 points. The effect is most substantial for collaborations with other companies, supporting the explanation that programs help firms signal technological capabilities and attract partners more than just reducing costs. The paper strongly implies that public R&D subsidies as a public policy have positive spillover effects by facilitating valuable research partnerships, especially between firms[81].

Greco et al. (2017) investigated the relationship between public R&D subsidies and the efficiency of firms in transforming external knowledge sourced through open innovation into valuable innovation outcomes. Using survey data on Italian firms' innovation performance during 2006-2008, they find that subsidy funding enhances open innovation efficiency only when appropriately aligned with a firm's technological trajectory. Specifically, subsidy funding increases innovation performance from openness only when firms rely on external knowledge that builds on their existing capabilities. In contrast, subsidizing the exploration of new technological areas where a firm lacks experience is ineffective. The paper implies that public subsidies boost open innovation efficiency, but only when they provide focused support for exploiting a firm’s current innovative competencies rather than exploring unfamiliar technologies. Overall, the results emphasize the importance of targeted subsidies reinforcing a firm's technological strengths to successfully leverage open innovation[82].

# 3. Research Approach

## 3.1. Gap in Literature

The concept of open innovation has permeated the business world, and many companies are trying to implement open innovation in their R&D to create innovation. The quality and availability of external knowledge are increasing, and the strategic advantage of innovation based on internal R&D is eroding, so companies need to use external knowledge to innovate.

Since Chesbrough first introduced the concept of open innovation in 2003, many academic articles have been published that have expanded and enriched our understanding of the concept over time, as summarized in Section 2.4. In particular, the most critical concept is "absorptive capacity," which refers to an organization's ability to recognize the value of external knowledge, assimilate it, and apply it to commercial ends. It is essential for companies that want to benefit from open innovation because it enables them to leverage external sources of ideas and technology more effectively. Articles show that companies that invest in nurturing absorptive capacity are better equipped to translate openness into innovation. At the same time, however, some trade-offs are found, meaning that greater absorptive capacity does not necessarily linearly improve open innovation performance. While absorptive capacity enables companies to extract more value from openness, it must be strategically developed in line with a company's specific open innovation approach. The point is that the exact components of absorptive capacity needed to optimize open innovation outcomes remain unclear. It is necessary to clarify how much and what kind of absorptive capacity is needed for companies to benefit from open innovation.

Looking at real firm examples, as discussed in Section 2.5, many individual firms, such as P&G, GE, etc., are reported to be using open innovation, suggesting that they are strategically implementing the concept of openness to boost their innovation by increasing their absorptive capacity. In addition, some large-scale national surveys help to identify some barriers that prevent companies from implementing open innovation. However, there is no solid evidence about the detailed mechanism and generalized flows for open innovation to take root in each firm and how effective it is. Some disconnect and incoherence between academic research and real industry and enterprise status of open innovation can be found, and there seems to be no systematic understanding of the implementation of open innovation. This leads to unaddressed questions about what kinds of drivers are needed for the firm to derive much benefit from open innovation. Moreover, while some studies suggest that government policies, such as R&D subsidies, have some influence in promoting open innovation and/or, conversely, hindering firms' efforts, little literature details how government policies affect firms' open innovation initiatives.

In summary, while academic research has advanced our conceptual understanding of open innovation and absorptive capacity over the past two decades, significant gaps remain between academic theory and real-world business practice. The existing literature has yet to coherently articulate the precise mechanisms, workflows, and configuration of capabilities needed for firms to successfully operationalize open innovation and derive meaningful innovation outcomes. There is a lack of systematic insight into how leading firms implement open innovation strategies, what specific internal levers influence success, and how external factors such as government policies shape firms' open innovation initiatives. This research aims to fill these gaps by developing an actionable framework for understanding the components of absorptive capacity in driving effective open innovation adoption, with a particular focus on large Japanese firms. The findings can contribute both theoretical knowledge to extend previous academic perspectives, as well as practical guidance to enhance the effectiveness of open innovation strategies and management practices within firms.

## 3.2. Research Structure

As summarized in Chapter 1, this thesis is fundamentally motivated by Japan's current state of innovation, encompassing the challenges faced by Japanese industry as well as the potential role of collaborative R&D activities between large Japanese firms and other actors as a catalyst to drive innovation. The research about the ways of transforming Japanese companies to adopt more openness by using their own efforts and external driving forces such as public policies seems imperative for restructuring the Japanese industries and creating innovation in society. Based on this motivation, Section 1.6 outlines the core research questions that this thesis aims to address:

*Q. What are the critical levers to activate collaborative R&D activities in large Japanese enterprises?*

The literature review conducted in Chapter 2 identifies the fragments between academic research and real-world examples and experiences of open innovation implementation within firms. These gaps imply that the primary focus of this thesis should be to frame the absorptive capacity, one of the most critical architectures in the open innovation model, and it is necessary to identify the critical components of the absorptive capacity for answering the research questions defined above. The identified gaps inspire us to develop and refine the research question in the following ways:

*Q1. How can absorptive capacity be depicted as a framework to express the mechanism of open innovation practices?*

*Q2. What decisions, those related to the absorptive capacity of the firm, are significant for the successful implementation of open innovation in large Japanese companies? Given these decisions, how can the firm optimize their absorptive capacity to maximize their innovation performance?*

To address these questions, the literature review helps us deepen our understanding of absorptive capacity as follows: While concepts such as absorptive capacity are well defined and describe technical capabilities to identify, assimilate, and exploit external innovation, case studies and questionnaire-based research suggest that strategic, organizational, and cultural factors also shape success. In particular, the review shows that setting up appropriate organizational structures and clearly defining innovation needs and areas where external technologies are required is an initial prerequisite for open innovation journeys and has a direct impact on subsequent outcomes. Therefore, it seems plausible to formulate the following hypotheses based on the research questions defined above:

*H1. Absorptive capacity for open innovation is not only composed of three proven capabilities - recognition, assimilation, and exploitation - but also includes strategic, organizational, and cultural factors that go beyond technical capabilities.*

*H2. Identifying technological needs for open innovation projects is the fundamental basis for a company's feasible openness and its absorptive capacity.*

*H3. Effective organizational structures increase a firm's openness and improve its absorptive capacity.*

By addressing these research questions and validating the hypotheses, this thesis aims to make meaningful contributions to both the academic discourse and the practical implementation of open innovation strategies. The findings can provide a comprehensive, actionable framework for understanding the key components of absorptive capacity that drive impactful open innovation adoption within large Japanese firms. Furthermore, insights into the role of public policy can inform the development of effective policy tools to catalyze greater openness and collaborative innovation among Japanese firms. As shown in the literature review, public policy interventions can be sufficiently effective in changing firm behavior to promote innovation in the private sector. Ultimately, the research seeks to advance the theoretical knowledge of open innovation while providing practical guidance to improve management practices and strategies for leveraging open innovation within Japanese firms.

## 3.3. Research Approach Overview

To address these unexplored areas, this thesis uses a system architecting method as a research approach, with some analysis of secondary data on open innovation and case studies of Japanese companies. System architecting is a structured approach to understanding complex systems and their components, focusing on how these components interact and influence each other. It involves identifying key components, connectivities, sensitivities, and decision variables within a system and analyzing their dynamics to gain insight into system behavior and performance[83]. In the context of this research, system architecture enables a holistic examination of the critical factors influencing the adoption and implementation of open innovation practices in large Japanese corporations. Specifically, by architecturally analyzing the absorptive capacity framework and its decision variables, the research aims to elucidate the mechanisms underlying successful open innovation strategies. Given the difficulties in quantifying innovation performance in a firm, this thesis includes case studies about Japanese firms. These qualitative investigations allow for a deeper understanding of the challenges, opportunities, and best practices associated with implementing open innovation in the Japanese business context.

Therefore, by combining theoretical analysis with empirical investigation, this thesis aims to generate actionable insights and practical recommendations for both academics and practitioners seeking to improve their understanding and implementation of open innovation strategies. Overall, the systems architecture approach serves as a robust framework for conducting interdisciplinary research that bridges the gap between academic theory and real-world business practice with respect to open innovation. This comprehensive methodological design is intended not only to fill the existing gaps, but also to provide a robust framework for policy formulation and strategic decision-making in open innovation.

# 4. Research Method

This chapter presents the methodologies for designing large Japanese companies' open innovation absorptive capacity systems.

## 4.1. System Scope

This thesis takes the multi-phase approach to define the scope of the system, that is, the absorptive capacity of open innovation. First, based on the academic literature and real-world examples, the primary scope for the open innovation type is defined. Next, using the "To-By-Using" system architecture construct[83], a high-level system problem statement is set to define the system goals. Finally, a stakeholder analysis is also conducted to categorize and detail various entities that interact with or are interested in the system. Stakeholder needs and prioritization rankings are evaluated for the system design of absorptive capacity.

## 4.2. System Functional Architecture

The system functional architecture aligns the conceptual framework with the realities of implementing open innovation in an organization. The following steps are taken to define the functional decomposition of the open innovation absorptive capacity system: First, an in-depth and thorough review of the existing academic literature is conducted to identify prevalent indicators and metrics used to measure absorptive capacity quantitatively. The literature proposing composite frameworks and absorptive capacity capabilities models is also closely examined. On this basis, an initial functional decomposition of absorptive capacity is developed. Next, Japan's recent open innovation implementation guidelines and Japanese government and industry reports are analyzed to capture and incorporate real-world insights into how leading firms are configuring processes and organizational structures to drive open innovation success. Neutral and generalized surveys and research are used to avoid bias from specific success stories. Each source of information is then synthesized, focusing on decomposing the interrelated capabilities that make up absorptive capacity as a functional decomposition of capacity; that is, the initial decomposition is revised by incorporating insights about mechanisms and processes, including management elements. The combined review of prior academic research on absorptive capacity and the analysis of open innovation implementation lead to an evidence-based definition of functional decomposition of the architecture, which outlines the key capabilities and elements that constitute absorptive capacity for open innovation in firms.

## 4.3. Architecting Decision Variables

Key architectural decision variables, which are imperative to shape the design of absorptive capacity systems that enable the implementation of open innovation, are identified in this section. The variables presented capture selective critical elements extracted from the functional analysis of absorptive capacity's underlying capabilities. The choice of these variables and their extensive options reflect an integrated synthesis of lessons mainly from exhaustive corporate surveys on adoption considerations and reference guides detailing activation steps. Including expansive possibilities based on empirical evidence and conceptual feasibility aims to secure the solution neutrality and mitigate selectivity biases that could preclude potentially optimal choices.

## 4.4. Use Case Selection

To identify successful large Japanese companies engaged in open innovation, the following key steps are taken based on published financial statements and government research reports: First, large Japanese companies listed on the Prime Market of the Japan Stock Exchange are focused on, which represents the highest level of publicly traded Japanese companies and is known for its stringent criteria in terms of market value, profitability, and liquidity. The scope is determined by excluding some sectors with R&D expenditures below certain criteria on average, based on government research. Then, annual securities reports from 2015 to 2022 are thoroughly examined to identify companies that actively promote open innovation through a keyword search. Each company is then assigned a score based on a variety of publicly available documents, including white papers, success case lists, government guidelines, and working papers. The scores are weighted according to the neutrality and objectivity of the sources. Based on the scores, the "Open Innovation Index" is defined, which leads to the exhaustive identification of Japanese companies engaged in open innovation. A selection process is then conducted to identify five companies for in-depth architectural analysis by industry and company ranking.

## 4.5. Case Studies

The case studies in this thesis aim to provide an in-depth analysis of how large Japanese companies have successfully implemented open innovation by selecting specific architectural decision options for their absorptive capacity systems. The scope of the case studies is determined by the use case selection process described in Section 4.4, which identifies five companies from different industries. For each case study, a comprehensive review of publicly available information, including company documents, case studies, books, and interviews with key personnel, is conducted to examine the architectural choices made by the company in implementing open innovation. The analysis is structured to show how the company chose different options for the previous architectural decisions as defined in Section 4.3. The case studies also follow a consistent format, starting with an overview of the company's basic information, including its R&D focus and financial data related to R&D expenditures and R&D intensity. This is followed by an analysis of the external landscape that led the company to pursue open innovation, such as industry trends, competitive pressures, and technological disruptions. In addition, it presents the performance of the company's open innovation initiatives, using both quantitative and qualitative measures to assess whether the company is succeeding in achieving its intended goals. In the last part, the results of five case studies are consolidated to identify commonalities and differences in architectural decision options to analyze the critical factors of absorptive capacity systems for open innovation projects.

## 4.6. Connectivity and Sensitivity Analysis

This section identifies the dependencies and sensitivities of the architectural decisions that shape the absorptive capacity of open innovation systems. Using a Design Structure Matrix (DSM) approach and a weighted scoring method based on the case study data, the coupling analysis seeks to uncover the critical variables and their influence on the overall system performance[83]. The DSM captures the strength of the couplings between variables, as determined by their occurrence in the case studies, while also clustering the variables into capability groups and analyzing the clusters based on the level 1 functions of absorptive capacity defined in the previous section to provide some insight into the underlying structure of the open innovation absorptive capacity system. In addition, the sensitivity analysis quantifies the importance of each variable based on its impact on system performance, using the Open Innovation Index scores and identifying primary variables in the case studies. By assessing the relative influence of each variable on the overall effectiveness of the system, this analysis aims to guide decision-making and prioritization efforts in the design and optimization of open innovation architectures. The insights gained from these analyses contribute to a deeper understanding of the key drivers and enablers of absorptive capacity for successful open innovation projects.

## 4.7. Framework of Absorptive Capacity

This section consolidates the results and implications derived from the detailed system architecting analysis in the previous sections and proposes a comprehensive systems framework for architecting absorptive capacity of open innovation for Japanese enterprises. Concretely, the systems framework is constructed by synthesizing the findings from the functional analysis, architectural decision mapping, case studies, and connectivity and sensitivity analyses in all of the previous sections.

# 5. Analysis and Results

## 5.1. Overview

This chapter provides a comprehensive analysis of the results obtained from the framework in this thesis to design the absorptive capacity system for open innovation in large Japanese companies. Section 5.2 defines the system scope for the open innovation type, establishes a high-level system problem statement, and conducts a stakeholder analysis. Section 5.3 presents the development of the system functional architecture that aligns the conceptual framework with the practical implementation of open innovation. This process includes a comprehensive literature review, an analysis of Japanese open innovation implementation guidelines and reports, and a synthesis of the findings to define the functional decomposition of the architecture. Section 5.4 identifies key architectural decisions and options that are critical to shaping the framework of absorptive capacity systems and maps them to the level 2 functions obtained through the functional decomposition. Section 5.5 describes the use case selection process, which focuses on large Japanese companies listed on the Prime Market of the Japan Stock Exchange. The process involves examining annual securities reports, assigning scores based on various publicly available documents, and selecting five companies for in-depth architectural analysis. Section 5.6 presents the case studies of the five selected companies, providing an analysis of their architectural choices in implementing open innovation. The case studies follow a consistent format, including an overview of basic company information, an analysis of the external landscape, and an assessment of the performance of the company's open innovation initiatives. The section concludes with a synthesis of the case study findings, identifying commonalities and differences among the architectural decision options selected by the five companies. Section 5.7 focuses on the connectivity and sensitivity analysis of the architectural decisions using a design structure matrix approach and a weighted scoring method based on the case study data. This analysis aims to uncover the critical variables and their influence on overall system performance, revealing the central role of organizational structure and the significant impact of management capability variables on detection and assimilation capabilities. Finally, Section 5.8 consolidates the findings and implications derived from the previous sections and proposes a comprehensive system framework for designing open innovation absorptive capacity for Japanese firms. This framework synthesizes the findings from the functional analysis, architectural decision mapping, case studies, and connectivity and sensitivity analyses, and emphasizes the importance of adopting a systems approach that recognizes the interconnectedness and relative importance of architectural decisions.

## 5.2. System Scope

As described in Section 2.4, the literature identifies three types of open innovation processes: Outside-in (inbound), Inside-out (outbound), and Coupled. This thesis mainly focuses on the outside-in process, which involves the assimilation of externally sourced ideas, technologies, and discoveries into a firm's innovation process through SME partnerships, university collaborations, and startup acquisitions. The reason for the focus is that the thesis is motivated by the technological competitiveness challenges large firms face, including Japanese companies. In general, they have multiple business areas, including various competitors, making it difficult to export their technologies externally. On the contrary, smaller companies tend to be more proactive in the "inside-out" process since they often lack complementary assets such as manufacturing to commercialize technologies by themselves and desire to externalize technologies by licensing out. The aim is to analyze the architectures and mechanisms of absorptive capacity in outside-in (inbound) open innovation cases that allow Japanese firms to absorb and successfully benefit from inbound innovation originating from outside by standing the viewpoints of large Japanese companies.

What does outside-in (inbound) open innovation mean in reality? Bayer is an example of the outside-in (inbound) open innovation cases, as they define each open innovation activity as shown in Figure 2-6. In the development phase, external knowledge sources are integrated with internal R&D to advance drug compounds toward final products, and this phase includes workbench contracting of development tasks, in-licensing of compounds from academics or biotechs, joint development projects, and strategic partnerships [57], [84]. In addition, in a book about open innovation in Japan, written by generalizing actual cases of open innovation adoption by Japanese companies, the outside-in (inbound) type of open innovation is introduced as "technology exploration type" open innovation. This type, which involves taking in external technological elements, is discussed as a category with a higher likelihood of leading to outcomes that many previous cases have proved. The objectives on the company side that pursue "technology exploitation type" open innovation are relatively clearer than other types of open innovation projects, and some mismatches between the externally provided knowledge/technology and the company's needs are easily resolved in the process of partnerships and coordination because of the intention to utilize external sources[84].

Based on these evidences, this thesis defines the high-level system problem statement of absorptive capacity as follows:

*To* enhance competitiveness and accelerate innovation in large Japanese companies
*By* leveraging valuable external knowledge and implementing it within existing mechanisms
*Using* in-house capabilities of identifying, assimilating, and exploiting external innovation seeds.

The absorptive capacity systematically aims to ingest and convert external innovation into positive business performances for companies by absorbing the most promising external assets and implementing them into the firm's mechanism, utilizing internal capabilities of detecting external values and internalizing them to make innovation.

Next, a stakeholder analysis is conducted to identify all entities interacting with the absorptive capacity of large Japanese companies to gain a comprehensive view of the entire system and assess each stakeholder's needs, as shown in Table 5-1. Stakeholders are generally categorized into internal corporate groups, external potential partners, and others. Internally, executives always pursue revenue growth, productivity, competitiveness, new business opportunities, and the ability to change their companies. The R&D department needs access to external innovation, innovation skills development, and benchmarking data through an open innovation mechanism. Other employees in other divisions also value business growth and productivity, which is reflected in compensation. The C-suite and R&D units seem clearly indispensable for building absorptive capacity systems to achieve open innovation success, which means they are prioritized the most compared to other departments and employees.

Regarding potential external partners, large companies, including competitors in the market and those from different business sectors, desire pre-competitive alliances to combine resources such as budget and talent and expect spillover effects of R&D and innovation. In contrast, high-potential startups and academics seek additional financial and human resources, commercialization pathways, real-world testing grounds for theoretical concepts, and industry visibility to attract further investment for their anticipated business. Nimble tech startups generally warrant higher prioritization than competitors or highly regulated academic institutions due to greater partnership agility. Other parties, such as shareholders, want financial returns and stock stabilities, business partners need sustainable partnerships, customers value cutting-edge innovation, and governments seek to stimulate competitiveness and innovation rankings as a country.

Note that shareholders and business partners make it possible for the company to continue functioning, thus maintaining a moderate prioritization.

**Table 5-1 Summary of stakeholders and needs**

| Category | Stakeholder | Needs | Priority |
|---|---|---|---|
| Corporate | Executives | - Revenue growth<br>- Increased productivity<br>- Sustained competitiveness in market<br>- Expanded business opportunities<br>- Facilitating transformation | High |
| | R&D Department | - Increased divisional productivity<br>- Access to innovative technological sources<br>- Cultivating R&D talents and learning capabilities<br>- Benchmarking data from other companies | High |
| | Other Departments (Employees) | - Increased divisional productivity<br>- Expanded business opportunities | Low |
| External Partner Candidates | Large Companies | - Pooled resources<br>- Pre-competitive collaboration platforms<br>- Avenues to transfer innovations across industries<br>- Spillover effects for new or adjacent markets | Mid |
| | Tech Startups | - Expanded resources<br>- Commercialization pathways<br>- Platforms for pilot projects and integration<br>- Investor visibility from corporate partners | High |
| | Academics (Universities or Research Institutes) | - Expanded resources<br>- Implementation channels for theoretical work<br>- Industry connectivity | Mid |
| Others | Shareholders | - Revenue growth and ROI improvement<br>- Increased competitiveness | Mid |
| | Business Partners | - Continuing business integration<br>- Sustained competitiveness in market | Mid |
| | Customers | - New or revised products incorporating cutting-edge innovation | Low |
| | Government | - Stimulate competitiveness<br>- GDP growth and raising innovation rankings | Low |

## 5.3. System Functional Architecture

This section defines the system functional architecture of the absorptive capacity of enterprises by using the system decomposition method.

First, existing research has used quantitative approaches to measure an enterprise's absorptive capacity. The leading quantitative indicators are total R&D expenditure and R&D intensity (R&D expenditure divided by sales revenue). This is consistent with the understanding that R&D and absorptive capacity interact to expand a firm's knowledge base and innovation output[48], [85]. Studies that take a broader view also use metrics such as firm age, based on the commonly argued negative correlation between age and innovation, suggesting an indirect negative relationship between age and openness as well as firm size[86]. In addition, some quantitative indicators focus specifically on human resources - for example, the number of employees with a university degree[50], the percentage of scientists and engineers in the total workforce[87], and investment in scientific and technical training[88]. Note that the widespread use of such quantitative measures is largely due to the reliance on the European Community Innovation Survey (CIS) database for analysis. The CIS is a comprehensive biennial assessment conducted in collaboration with the EU's statistical agency, Eurostat, and national statistical offices to collect key data points on the innovation activities of more than 200,000 enterprises in member countries[89]. While this panel dataset may have limited variations of researchers' approaches to the aforementioned quantifiable metrics, previous literature strongly implies that quantitative information as a company's basic capabilities could be the foundation of the absorptive capacity[51].

Next, the functional decomposition of absorptive capacity is examined by focusing on its components. Zobel (2017) attempts to define absorptive capacity using a multidimensional model and concludes that it consists of three components: recognition, assimilation, and exploitation. As shown in Table 5-2, he also proposes processes, specific activities, and actions underlying each component as the building subblocks of absorptive capacity[53]. On this basis, taking into account the basic capabilities of the firm that we consider important, the functional decomposition of absorptive capacity can be outlined as shown in Figure 5-1.

**Table 5-2 Components and underlying processes of absorptive capacity**
(from Zobel[53])

| Original Components of Absorptive Capacity | OI Activities and Sets of Actions | Underlying Processes of Absorptive Capacity |
|---|---|---|
| **Recognition**: the capacity to explore, identify, and value external knowledge | • Wide-range scanning of external markets, technologies, partners (Chen, Chen, and Vanhaverbeke, 2011; Chesbrough and Crowther, 2006)<br>• Searching broadly and deeply across external knowledge sources (Cooper, 2008; Laursen and Salter, 2006)<br>• External technology and trend scouting, roadmapping, and R&D mining (Caetano and Amaral, 2011; Ili, Albers, and Miller, 2010; Rohrbeck, 2010; Porter and Newman, 2011)<br>• Portfolio considerations and evaluation procedures of external innovation sources (Chiaroni, Chiesa, and Frattini, 2010; Chiaroni et al., 2011)<br>• Identifying fit with firm's core businesses (Chesbrough and Crowther, 2006)<br>• Recombining with best possible partners (Almirall and Casadesus-Masanell, 2010)<br>• Evaluating unsolicited external ideas and proposals (Alexy, Criscuolo, and Salter, 2011) | 1) **External scanning**: Broad external monitoring of emerging partners, technologies, and markets<br>2) **Strategic assessment**: organizational activities involved in evaluating external innovation sources and assessing their fit with the firm's businesses |
| **Assimilation**: the capacity to analyze, process, and diffuse external knowledge | • Connecting employees with external knowledge sources (Foss, Laursen, and Pedersen, 2011)<br>• Assignment of new roles and responsibilities, e.g., boundary spanners (Chiaroni et al., 2010, 2011; Holmes and Smart, 2009)<br>• Coordinating and synchronizing external innovation resources (Chatenier, Verstegen, Biemans, Mulder, and Omta, 2010)<br>• Cross-functional working and in-house connectors (Love, Roper, and Bryson, 2011; Whelan, Parise, de Valk, and Aalbers, 2011)<br>• Overcoming adverse behavior, e.g., "not-invented-here" (NIH) syndrome (Chesbrough and Crowther, 2006)<br>• Reward systems and knowledge incentives (Chiaroni et al., 2010, 2011; Foss et al., 2011; Ili et al., 2010)<br>• Legitimizing and authorizing OI activities (Asakawa, Nakamura, and Sawada, 2010)<br>• Encouraging social interaction mechanisms (Chatenier et al., 2010)<br>• Communicating external knowledge to relevant units and employees (Foss et al., 2011)<br>• Knowledge infrastructure to facilitate transfer and utilization of external knowledge (Chiaroni et al., 2010, 2011)<br>• Information and communication technologies (Dodgson, Gann, and Salter, 2006; Hughes and Wareham, 2010) | 1) **Coordinating**: formal and informal mechanisms for linking external knowledge resources with internal businesses<br>2) **Integrating**: activities and tools that stimulate the acceptance and implementation of external knowledge resources<br>3) **Knowledge management**: formal infrastructure for articulating, codifying, and disseminating external knowledge resources |
| **Exploitation**: the capacity to determine applications of the assimilated knowledge resources and to recombine them with internal knowledge resources | • Resource orientation—careful analysis and planning of internal resources (Cheng and Huizingh, 2014)<br>• Understanding of internal constraints (Garriga, von Krogh, and Spaeth, 2013)<br>• Continuous selection and formulation of problems to enable novel solutions (Sieg, Wallin, and von Krogh, 2010)<br>• Transferring externally acquired resources from one concrete internal setting to another (Robertson, Casali, and Jacobson, 2012)<br>• Searching for analogical solutions and their subsequent translation and multiplication (Enkel and Gassmann, 2010)<br>• Discovering new opportunities for complementarities (Cheng and Huizingh, 2014)<br>• Identifying and evaluating knowledge arbitrage opportunities (combinative value of internal and external knowledge) (Hughes and Wareham, 2010) | 1) **Resource cognition**: active internal observation and monitoring to identify new problem spaces<br>2) **Recombining**: activities to match and bundle resources stemming from external and internal innovation sources |

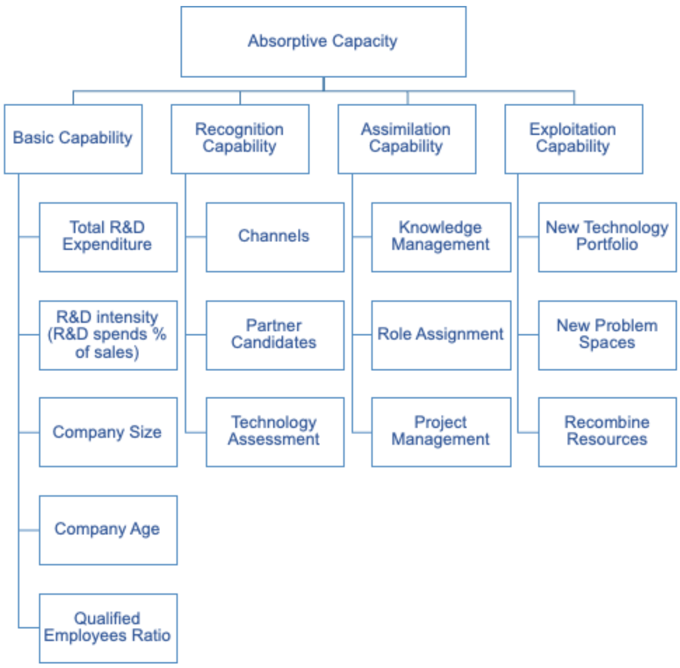


**Figure 5-1 Functional decomposition of absorptive capacity (Ver 1.0)**

"Recognition Capability" is defined as the ability to explore, identify, and evaluate external knowledge. The constituent elements of this capability include broad and deep exploration of external knowledge sources, investigation of external technologies and partners, evaluation of external innovations, and matching with the company's capabilities (as shown by the subcomponents as Channels, Partner Candidates, and Technology Assessment in the figure).

For "Assimilation Capability", defined as the ability to analyze, process, and diffuse external knowledge, the elements are systematizing external knowledge resources, building infrastructure, assigning roles, and project management to facilitate acceptance of external knowledge resources (as shown by the subcomponents as Knowledge Management, Role Assignment, and Project Management in the figure). He implies that this capability also encompasses organizational and cultural aspects like restructuring the organizational structures and overcoming the Not-Invented-Here syndrome.

"Exploitation Capability" is defined as the ability to determine the applications of assimilated knowledge resources and recombine them with internal knowledge resources. The capability's elements listed are regenerating portfolios based on external knowledge, identifying new problem domains, analyzing internal resources, and recombining usage plans (as shown by the subcomponents as New Technology Portfolio, New Problem Spaces, and Recombine Resources in the figure)[53].

However, as discussed in Chapter 3, there is a gap between the academic modeling described above and the interpretation of absorptive capacity and the mechanisms underlying the real-world implementation of open innovation. In other words, the decomposition of absorptive capacity as a system proposed in Figure 5-1 is unlikely to completely reflect the realities of open innovation practice. Therefore, in the following, the functional decomposition proposed in Figure 5-1 is revised based on surveys of companies engaged in open innovation, white papers on open innovation, and books that summarize the implementation of open innovation in companies, as shown in Figure 5-2. It is important to note that the decomposition still provides a structured breakdown of its components but does not fully capture the complex interactions and dynamics that occur in practice. The absorptive capacity, in reality, is more than just a hierarchical structure; it is a network of interconnected elements that work together in a dynamic manner, leading to the emergence of the system's overall function. These perspectives are mainly discussed in Section 5.7 based on case studies in Section 5.6.

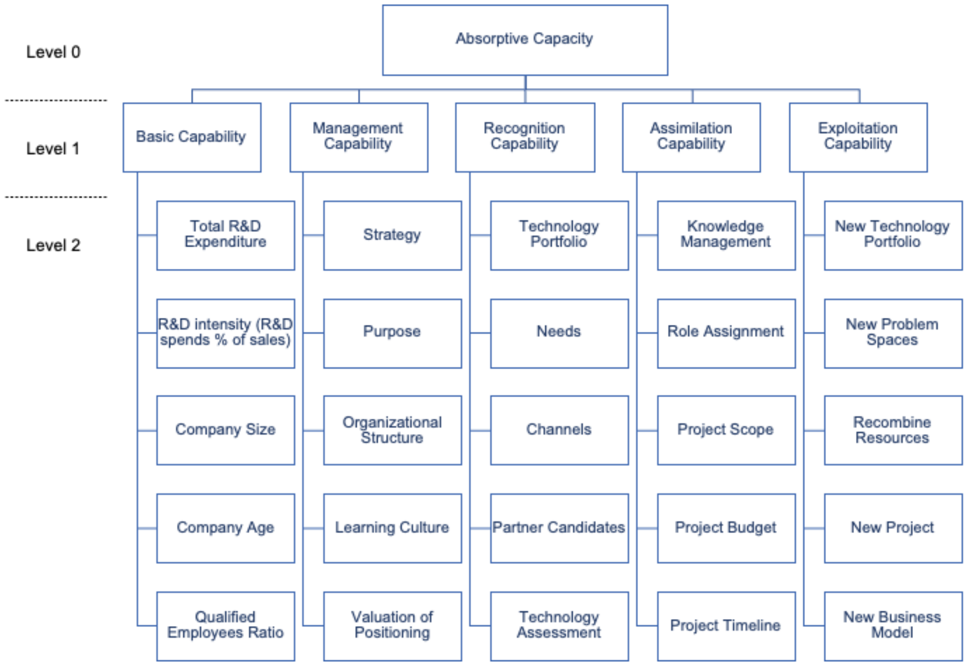


**Figure 5-2 Functional decomposition of absorptive capacity (Ver 2.0)**

The details of Figure 5-2 are as follows: First, as noted in Section 2.5, companies tend to view the practice of open innovation as a strategic management imperative[33]. This suggests that a company's "Management Capability" can significantly influence its absorptive capacity as a system. The component of this capability is the positioning of open innovation within medium- and long-term management plans and the clear definition of objectives for implementing open innovation initiatives (as shown by Strategy and Purpose in the figure). The white paper on open innovation generalizes and distills past open innovation success stories to outline the components necessary for successful adoption. Among these, it emphasizes the need to clarify open innovation within corporate and management strategies and to set appropriate goals[90]. This is also a prominent factor in the P&G case. Specifically, in its "Organization 2005" strategy, P&G explicitly articulated the need to stimulate innovation at the corporate level by focusing on external resources and integrating them with internal capabilities. In addition, based on this strategy, the new CEO launched the Connect + Develop (C+D) program in 2003, with the goal of sourcing 50% of innovation externally to reduce costs and time dramatically. In other words, P&G integrated open innovation into its corporate strategy and clarified its goals and objectives as a prerequisite for systematically implementing open innovation[56]. (As a result, P&G's increased use of external sourcing led to a 60% rise in R&D productivity and a decrease in R&D spending as a percentage of sales from 4.8% to 3.4% between 2000 and 2006[55].)

Another critical "Management Capability" element is the appropriate organizational structure to drive open innovation, while in the functional decomposition version 1.0 shown above, the organizational structure is grouped under "Recognition Capability". Through a survey of 125 European and American companies, Chesbrough and Brunswicker (2014) find that organizational transformation is the biggest challenge perceived by CEOs or CTOs in adopting open innovation[33]. In addition, the white paper concludes that operational readiness is necessary to execute open innovation initiatives, followed by organizational ingenuity. Specific measures include establishing dedicated organizations, forming core teams, and assigning accountability, as discussed later. Cultural factors are also part of the management capability. To overcome the Not-Invented-Here syndrome, the organization's approach to learning and mindset toward introducing new external resources and knowledge is a key: It should be well assessed how top-down directives are applied and percolated through the organization and the mindset of R&D departments[90]. Therefore, Organizational Structure and Learning Culture seem to be two key elements of this management capability.

In addition, one facet of management capability is assessing the company's position relative to external market conditions and competitive dynamics (as shown by Valuation of Positioning in the figure). Recognizing changes in the external environment and business challenges provides the rationale for initiating open innovation efforts. The strength of this capability can influence the extent of a firm's absorptive capacity[61].

Next, the three capabilities defined in functional decomposition version 1.0 are examined, namely, the capabilities of recognition, assimilation, and exploitation. Hoshino (2015) argues that the process of technology exploration-type open innovation involves four steps: selecting the technological scope that exists externally ("Want"), exploring external technologies ("Find"), evaluating them ("Get"), and assimilating one of the external technologies into the firm ("Manage"). These four steps are consistent with those outlined for corporate alliances in the book by Slowinski and Sagal (2003)[84], [91]. The technology selection step involves gaining an overall picture of the firm's existing technologies, prioritizing which areas require focused R&D investment, and identifying needs that must be met externally to achieve development goals. The technology exploration step refers to learning about relevant external technologies and locating organizations that possess them in order to establish relationships. The technology evaluation step means examining the content of potential partners' external technologies to make adopt-or-reject decisions. The technology assimilation step involves integrating selected technologies internally, structuring open innovation projects, and determining collaboration styles[84]. Comparing these steps to the definitions of the three capabilities above, including technology selection through evaluation under the "Recognition Capability" and technology assimilation under the "Assimilation Capability" is plausible. In particular, technology selection is not covered as an element of the "Recognition Capability" in the functional decomposition of version 1.0. Then, as shown in Figure 5-2, the "Recognition Capability" can be updated. This capability consists of; Technology Portfolio, which refers to the company's ability to strategically understand its technologies and identify critical areas; Needs, which concretely defines technology areas where external resources are required because internal capabilities cannot fully address the challenges of the company; Channels, as a means to explore external technologies; Partner Candidates, as potential collaboration targets; and Technology Assessment, to evaluate and select external technologies collected for subsequent Assimilation. The "Assimilation Capability" consists of Project Integration, Role Assignment, and Project Management, which is further clarified into three elements: Scope, Budget, and Timeline, based on the triple constraints of project management. The white paper on open innovation suggests a stage-gate approach for external knowledge assimilation projects to enable progress monitoring and evaluation[90]. Hoshino (2015) also states that careful progress management is essential to assimilation, and securing and allocating the necessary funds can impact external knowledge assimilation[84]. These correspond with the functional elements of "Assimilation Capability" in the figure. Next, as mentioned earlier, the "Exploitation Capability" is defined as the ability to determine the applications of assimilated knowledge resources and recombine them with internal knowledge resources. Figure 5-1 shows this capability: using newly acquired external knowledge through open innovation to update the firm's technology portfolio and resources. However, some research also views the capability as an ability to make more profitability and includes linking open innovation results to new projects and business models as elements of this capability[92]. Therefore, the exploitation capability should also include linking results to new projects and business models, as shown by New Project and New Business Model in Figure 5-2.

Then, the system problem statement is revised as follows to more systematically encapsulate the key elements of the absorptive capacity of open innovation:

[Before]

*To* enhance competitiveness and accelerate innovation in large Japanese companies
*By* leveraging valuable external knowledge and implementing it within existing mechanisms
*Using* in-house capabilities of identifying, assimilating, and exploiting external innovation seeds.

[After]

*To* enhance competitiveness and accelerate innovation in large Japanese companies
*By* strategically absorbing promising external innovations and integrating them into internal mechanisms
*Using* in-house capabilities of managing innovation, recognizing valuable external technologies, assimilating them, and exploiting them for business growth.

The "By" statement is revised since the functional architectural decomposition reveals that specifically identifying and selectively acquiring the most promising external innovations, rather than indiscriminately sourcing all external knowledge, is critical. Similarly, the decomposition implies that active integration into internal mechanisms through structural changes is needed.

The "Using" statement can be refined to focus on the core capabilities identified in the above analysis: innovation management, recognition of strategically valuable external technologies, assimilation, and exploitation. Managing innovation includes strategically positioning open innovation within the organization, setting clear goals, and establishing appropriate structures to support the open innovation process, beyond purely technical aspects. Recognizing valuable external technologies involves identifying areas where external resources are needed to complement internal capabilities, actively exploring technologies in the market, and selecting the most suitable partners for collaboration. Assimilating external innovations covers the effective management of open innovation projects and the seamless integration of external knowledge into the company's existing knowledge base. Exploiting absorbed knowledge and technologies deals with determining their optimal applications, updating the company's portfolio to reflect the newly acquired capabilities, and translating the results of open innovation into new projects and business models that drive business growth.

The revised system problem statement addresses some gaps between initial assumptions and architecture-driven insights on success factors, highlighting the importance of a strategic approach to absorbing and integrating external innovations using a range of organizational capabilities.

In summary, this section updates the functional decomposition of absorptive capacity, which reflects insights from open innovation practices. This decomposition aims to provide an implementation-oriented framework reflecting pragmatic practices. Conceptualizing the key components of how firms absorb external knowledge and innovation in this section leads to further analysis of the critical variables that contribute to open innovation success in the next section.

## 5.4. Architecting Decision Variables

This section frames the architectural decisions and options for absorptive capacity based on the functional decomposition defined above in Section 5.3. Architectural decisions represent some of the most critical choices in system design, i.e., they fundamentally differentiate potential system architectures. Thus, the following architectural decisions drive the systematic design for absorptive capacity that enables the implementation of open innovation.

The architectural decisions represent the selection of primary elements for shaping system design from the level 2 components obtained in the functional decomposition of absorptive capacity described in the previous section. The choice of such variables and their associated options (architectural decision options) reflect the synthesis of insights aggregated from published corporate surveys and analyses on open innovation, case studies of real companies implementing open models, and reference guides on how to activate open innovation in organizations[33], [57], [61], [62], [90], [92], [93], [94], [95]. It is helpful to curate comprehensive variations for architectural decision options rather than limiting them to factors observed in known successful examples. Theoretically, possible choices should be included to ensure solution neutrality and mitigate biased elimination. Note that in the following, the square brackets [] represent tags denoting the architectural decisions ([X]) and the architectural decision options for each variable ([X#]).

(Architectural Decisions and Options)

- **Strategy[A]**: This variable reflects the extent to which open innovation is prioritized and integrated into an organization's overall strategy. Possible options, in order of strategic emphasis, are the articulation of open innovation as a core component of the medium/long-term strategy[A1]; explicit identification of open innovation as a short-term tactical approach in public materials[A2]; implicit endorsement of open innovation principles, as evidenced by internal memos or directives[A3]; or the absence of any overt strategic stance on open innovation[A4]. In cases where multiple sources, such as a mid-term to long-term strategy and an annual plan, demonstrate a commitment to fostering open innovation within the enterprise, the highest level of strategic integration is designated as the architectural decision option.

- **Purpose[B]**: This variable indicates the reasons why open innovation should be adopted in a company. Possible motives are categorized into the perspectives of cost, speed, human resources, and the actual output of R&D. They are financial benefits by sharing assets through collaborations to reduce expenses[B1], accelerated R&D cycles[B2] or shortened production/marketing/commercialization timelines[B3], enhanced innovation capabilities of R&D personnel[B4] or improved human resource efficiency by pooling personnel[B5], expansion of existing product/service offerings[B6], and development of new markets and distribution channels[B7]. For companies with multiple objectives, the primary intended objective is selected.

- **Organizational structure[C]**: Companies seeking to adopt open innovation have several structural options for determining which internal group will drive implementation. One option is an entirely new, dedicated, neutral, independent team with the exclusive mandate to integrate external innovation[C1]. Another option is to house specialized subgroups within existing R&D departments[C2]. A third construct involves assigning selected R&D personnel additional open innovation responsibilities without broader structural changes[C3].

- **Learning culture[D]**: Learning culture shapes how employee mindsets and training are fostered around open innovation. Options include top-down[D1], bottom-up[D2], or cross-functional systems[D3]. The top-down system, which determines the direction of employee training, is led by the management team, but the bottom-up system promotes learning based on the needs of individual employees and the front line. The cross-functional system refers to an organizational state where clear vertical silos and hierarchies are absent and simple top-down or bottom-up learning cultures have not been established.

- **Needs[E]**: This variable indicates how an organization identifies the external knowledge or technology it needs. The decision options are as follows. The in-house R&D department identifies the company's technology gaps based on the challenges in its day-to-day R&D activities and determines which technologies to source externally based on its technology portfolio or roadmap[E1]. Non-R&D departments, such as manufacturing, marketing, and sales, benchmark competitors' products/services to identify gaps in the company's offerings and determine needed technologies through backward planning[E2]. When management defines an entirely new vision that departs from existing businesses, the required knowledge and technologies are identified[E3]. While multiple options can influence each other, the dominant approach is selected in the following section.

- **Channels[F]**: This refers to the types of pathways used to seek external knowledge. The decision options are searching internally through public records such as academic papers and patents[F1], investigating technologies held by existing partners[F2], openly posting on the firm's website the specific technology needs being sought and waiting for approaches from candidates[F3], hiring external research agencies or consultants or investing to the venture capitals to explore potential partnerships around the required expertise[F4], participating in platforms operated by matching agencies or governments to identify partners with the desired capabilities[F5], or attending industry trade shows and conferences where potential partners congregate[F6]. If a company uses more than one channel, the one as a decision option is selected where the most effort is focused or that appears to yield the greatest results.

- **External partner candidates[G]**: Potential targets for external knowledge-seeking and partnerships may include large corporations, SMEs, start-ups, universities, and public research institutes. Based on this, the decision architecture offers two kinds of options - linking with multiple or a single type of partner and vertically integrating with suppliers/customers in existing value chains versus horizontal alliances without prior relationships. (Label as follows: vertical multiple partners[G1], vertical single partner[G2], horizontal multiple partners[G3], or horizontal single partner[G4]).

- **Technology assessment[H]**: This variable indicates how to evaluate external knowledge as a candidate and sublimate it into open innovation projects. The decision options are qualitative/quantitative desk assessment by the corporate R&D department or the open innovation team[H1], third-party assessment using external neutral organizations[H2], and immediate progression to Proof of Concepts or prototypes without extensive assessment[H3].

- **Knowledge management[I]**: In general, private companies have established techniques for managing corporate knowledge - such as non-disclosure agreements with partners, internal manuals to prevent technology leakage, or access controls for sensitive data - to influence the promotion of open innovation partnerships. This variable relates to the impact of the in-house maturity of such techniques and protocols on the open innovation project (external knowledge assimilation), and the decision options are high[I1], moderate[I2], or low capabilities[I3].

- **Project Budget[J]**: This variable defines the internal budgetary arrangements for assimilating external knowledge into internal resources to implement open innovation projects - specifically in the technology exploration phase versus the assimilation/implementation phase. The decision options are as follows: budgets secured for both phases[J1], only the exploration phase is budgeted (further funding depends on the results of the exploration)[J2], or only from existing R&D budgets (only allocated labor costs)[J3].
- **Project timeline[K]**: This is how the project timelines for external knowledge assimilation are determined. The decision options are fully based on company priorities (requirements dictated by internal schedules)[K1], fully deferred to partners (acquiescing to external party preferences)[K2], or via coordination of company needs with external expectations[K3].

In summary, the above-outlined architectural decisions and options represent key building blocks that fundamentally shape the design of absorptive capacity systems for open innovation.

## 5.5. Use Case Selection

Quantitative evidence of improved business performance from open innovation is very challenging to gather. As mentioned in Section 2.4, it is difficult to isolate the impact of open innovation because it is intertwined with the other management factors of the companies, and some companies pursuing open innovation tend to have many substantial resources already. As a result, objectively measuring the system performance of the absorptive capacity of open innovation does not seem feasible for this study. Therefore, this research adopts a use-case approach to discuss the system by applying defined architectures to specific examples. Since quantitative validation of systemic performance remains elusive, case studies of successful adopters facilitate a qualitative assessment of how improving absorptive capacity capabilities can translate into business returns.

Careful case selection and consolidated evidence for each case provide the bridge between architecture analysis and practical results.

This section aims to identify and evaluate large Japanese companies engaged in open innovation initiatives. This review will allow us to identify suitable companies to study as use cases.

In Japan, companies are classified as large, medium, or small based on their capitalization and number of regular employees. In the Small and Medium-Sized Enterprise Basic Act, SMEs can be defined as those with capital of less than 300 million yen or fewer than 300 regular employees[96]. Based on this, large companies can be defined as those with more than 300 million Japanese yen capital and more than 300 regular employees. The Japan Exchange Group operates several stock markets to meet the diverse needs of public companies and investors in Japan, and the various markets are tailored to companies based on their stage of growth and development. The Prime Market, the flagship market, generally lists large, well-established Japanese companies that meet strict standards of market value, profitability, and liquidity, and it represents the premier league of Japanese companies compared to the Standard Market and Growth Market. Specifically, to qualify for the Prime Market, a company must meet stringent criteria: First, companies must have substantial tradable equity of more than 10 billion Japanese yen, indicating substantial capital resources. They must also have solid profitability, with an operating profit of over 1 billion Japanese yen in the most recent fiscal year. In addition, a free float ratio of at least 35% is required to ensure adequate liquidity for trading. Finally, Prime Market companies must implement rigorous corporate governance systems in accordance with the National Corporate Governance Code. As a result, the select group of companies listed on the Prime Market is considered dominant industry leaders in Japan with large market capitalization, established track records, and financially sound performance[97].

As outlined in the research questions, this thesis focuses on large Japanese companies. Based on the positioning of the Prime Market mentioned above, it would be appropriate to comprehensively investigate whether open innovation is being implemented by companies listed on the Prime Market. Since the Prime Market represents the highest level of publicly traded Japanese companies, screening companies within this segment is consistent with the goal of examining the adoption of open innovation among leading large companies in Japan.

Companies listed on the Prime Market segment are published in a list by the Japan Exchange Group and categorized into 33 industries[98]. Research by the National

Institute of Science and Technology Policy in Japan indicates that certain industries, such as wholesale and retail trade, banking, insurance, securities and commodity futures, real estate, and services, have been identified as having R&D expenditures of less than 5 billion Japanese yen per company on average, which is relatively smaller than other industries such as manufacturing and pharmaceuticals[99]. Therefore, these industries are excluded from the scope of our research, leaving 25 industry categories and 1,065 companies. Then, using the database of annual securities reports published by the Japan Financial Services Agency, the reports from 2015 to 2022 for these 1,065 companies are comprehensively examined[100]. The securities report is a disclosure document that listed companies in Japan are legally required to submit annually under the Financial Instruments and Exchange Act[101]. Its purpose is to publish important business and financial information of listed companies and ensure transparency of corporate information. The reports include audited financial statements, analysis of the company's industry and competitive environment, profiles and commentary on management and governance, details on facilities and operating metrics, and management's vision and future business plans. Examining the content of securities filings can, therefore, help determine whether a company is proactively promoting open innovation and the extent to which open innovation is positioned in the company's strategy. In this research, the database is searched using "open innovation" as a keyword, and +1 is counted if the promotion of open innovation is clearly stated in the reports. Merely including "open innovation" in an executive's biography or annual report is not counted.

As a result, the breakdown by industry is shown in Table 5-3, which highlights that when focusing on industries with a total of at least 10 companies, the chemical, pharmaceutical, electricity and gas, electrical equipment, and precision instruments industries have over 30% of companies promoting open innovation in some form. In addition, the chemical, pharmaceutical, and electrical equipment industries are more likely than other industries to have companies explicitly stating that they have been promoting open innovation for 5 years or more. These findings suggest that companies in these industries may have been relatively early adopters and implementers of open innovation approaches. Their longer-term initiatives could be models of how large Japanese companies have integrated open innovation into their R&D and business activities.

**Table 5-3 Number of companies declaring in the securities reports that they promote open innovation depending on industry**

| Industry | Mentioned | # of mentions | | | | | | | | Not Mentioned | Total | Mentioned Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | [#] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | [#] | [#] | [%] |
| Air Transport | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 100% |
| Chemicals | 58 | 11 | 7 | 10 | 7 | 6 | 7 | 3 | 7 | 65 | 123 | 47% |
| Pharmaceuticals | 13 | 2 | 1 | 0 | 2 | 3 | 1 | 2 | 2 | 21 | 34 | 38% |
| Electricity and Gas | 8 | 4 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 13 | 21 | 38% |
| Electrical Equipment | 47 | 8 | 13 | 3 | 7 | 7 | 3 | 3 | 3 | 83 | 130 | 36% |
| Fisheries and Forestry | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 6 | 33% |
| Petroleum and Coal Products | 2 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 4 | 6 | 33% |
| Precision Instruments | 8 | 2 | 1 | 1 | 3 | 1 | 0 | 0 | 0 | 19 | 27 | 30% |
| Transport Equipment | 12 | 4 | 1 | 4 | 1 | 0 | 1 | 1 | 0 | 29 | 41 | 29% |
| Rubber Products | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 11 | 27% |
| Construction | 18 | 9 | 4 | 3 | 1 | 0 | 1 | 0 | 0 | 57 | 75 | 24% |
| Nonferrous Metals | 5 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 16 | 21 | 24% |
| Food Products | 16 | 2 | 3 | 4 | 5 | 1 | 0 | 1 | 0 | 53 | 69 | 23% |
| Machinery | 25 | 8 | 6 | 4 | 2 | 1 | 2 | 1 | 1 | 88 | 113 | 22% |
| Mining | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 5 | 20% |
| Steel | 4 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 18 | 22 | 18% |
| Land Transport | 7 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 32 | 39 | 18% |
| Textile Products | 3 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 18 | 21 | 14% |
| Information and Communication | 25 | 10 | 5 | 2 | 0 | 3 | 2 | 2 | 1 | 158 | 183 | 14% |
| Glass and Stone Products | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 19 | 22 | 14% |
| Other Manufacturing Products | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 33 | 37 | 11% |
| Metal Products | 3 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 26 | 29 | 10% |
| Pulp and Paper | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 10 | 10% |
| Maritime | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0% |
| Warehousing and Transport Related Services | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 13 | 0% |

A total of 1,065 companies are then scored based on the following publicly available documents:

- Annual Securities Reports: As mentioned above, if a company's Securities Report contains language indicating that it promotes open innovation at the corporate level, it scores +1. Since fiscal years from 2015 to 2022 are examined, the minimum score is 0, and the maximum is +8, with the score increasing in increments of +1.

- White paper on open innovation: Published by the Japan Open Innovation Council (JOIC) in collaboration with the New Energy and Industrial Technology Development Organization (NEDO), which is Japan's national R&D management organization for industrial, energy, and environmental technologies. The purpose of the white paper is to provide a comprehensive overview of open innovation activities in industry and academia in Japan, summarizing trends and statistical data on the adoption of open innovation approaches. The first edition, published in 2016, and the second edition, published in 2018, showcase examples of companies successfully implementing open innovation[90], [95], and companies profiled as success stories in these reports receive +10 points in this survey.

- JOIC success case list: JOIC, in collaboration with NEDO, conducts desk research and surveys of Japanese companies on open innovation in 2021-2022. The goal is to organize actual practices and challenges in creating businesses using external technologies, human resources, etc., to promote the adoption of open innovation by large Japanese companies. Identified companies are interviewed, and those selected as success cases are published on the JOIC website[94]. As with the white papers, JOIC and NEDO lend neutrality and objectivity to their research, and the survey covers 10,000 companies, demonstrating a comprehensive scope. As a result, companies on this list receive +10 points for this research.

- Guidelines for cooperation between companies and R&D startups: Produced by the Ministry of Economy, Trade and Industry to promote partnerships between companies and R&D ventures for innovation. The 2018 second edition presents partnership models and success stories[93], with +10 points awarded to the profiled companies based on the objectivity provided by a national government publication.
- RIETI Policy discussion paper: Published by the Research Institute of Economy, Trade and Industry (RIETI), Japan's national economic policy think tank, which conducts research that contributes to the development of a dynamic economic and social structure through economic policy research focused on economic structural reform and administrative reform. For a 2011-2013 project titled "Empirical Studies on the International Comparison of Open Innovation," RIETI interviewed nine major Japanese manufacturers to summarize new developments in external partnerships and globalization around corporate R&D and business strategy[92]. Due to RIETI's neutrality as a national institute, the nine interviewed companies receive +10 points.
- Japan Open Innovation Prizes (2018 - 2022FY): Launched in 2018 by the Japanese government to recognize pioneering open innovation efforts with high social impact and sustainability. The awards are presented by ministers and leaders of business and academic associations, with the highest recognition being the Prime Minister's Award[102]. The publicly listed winners and then their company affiliations are assigned +6 points in this report. As the details of each recipient's contribution and their companies' commitment are unclear from publicly available information, the scores are set lower than other criteria.

The "Open Innovation Index" in this study can be defined for the 1,065 Prime Market companies as previously defined by compiling the scores from these sources. Of these, 293 companies receive non-zero scores, the distribution of which is shown in the histogram in Figure 5-3. Companies with scores of 11+ were extracted into a total of 47 companies and categorized by industry in Table 5-4. As a result, the electricity and gas, chemical, and electrical equipment sectors are prominent, while pharmaceuticals drop out compared to Table 5-3. This suggests that despite active open innovation efforts, pharmaceutical companies may not communicate externally or limit initiatives internally.

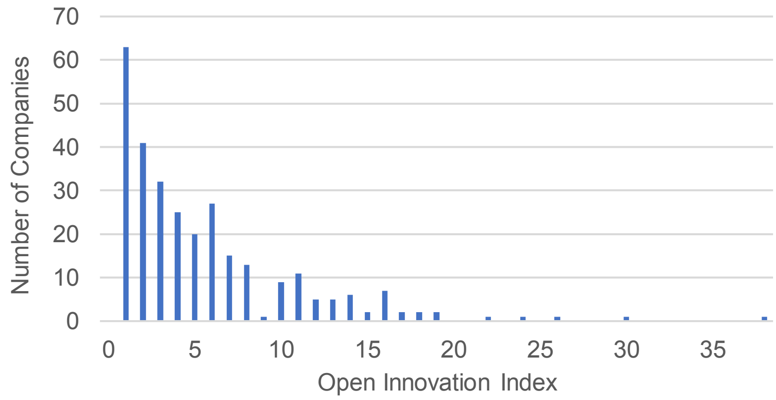


**Figure 5-3 Distribution of the number of companies per Open Innovation Index**

**Table 5-4 Companies and industries of high Open Innovation Index (OII)**

| Industry | | Company Name | OII |
|---|---|---|---|
| Electricity and Gas | Electricity and Gas | Osaka Gas Co., Ltd. | 38 |
| | Electricity and Gas | Kansai Electric Power Company, Incorporated | 17 |
| | Electricity and Gas | Chubu Electric Power Co., Inc. | 16 |
| | Electricity and Gas | Tokyo Gas Co., Ltd. | 15 |
| Chemicals and Materials | Chemicals | Mitsubishi Chemical Group Corporation | 19 |
| | Chemicals | POLA ORBIS HOLDINGS INC. | 16 |
| | Chemicals | Takasago International Corporation | 16 |
| | Chemicals | Shiseido Company, Limited | 15 |
| | Chemicals | Mitsui Chemicals, Inc. | 14 |
| | Chemicals | Asahi Kasei Corporation | 13 |
| | Chemicals | Sekisui Chemical Company, Limited | 12 |
| | Chemicals | Fujifilm Holdings Corporation | 11 |
| | Glass and Stone Products | AGC Inc. | 13 |
| | Textile Products | Toray Industries, Inc. | 11 |
| Machinery | Machinery | Komatsu Ltd. | 16 |
| | Machinery | Daikin Industries, Ltd. | 16 |
| | Machinery | Nachi-Fujikoshi Corp. | 13 |
| Equipment & Device | Electrical Equipment | Panasonic Holdings Corporation | 26 |
| | Electrical Equipment | Hitachi, Ltd. | 24 |
| | Electrical Equipment | Ricoh Company, Ltd. | 18 |
| | Electrical Equipment | Sharp Corporation | 16 |
| | Electrical Equipment | NEC Corporation | 14 |
| | Electrical Equipment | Kyocera Corporation | 14 |
| | Electrical Equipment | Yaskawa Electric Corporation | 13 |
| | Electrical Equipment | Konica Minolta, Inc. | 12 |
| | Electrical Equipment | Mitsubishi Electric Corporation | 11 |
| | Electrical Equipment | FANUC Corporation | 11 |
| | Transport Equipment | Toyota Motor Corporation | 20 |
| | Transport Equipment | Denso Corporation | 19 |
| | Precision Instruments | Olympus Corporation | 14 |
| | Precision Instruments | Shimadzu Corporation | 11 |
| | Other Manufacturing | Toppan Holdings Inc. | 18 |
| | Other Manufacturing | Dai Nippon Printing Co., Ltd | 11 |

| Industry | | Company Name | OII |
|---|---|---|---|
| Information and Communication (IC) | IC | KDDI Corporation | 22 |
| | IC | Mitsubishi Research Institute, Inc. | 17 |
| | IC | Nippon Telegraph and Telephone Corporation | 16 |
| Food | Food Products | Asahi Group Holdings, Ltd. | 14 |
| | Food Products | Ajinomoto Co., Inc. | 13 |
| | Food Products | Morinaga & Company, Ltd. | 13 |
| | Food Products | Kewpie Corporation | 11 |
| Transportation | Land Transport | East Japan Railway Company | 14 |
| | Air Transport | All Nippon Airways Co., Ltd. | 12 |
| Construction | Construction | Taisei Corporation | 12 |
| | Construction | TOKYU CONSTRUCTION CO., LTD. | 11 |
| | Construction | Daiwa House Industry Co, Ltd. | 11 |
| Pharmaceuticals | Pharmaceuticals | Shionogi & Co., Ltd. | 11 |
| | Pharmaceuticals | Daiichi Sankyo Company, Limited | 11 |

Based on the previous table, Osaka Gas Co., Ltd., which has the highest Open Innovation Index score among all industries, is selected as the primary case study in the next section. Four other companies are selected for their relatively high scores within their respective industries and their notable open innovation practices: Mitsubishi Chemical Group Corporation for its top score in the chemical industry; Toray Industries, Inc. for its well-known pioneering role in collaborative textile manufacturing; Komatsu, Ltd. for its high score in the machinery industry and its strong position as a construction equipment manufacturer in Japan; and Konica Minolta, Inc. for its famous active engagement in open innovation initiatives in digital imaging and printing solutions. These diverse case studies from different industries provide a comprehensive understanding of open innovation practices among major Japanese companies.

## 5.6. Case Studies

This section presents detailed case studies of five large Japanese companies (5.6.1-5.6.5) that have successfully implemented open innovation strategies, selected based on Section 5.5. Each case study examines the company's baseline information, external landscape, architectural decision options, and performance outcomes related to open innovation. The case studies provide insights into how these companies selected specific options for key architectural decisions defined in Section 5.4. The section concludes with a synthesis of the case study findings (5.6.6), which identifies commonalities and differences among the five companies and contributes to a comprehensive understanding of the critical factors of absorptive capacity systematically for successful open innovation practices in large Japanese firms. The analysis in each subsection of the case studies integrates information from multiple sources, which are collectively cited at the beginning of each subsection, to provide a comprehensive overview of the references used.

### 5.6.1. Osaka Gas Co., Ltd.

As mentioned in Section 5.5, Osaka Gas Co., Ltd. ("Osaka Gas") has the highest Open Innovation Index score and has been extensively studied in literature sources as a case example of open innovation in Japan. In this section, it is examined how Osaka Gas selects its architectural choices for implementing open innovation based on a variety of publicly available information, including all documents published by the company, case studies, books, and many scattered interviews with key people in Osaka Gas[84], [92], [95], [103], [104], [105], [106], [107], [108], [109], [110], [111], [112], [113], [114], [115]. Specifically, it is structured and analyzed to show how Osaka Gas selects the various options for the previously defined architectural decisions.

(Basic Information)

Founded in 1897, Osaka Gas is a leading Japanese company with approximately 5 million gas supply contracts in the Kansai area. The company has approximately 20,000 consolidated employees and a capital of approximately 132.1 billion Japanese yen. Its main businesses include domestic energy business (production, supply, and sales of city gas, gas equipment sales, gas pipeline construction, LNG sales, LNG transportation, LPG and industrial gas sales, power generation and electricity sales, etc.), overseas energy business (natural gas development, investment and energy supply, etc.), and lifestyle and business solutions (real estate development and leasing, IT services, sales of fine materials and carbon products, etc.). In terms of R&D, Osaka Gas focuses on core technology areas in which it has expertise, such as catalyst and materials technology, LNG vaporization/storage/cold energy utilization/receiving facility design and construction techniques, energy utilization technologies such as gas air conditioning systems, natural gas cogeneration, fuel cells, and fuel processing techniques. Data on total R&D expenditures and R&D intensity (R&D expenditures as a percentage of total revenues) over the past nine years are shown in Figure 5-4. The government research shows that the average R&D intensity for 18 companies in Japan's electric power, gas, heat supply, and water industries is 0.3%[99]. Thus, Osaka Gas has maintained an R&D intensity exceeding 0.5% over ten years and makes more significant R&D investments than the industry average.

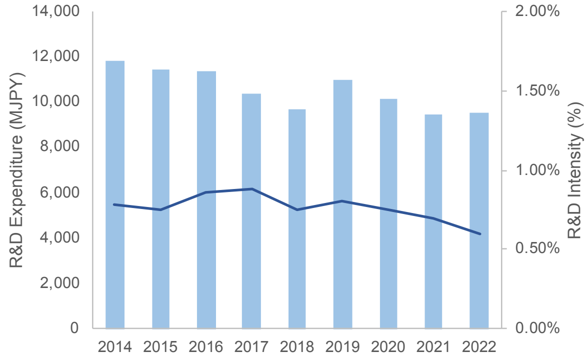


**Figure 5-4 R&D expenditures and R&D intensities (Osaka Gas)**

(External Landscape)

Osaka Gas began open innovation activities in 2009. One of the main reasons is that the company recognized the risks of business model disruption from electrification trends and related developments. The shift toward complete electrification of energy use, known as "all-denka," posed an existential threat to gas companies. As more homes and buildings switched their heating and cooking functions from natural gas to electric-powered alternatives such as heat pumps, gas companies lost a significant source of revenue. While the company traditionally worked with manufacturers to co-develop equipment and facilities, it realized that relying solely on traditional alliances would not adequately address these challenges. Osaka Gas anticipates that open innovation will enable it to leverage external ideas and technologies to diversify into related energy solutions.

(Architectural Decision)

The following is a summary table of the architectural decision options selected by Osaka Gas, followed by detailed explanations:

**Table 5-5 Architectural decision options (Osaka Gas)**

| Decision Variable | Selected Decision Option |
|---|---|
| Strategy | [A1] Published Long-term Strategy |
| Purpose | [B2] Accelerate R&D<br>Sub: [B1] Reduce Expenses and [B6] Upgrade Final Products |
| Organizational Structure | [C1] New Dedicated Team |
| Learning Culture* | [D2] Bottom-Up |
| Needs* | [E1] R&D Identifies Needs |
| Channels | [F4] Hiring Agencies<br>Sub: [F1] Searching Public Information and<br>[F3] Posting Needs Online |
| External Partner Candidates | [G3] Horizontal Multiple Partners |
| Technology Assessment | [H1] Evaluated By R&D or Open Innovation Team |
| Knowledge Management | No Data |
| Project Budget | No Data |
| Project Timeline | [K1] Prioritized Internal Schedules |

* Architectural decisions prioritized by Osaka Gas

- Strategy: [A1] Published long-term strategy is selected because open innovation is directly mentioned as a key method for rapid and efficient technology development in Osaka Gas's medium-term plan entitled "Field of Dreams 2020." The 2023 Annual Management Plan also mentions using open innovation to create new businesses, citing areas like phase-change materials and energy storage. Executives internally define an open innovation vision and policy aligned with management strategies each year to demonstrate leadership and commitment to open innovation projects.

- Purpose: [B2] Accelerating R&D is the main purpose initially because of the negative impact of the consumer shift from gas to electrification. Osaka Gas also expects to improve product performance levels, such as fuel cell efficiency[B6] and reduction of R&D expenses[B1], as a secondary effect of the open innovation project. They believe the tight focus on pursuing the 3 "Ups" of speed, performance, and cost competitiveness will lead them to aggressively tap external technologies to strengthen internal R&D.

- Organizational structure: [C1] A dedicated, cross-functional new Open Innovation Office was created in 2010 as an internal innovation agent to coordinate external knowledge inflows. The Open Innovation Office is now located within the Innovation Promotion Department, established in 2018. A dedicated, neutral office functionally independent of the business units helps explore "out-of-the-box" ideas.

The office leverages staff with different specializations from different R&D areas - information technology, materials science, etc. This enables the company to understand and translate the needs of the business units when scouting for external knowledge and innovation.

- Learning culture: [D2] Although the initial top-down mandate is in place, Osaka Gas believes that the bottom-up culture among developers and researchers is critical to getting internal buy-in that open innovation strengthens, not threatens, internal technical strengths. Explaining the importance of open innovation by the open innovation office and having R&D voluntarily try it out created the internal momentum for open innovation. Osaka Gas regards this cultural perspective as the primary driving force behind the implementation of open innovation and the enhancement of its absorptive capacity.

- Needs: [E1] Each R&D department identifies the technology gaps and external solutions needed based on the challenges they face in their ongoing projects. They submit these needs to the Open Innovation Office, whose staff understands the underlying science and translates it into specifics for the external search belief. Two-way communication then facilitates this alignment of technical needs between individual R&D groups and the office, enabling joint ownership of meeting technology-specific needs by looking outward while strengthening internal development paths. Osaka Gas recognizes that accurate identification of needs is essential for effective open innovation projects. The Open Innovation Office always works to teach each R&D department to identify its core competencies. This enhances their ability to identify missing pieces, activating subsequent communication between the R&D department and the office.

- Channels: [F4] Osaka Gas primarily uses specialized external agencies such as NineSigma Inc. to identify potential partners with relevant capabilities. These innovation agents are valued for their expertise in deeply understanding Osaka Gas's needs and searching globally for matching technologies to advise on likely solutions. Other exploration approaches include internal searches of academic papers and patent databases[F1] to uncover technologies owned by various external parties and targeted online posting of technology needs on the Osaka Gas website[F3] to attract prospects who proactively reach out with potentially relevant solutions.

- External Partners: [G3] Casting the net widely across large corporations, startups, SMEs, academic labs, and global players allows niche capabilities to be tapped across vertical, geographic, and size boundaries. That is, Osaka Gas does not select partners based solely on their existing relationships; they believe that diverse partners can mitigate the risk of over-dependence. They also have formed several partnerships in Silicon Valley that provide early signals of emerging technologies for new offerings.

- Technology Assessment: [H1] The Open Innovation Office conducts an initial screening of identified external technologies and presents shortlisted technologies to internal groups for further feasibility assessment. If the potential fit appears high, they proceed with the implementation of open innovation projects. It is assumed that the cross-functional expertise within the office and individual R&D groups allows for detailed assessment of fit with specified needs, and their clear processes are followed to screen externally sourced technologies prior to co-development investment.
- Knowledge Management and Project Budget: The publicly available information does not directly reference the knowledge management initiative and the project budget at Osaka Gas.
- Project Timeline: [K1] There are no direct mentions of the timelines. Considering the information that they focus on the change of their internal R&D schedules, it can be guessed that they believe smooth assimilation of externally sourced solutions relies on synchronization with internal development cycles and product roadmaps. Thus, the option of following the internal timelines is selected, which allows for integrated planning, proper coordination, and R&D improvement.

(Performance)

Osaka Gas's approach to open innovation has produced tangible results over more than a decade of progress since it began in 2009. They mainly evaluate their open innovation projects by the number of concrete innovations. Specifically, as of 2021, the company has aggregated a total of 890 technology needs submissions from various internal groups across the company and received approximately 8,200 suggestions from external parties. More than 130 of these have resulted in concrete innovations through co-development and open innovation projects. They acknowledge that the success rate for R&D through open innovation is higher compared to the success rate for conventional R&D. Moreover, they have achieved the intended objectives of accelerating technology development speed, upgrading product performance, and boosting cost competitiveness.

### 5.6.2. Mitsubishi Chemical Group Corporation

Mitsubishi Chemical Group Corporation ("MCGC") is selected for this case study because it has the highest Open Innovation Index score within the chemical industry, as described in Section 5.5. This section examines the architectural variable choices made by MCGC in implementing open innovation practices, drawing implications from various published sources, including MCGC's corporate documents for investor relations and interview articles with executives and employees involved in R&D[92], [116], [117], [118], [119], [120], [121], [122], [123], [124], [125], [126], [127]. The analysis is structured to show how MCGC chooses different options in relation to the previously defined architectural choices, providing a comprehensive understanding of the company's approach to open innovation.

(Basic Information)

MCGC is a specialty materials company operating in six business areas: Specialty Materials, Industrial Gases, Health Care, MMA, Petrochemicals, and Carbon Products. With a strong foundation in chemistry, MCGC aims to lead the realization of KAITEKI, a vision of a sustainable future where people, society, and the planet thrive in harmony. The company provides innovative solutions that contribute to the well-being of all stakeholders and the sustainability of society and the earth. The slogan is "Science. Value. Life." which means that innovation driven by science is the key driver for MCGC to create value and realize KAITEKI. As of 2022, MCGC has a consolidated number of employees of 68,639 and generated sales of 4,634.5 billion Japanese yen. In terms of R&D and innovation, MCGC has created a technology platform that consolidates the core technologies of its constituent companies, including Mitsubishi Chemical, Mitsubishi Plastics, Mitsubishi Rayon, and Nippon Synthetic Chemical Industry. This platform serves as a foundation for value creation in a wide range of fields. The technology platform consists of three areas: Molecular Design Technology (catalysts, organic materials, inorganic materials, polymers, and biotechnology), Functional Design Technology (spinning, composites, film production, and molding), and Common Basic Technology (digital materials science, analytical properties, and process technology). Figure 5-5 shows MCGC's total R&D expenditures and R&D intensity (the ratio of R&D expenditures to total sales) over the past decade. The ratio has consistently hovered around 4%. (Note that data before 2014 complies with Japanese accounting standards, while data from 2015 onward adhere to International Financial Reporting Standards

(IFRS).) According to government research, the average R&D intensity for Japan's comprehensive chemical industry ranges from 3.9% to 8.1%, indicating that MCGC's R&D investment is in line with the industry average[99].

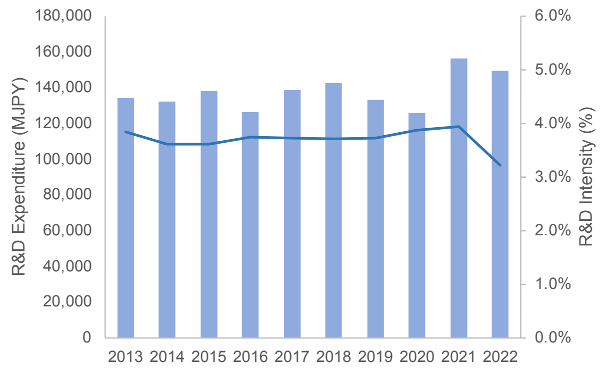


**Figure 5-5 R&D expenditures and R&D intensity (MCGC)**

(External Landscape)

The external landscape described here primarily reflects the challenges and market dynamics faced by the former Mitsubishi Chemical Corporation around 2013, prior to the formation of the current MCGC. Its R&D focus at that time has evolved over time, reflecting changing industry and market demands. In the past, the company's R&D efforts were primarily focused on petrochemicals, which required the development of large-scale infrastructure for manufacturing. However, as the company expanded into new areas such as information electronics and performance chemicals, the nature of its R&D activities began to shift. These new areas require the company to provide materials for rapidly evolving industries, which significantly accelerate the pace of development and necessitate changes in the company's approach to R&D.

(Architectural Decision)

The following is a summary table of the architectural decision options selected by MCGC, followed by detailed explanations:

**Table 5-6 Architectural decision options (MCGC)**

| Decision Variable | Selected Decision Option |
|---|---|
| Strategy | [A1] Published Long-term Strategy |
| Purpose | [B2] Accelerate R&D<br>Sub: [B1] Reduce Expenses (Financial Benefits) and<br>[B3] Shorten Timelines Except for R&D |
| Organizational Structure | [C1] New Dedicated Team |
| Learning Culture | [D1] Top-Down |
| Needs* | [E1] R&D Identifies Needs |
| Channels | [F4] Hiring Agencies<br>Sub: [F2] Investigating Existing Business Partners |
| External Partner Candidates | [G3] Vertical Multiple Partners |
| Technology Assessment | [H1] Evaluated By R&D or Open Innovation Team |
| Knowledge Management | [I2] Moderate Knowledge Management Capabilities |
| Project Budget | No Data |
| Project Timeline* | [K2] Prioritized Partner Preferences |

* Architectural decisions prioritized by MCGC

- Strategy: [A1] MCGC's commitment to open innovation is clearly reflected in its published long-term strategies. The company's current mid-term management plan, "Forging the future", which was set for 2021, highlighted the importance of open innovation in the context of R&D efficiency. MCGC expected to streamline processes by actively leveraging open innovation through partnerships with universities, ventures, and companies worldwide. In addition, the company's innovation strategy explicitly states the need to "accelerate growth by combining internal R&D with open innovation" as one of its main directions. The CTO's message in the integrated report also clearly mentions the need to expand open innovation on a global scale.

- Purpose: [B2] MCGC emphasizes the importance of strategically combining internal R&D with open innovation by collaborating with universities, startup companies, corporate partners, and government agencies to promote innovation, focusing on improving the quality and speed of innovation. Among the four innovation pillars established by MCGC, "Focus on End Markets" aims to deliver value quickly through agile product development in collaboration with end customers. The company is also introducing the "innovation sandbox system" to quickly test the effectiveness of new ideas that go beyond the scope of existing businesses. These initiatives are primarily aimed at improving speed not only in the R&D department but also in other divisions[B3]. In addition, as mentioned above, the medium-term management plan indicates that open innovation is expected to streamline the R&D process, improving the EBITA margin. It implies that management views open innovation as a means to achieve financial benefits[B1].

- Organizational Structure: [C1] In 2010, the R&D Strategy Office was established within the corporate strategy and corporate divisions of the former Mitsubishi Chemical Corporation to assume the role of open innovation. Following the integration of the three companies (Mitsubishi Chemical, Mitsubishi Plastics, and Mitsubishi Rayon) in 2017, an organizational restructuring took place, and then the Frontier & Open Innovation Headquarters was established within the Innovation Division. In addition, the Science & Innovation Center currently operates as an independent division of the center, described below.

- Learning Culture: [D1] MCGC takes a top-down approach to its learning culture. In the past, in Mitsubishi Chemical, top management strategically determined focus areas to build the next generation of businesses. The CEO and the management team determine the allocation of resources, and the R&D team follows such top-down cultures.

- Needs: [E1] Identifying the company's technology needs is a primary decision variable for MCGC. The company has been working to build its technology portfolio for many years, and the resulting intellectual capital has become a significant driving force for the company. That is, MCGC recognizes the importance of carefully considering which compounds to develop and the need to nurture its core technologies over time. The company believes its strength lies in its ability to consider how to create specialty chemical materials that can be sufficiently black-boxed. However, MCGC recognizes that it must work with external partners to expand the applications of these compounds, particularly in areas such as coating and dispersion technologies. Therefore, MCGC has a deep understanding of its own needs based on its own capabilities.

- Channels: [F4] MCGC forms strategic partnerships with startup companies through investments made by its corporate venture capital arm, Diamond Edge Ventures, established in 2018. These partnerships result in the development of new materials and other innovations. The company recognizes the importance of not only collaborating with startups but also supporting their growth and adding value to be selected as a partner. The venture division is responsible for creating the framework and opportunities, while the actual deployment is handled by the business divisions in collaboration[F2]. In some cases, the R&D department independently identifies the required technologies. Their Science & Innovation Center (SIC) serves as a hub for MCGC's medium- to long-term R&D activities, aiming to become a world-class R&D department that continuously generates innovation and contributes to society. The SIC creates opportunities for casual information exchange and open technology sharing with external parties, responding to employees' needs to obtain live information and sense new perspectives and demands.

- External Partner Candidates: [G3] MCGC collaborates with a wide range of partners, including universities, ventures, and other companies. Furthermore, through its CVC activities, the company realizes horizontal multiple partnerships.

- Technology Assessment: [H1] Although the way to conduct assessment in the current organization is not clear, in the past Mitsubishi Chemical uses the three criteria of "sustainability," "health," and "comfort" to decide whether to proceed with a research project. Having clear criteria helps the R&D department justify pursuing a project based on its potential applications and relevance to sustainability. Especially in the early stages of R&D, these criteria are always applied to ensure alignment with the company's direction, meaning that technology assessment is primarily led by the R&D functional department.

- Knowledge Management: [I2] While there is no information to identify specific knowledge management initiatives in the implementation of open innovation, MCGC places a high priority on IP management and treats its IP strategy on par with its innovation strategy. Due to the large number of subsidiaries, the company has established mechanisms and rules for the mutual use of IP owned by companies within MCGC, as well as cooperation to counter the IP of others. One of the key features of MCGC's strategy is the development of product-specific IP strategies, taking into account the diversity of products ranging from commodity materials to high-value-added products for specific applications. The IP department works closely with the business and R&D departments to clarify the business objectives for each product, accurately understand the market environment, technological trends, and IP landscape, and then determine IP measures and formulate and implement IP strategies.

- Project Budget: The publicly available information does not directly reference the project budget at MCGC.

- Project Timeline: [K3] The sense of time is a primary decision variable for MCGC in open innovation projects. The company emphasizes the importance of researchers having a clear understanding of the timeline for completing a project based on the timing of commercialization, rather than vague estimates. MCGC recognizes that the timing of a business is determined by societal needs, not by the company itself. The company believes that making researchers aware of the timeline and not allowing them to be lenient will lead to a departure from the "all-in-house" mentality.

(Performance)

MCGC has achieved notable successes through its open innovation initiatives, as evidenced by the recognition and partnerships formed in recent years. One significant achievement is the joint project with Astellas Pharma Inc. and CKD Corporation, winning the Environment Minister's Award at the 5th Japan Open Innovation Awards hosted by the Cabinet Office of Japan. The project, titled "Practical application of PTP packaging using environmentally friendly biomass plastics," is recognized for the successful commercialization of the product through the collaboration of three companies from different industries. The open innovation approach to commercializing bioplastics is praised for its excellence, and the project is expected to raise awareness of reducing environmental impact in the pharmaceutical industry and encourage the spread of similar initiatives. In addition, MCGC's corporate venture capital arm has been actively engaged with many startups, and investments have been decided in nine of them. The strengths of each startup and the details of the collaborations have been well received. For example, the partnership with DAIZ Inc., a plant-based protein food developer, combines DAIZ's technology with MCGC's expertise in oil and fat development to successfully add juiciness to plant-based meat products. These achievements demonstrate MCGC's commitment to leveraging open innovation to create value and address societal needs.

### 5.6.3. Toray Industries, Inc.

Toray Industries, Inc. ("Toray") is widely recognized as a pioneer in collaborative textile manufacturing technologies. The company's collaborative development of globally popular products, such as Uniqlo's HEATTECH and Ultra Light Down, and the extensive use of its carbon fiber in the structural components of the Boeing 787 are testaments to Toray's effective practices of openness. This case study examines the architectural choices Toray made to implement open innovation, drawing insights from a variety of publicly available sources, including investor materials, case studies, books, and interviews with the company's CTO[90], [128], [129], [130], [131], [132], [133], [134], [135], [136],

[137], [138]. By systematically examining how Toray selected specific options for the key architectural decisions outlined above, we aim to identify the essence of the company's approach to open innovation.

(Basic Information)

Toray, founded in 1926, is Japan's preeminent textile manufacturer, with sales of approximately 2,489 billion Japanese yen and a consolidated workforce of approximately 48,700, as of 2022. The company's core businesses include producing, processing, and selling fibers such as nylon and polyester, functional chemicals, and carbon fiber composites. Toray's R&D efforts are guided by its corporate slogan, "Innovation by Chemistry," and focus on core technologies in organic synthetic chemistry, polymer chemistry, biotechnology and nanotechnology. By leveraging these core technologies and advancing the integration of elementary technologies such as polymerization, spinning, advanced fiber processing, film production, and organic synthesis, Toray creates and commercializes cutting-edge materials in a wide range of business areas, including fibers, films, chemicals, resins, electronic information materials, carbon fiber composites, and pharmaceuticals. As part of its R&D and technology development strategy, Toray plans to invest a total of 220 billion Japanese yen in R&D over the three years from fiscal 2023, with a policy of actively allocating resources to large-scale, high-potential topics. Figure 5-6 shows the company's total R&D spending and R&D intensity over the past decade, which has been consistently around 3%. (Note that data before 2019 complies with Japanese accounting standards, while data from 2020 onward adhere to IFRS.) According to government statistics, the R&D intensity of Japan's textile industry ranges from 1.7% to 2.3%, while that of the overall chemical industry ranges from 3.9% to 8.1%[99]. This positions Toray as a standout in terms of R&D investment within the textile industry, with an investment level comparable to that of the comprehensive chemical industry.

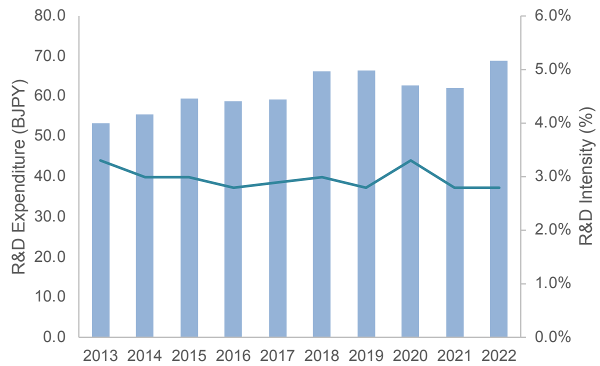


**Figure 5-6 R&D expenditures and R&D intensities (Toray)**

(External Landscape)

In 2002, Toray faced a financial crisis and posted its first net loss since its founding. This crisis prompted the management team to embark on a comprehensive management reform, which began by recognizing the need to address the deep-rooted Not-Invented-Here mentality within the organization. That is, the company realized that relying solely on internal R&D often meant longer development times and less chance of success. By collaborating with external partners and leveraging their expertise, resources, and capabilities, Toray has sought to accelerate its innovation process and increase the likelihood of success. This strategic reorientation led to Toray's subsequent adoption of open innovation as a core pillar of its mid-term management plan.

(Architectural Decision)

The following is a summary table of the architectural decision options selected by Toray, followed by detailed explanations:

**Table 5-7 Architectural decision options (Toray)**

| Decision Variable | Selected Decision Option |
|---|---|
| Strategy | [A1] Published Long-term Strategy |
| Purpose | [B4] Enhance R&D Capabilities<br>Sub: [B2] Accelerate R&D and [B6] Upgrade Final Products |
| Organizational Structure | [C3] Additional Responsibilities on Personnel |
| Learning Culture | [D1] Top-Down |
| Needs* | [E2] Several Departments (not only R&D) Identify Needs |
| Channels | [F2] Investigating Existing Business Partners<br>Sub: [F4] Hiring Agencies |
| External Partner Candidates* | [G1] Vertical Multiple Partners |
| Technology Assessment | [H1] Evaluated By R&D or Open Innovation Team |
| Knowledge Management | [I1] High Knowledge Management Capabilities |
| Project Budget | No Data |
| Project Timeline | [K2] Prioritized Partner Preferences |

* Architectural decisions prioritized by Toray

- Strategy: [A1] Toray's medium-term management plan, "New Toray 21," established immediately after the company reported a net loss, emphasizes the need to move away from self-reliance. The subsequent mid-term plan, "AP-G 2013" (Action Program for Growth 2013), explicitly states the promotion of open innovation. Therefore, the published long-term strategy is selected in this architectural decision.

Although more recent medium-term plans do not directly mention the word "open innovation," Toray's latest long-term management vision, "TORAY VISION 2030," outlines a policy of actively allocating resources to future major topics in R&D, and the current mid-term plan, "AP-G 2025," also states that 80% of R&D spending will be invested in growth areas such as sustainability and digital innovation. Toray's R&D strategy overview document also explicitly focuses on "strategic open innovation" based on their basic policy of creating new products by integrating technologies and pushing the limits.

- Purpose: [B4] Enhancing R&D capabilities is the primary purpose, as Toray strongly emphasizes moving away from self-reliance due to its deteriorating business performance in the 2000s. The company's corporate slogan, "Innovation by Chemistry," underscores its goal of solving global problems through the power of chemistry. To achieve this, Toray believes in the need to gather knowledge in various technological fields rather than focusing on a single area. This also leads to the company's goal of accelerating and promoting research[B2] and diversifying its end products[B6] by combining different fields and strengthening collaboration, as shown in Toray's R&D strategy.

- Organizational Structure: [C3] Additional responsibilities on each researcher for an open innovation project are selected. Toray consolidates its R&D functions, such as research divisions, development centers, and engineering departments, into a single organization called the "Technology Center," which oversees R&D for the Toray Group. The Technology Center brings together experts with diverse knowledge and experience, fostering an environment conducive to the generation of ideas and the development of versatile manufacturers capable of understanding multiple fields. Toray believes that this centralized R&D structure is effective in applying a single material to various businesses. Therefore, they do not set up a new dedicated team for the open innovation project. In addition, they encourage the entrepreneurial spirit of young researchers and intentionally let them do some skunk work by encouraging them to spend about 20% of their working time on research projects without reporting to their supervisors. They believe that the opportunity to conduct research based on their own ideas motivates researchers.

- Learning Culture: [D1] Toray adopts a top-down approach to promote a company-wide change in mindset from its previously strong self-reliance. In the early 2000s, top management, including the president, executives, and research directors, frequently visited research institutes to communicate the change in direction to front-line employees. They encouraged a transition from isolated research to speed-conscious research. Toray also actively promotes external collaborations with companies such as Uniqlo and Samsung Group, announcing these partnerships in the media to promote internal changes in mindset.

- Needs: [E2] Toray mainly uses a backcasting approach based on end-user needs and business partners' needs, as shown in the examples of Uniqlo (Fast Retailing. Co., Ltd.) and Boeing. The company works with customers in the supply chain from the product design stage to develop solutions to problems. Rather than taking a bottom-up approach to business development based on its own materials and technologies derived from R&D, Toray identifies end-user needs and develops materials accordingly. The company believes that open innovation is most effective when Toray has strengths in core basic technologies and some of the supporting peripheral technologies while seeking specific peripheral technologies that it lacks. Toray considers this process of identifying needs to be the most important factor because they clearly distinguish between the open and closed areas in open innovation by first turning their attention inward to identify their own core technologies.
- Channels: [F2] Toray focuses on collaborating with partner companies on prototyping and evaluation to conduct research on future material creation, mainly at the Technology Center, consisting of the Automotive & Aircraft Center (A&A Center) and the Environment & Energy Center (E&E Center). In addition, the "R&D Innovation Center for the Future" was established to transform Toray's basic technologies into innovative products through an open laboratory format and demonstration capabilities. The company also uses technology scouting to explore superior technologies from other companies, utilizing matching services provided by third-party institutions and intermediaries with global networks[F4].
- External Partner Candidates: [G1] As described above, Toray primarily focuses on multiple vertical collaborations within the supply chain. The company believes that involving similar material manufacturers can prevent each party from fully utilizing its capabilities. Toray collaborates with customers from the product design stage to create problem-solving solutions based on end-user needs rather than taking a bottom-up approach based on its own materials and technologies. They see such partner selection as a critical primary driver for implementing open innovation to improve their competitiveness.
- Technology assessment: [H1] Although not explicitly stated, it is reasonable to

assume that R&D conducts technology assessment given that Toray's R&D functions are consolidated within the Technology Center.

- Knowledge management: [I1] Toray clearly maintains a "closed" in-house development approach for its core technologies and does not open everything up to external parties. The company has established a clear patent responsibility system: Toray and its major affiliates appoint technical department heads as patent managers and hold regular "patent meetings" with members of the IP, research, technology development, and sales departments to promote activities related to patent application, rights acquisition, defense, and utilization. The company usually focuses on thoroughly concealing and "black-boxing" production methods and know-how accumulated through troubleshooting at its parent plants. In this way, Toray strategically balances patent applications, trade secrets and their openness. (As a result, the company ranks 16th in the Nikkei "Intellectual Property Management Ranking" and tops both the "Industry Deterrence Ranking" and the "Patent Asset Scale Ranking" for the fiber, paper, and pulp industry.) The company believes that while promoting an open innovation project to expand its business opportunities, a combination of strong production technology, strategic patenting, and trade secret protection is crucial to generating profits from R&D results and maintaining entry barriers against competitors.

- Project Budget: While Toray believes that budget decisions for open innovation projects should be made based on a comprehensive assessment of cost-effectiveness, there is no publicly available information on budget management.

- Project Timeline: [K2] Toray believes it is important to establish a significant barrier to entry for raw material formulation and manufacturing processes. Toray has consistently met these challenging requirements in a timely manner through open innovation projects with aircraft manufacturers, such as the development of carbon fibers with Bowing. The certification process for aerospace materials involves extensive testing and is time-consuming, but Toray has persevered in its efforts. As a result, they primarily prioritize partners' timelines in open innovation projects as an architectural decision variable.

(Performance)

Toray does not publicly disclose the number of open innovation projects implemented or the number of successful cases. As a specific quantitative performance measure, they cite an increase in the number of patents held. In the fiscal year 2004, Toray held 3,235 domestic patents and 2,610 foreign patents. However, with the advancement of open innovation, the company has experienced a reduction in research and development periods and an expansion of research areas. As a result, in the fiscal year 2014, the number of domestic patents increased to 5,639, and foreign patents reached 6,612. Moreover, regarding the company's financial loss in 2002, Toray attributed its subsequent business recovery and successful management realignment not only to the implementation of open innovation but also to various management efforts.

### 5.6.4. Komatsu, Ltd.

Komatsu, Ltd. ("Komatsu") has a high Open Innovation Index score in the machinery industry, as described in Section 5.5, and has established a strong position as a construction equipment manufacturer in Japan. This case study examines the architectural choices Komatsu has made in implementing open innovation. The analysis is based on various publicly available information sources such as Komatsu's corporate documents, interview articles with the CTO and R&D staff, case studies, and books [90], [139], [140], [141], [142], [143], [144], [145], [146], [147], [148], [149], [150], [151], [152]. The analysis of how Komatsu selects different options provides some insights into the company's approach to open innovation and the factors that contributed to its success.

(Basic Information)

Founded in 1921, Komatsu is a global leader in the manufacture and sale of construction and mining equipment, with a strong presence on job sites and in mines around the world. The company's core business revolves around providing machines that excel in a variety of demanding environments, contributing to the development of infrastructure and the extraction of essential resources. As of 2023, with consolidated net sales of 3,543 billion Japanese yen, Komatsu generates 90% of its sales from the construction, mining, and utility equipment business, which includes the manufacture and sale of construction and mining machinery, forklifts, forestry machines, and other equipment used in various applications. The company employs 64,343 people worldwide (as of 2023). Komatsu's R&D efforts focus on creating key components that determine the performance of its construction and mining equipment products. This includes in-house development and production of critical elements such as engines, hydraulic components, and electronic controls. By maintaining control over these core technologies, Komatsu ensures the quality, reliability, and competitiveness of its offerings. Over the past decade, Komatsu's R&D expenditures and R&D intensity have followed the trajectory shown in Figure 5-7.

The company's R&D intensity has been between 2% and 3%, although it has shown a downward trend in recent years. Komatsu's R&D intensity is relatively low compared to the average R&D intensity of 3.6-4.4% in the production machinery manufacturing industry, which includes construction machinery manufacturers[99]. It is important to note that the production machinery manufacturing industry includes a wide range of manufacturing industries, including not only construction machinery but also industries such as semiconductor and flat panel display manufacturing equipment, which are expected to have relatively high R&D intensities. This diversity within the industry may explain the observed difference in R&D intensity between Komatsu and the industry average.

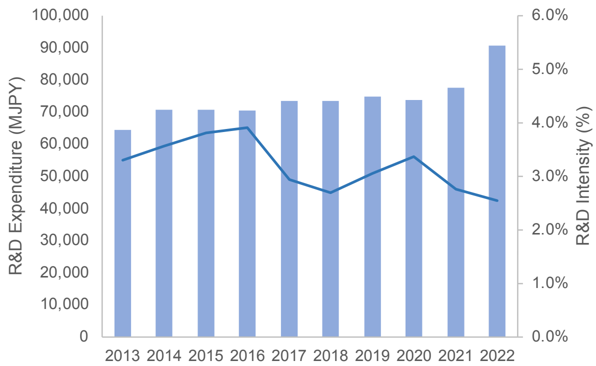


**Figure 5-7 R&D expenditures and R&D intensities (Komatsu)**

(External Landscape)

Komatsu has a long history of actively embracing new ideas and technologies. Komatsu's pioneering IoT system, "Komtrax," introduced in 2001, remotely collects and visualizes machine data from its global construction equipment fleet. This innovative, pre-digital-era solution was the result of a single engineer's idea to create customer value. Then, the global financial crisis of 2008 and the devastating Great East Japan Earthquake of 2011 left a profound impact on the industry and society as a whole. These events made Komatsu's former CEO acutely aware of the importance of collaborating with external partners to drive innovation and stay ahead in a rapidly evolving market. Recognizing that the traditional approach of relying solely on in-house R&D might not be sufficient to address the multiple challenges facing the industry, the CEO made a strategic decision to prioritize open innovation in 2012.

(Architectural Decision)

The following is a summary table of the architectural decision options selected by Komatsu, followed by detailed explanations:

**Table 5-8 Architectural decision options (Komatsu)**

| Decision Variable | Selected Decision Option |
|---|---|
| Strategy | [A1] Published Long-term Strategy |
| Purpose | [B6] Upgrade Final Products<br>Sub: [B2] Accelerate R&D and [B4] Enhance R&D Capabilities |
| Organizational Structure | [C1] New Dedicated Team |
| Learning Culture | [D2] Bottom-Up |
| Needs* | [E3] Management Defines Vision |
| Channels | [F4] Hiring Agencies<br>Sub: [F2] Investigating Existing Business Partners |
| External Partner Candidates | [G3] Vertical Multiple Partners |
| Technology Assessment | [H3] Proof of Concepts |
| Knowledge Management | [I2] Moderate Knowledge Management Capabilities |
| Project Budget | No Data |
| Project Timeline* | [K2] Prioritized Partner Preferences |

* Architectural decisions prioritized by Komatsu

- Strategy: [A1] Komatsu's commitment to open innovation is clearly reflected in its published long-term strategies. Based on the CEO's decision to pursue open innovation projects in 2012, in 2013 the company announced a new three-year medium-term management plan called "Together We Innovate GEMBA Worldwide," which emphasized innovation-driven growth as one of its three pillars. The plan stated that Komatsu must combine its core technologies with external knowledge, information, and technologies to accelerate technological innovation and create new customer value. This strategic direction has been consistently maintained in subsequent mid-term management plans. The most recent mid-term plan for 2022, "DANTOTSU Value - Together, to 'The Next' for Sustainable Growth," also prioritizes innovation-driven growth, highlighting initiatives such as digital solutions for construction sites and the development of electric construction equipment through cooperation with overseas companies. Komatsu's R&D strategy also emphasizes the importance of open innovation, which aims to accelerate technological innovation by integrating internal core technologies with external insights. By clearly articulating its commitment to open innovation in these published long-term strategies, Komatsu demonstrates its strategic focus on leveraging external partnerships to drive growth and innovation.

- Purpose: [B6] Komatsu's first and foremost purpose for engaging in open innovation is to enhance its end products by incorporating technologies that cannot be developed solely in-house. This goal was at the core of the CEO's decision to steer the company toward open innovation in 2012, as he saw that the rapid development of information and communication technologies was transforming the construction equipment industry. By integrating new technologies into its products through external collaborations, Komatsu aims to deliver greater value to its customers. In addition to this main objective, Komatsu's R&D strategy also emphasizes the goals of accelerating technological innovation through open innovation[B2] and strengthening the company's resilience by developing human resources capable of promoting open innovation[B4]. The company actively implements special programs to cultivate open innovation skills among its employees, a policy that is clearly stated in its medium-term management plans.

- Organizational Structure: [C1] Recognizing the need to rapidly integrate its core technologies with the latest external technologies, Komatsu established the Chief Technology Officer (CTO) Office as the headquarters for open innovation projects in April 2014. By establishing a dedicated team that reports directly to the CTO and has the ability to make quick decisions when opportunities arise, Komatsu has created an organizational structure that facilitates the acceleration of open innovation and the integration of external knowledge into its existing technologies. The CTO office is separate from the existing R&D department, which continues to focus on R&D for the core construction equipment business. This organizational structure enables Komatsu to pursue both "deepening knowledge" in its existing fields and "exploring knowledge" in new fields, effectively implementing an ambidextrous management approach. The CTO Office, which now has 30-40 members, works with Komatsu's global network of employees to gather information and promote partnerships both domestically and internationally.

- Learning Culture: [D2] Komatsu's learning culture is characterized by a bottom-up approach that is deeply rooted in its "Gemba" (worksite) philosophy. The company's employees, including management, are passionate about visiting customers' worksites to interact directly with customers and understand their challenges. This hands-on approach to problem-solving is ingrained in Komatsu's corporate culture and fosters an environment that is receptive to new ideas from employees at all levels. The development of the Autonomous Haulage System for mining dump trucks is an example of how this gemba-driven culture enables innovation. Through frequent visits to mining sites, Komatsu is able to identify the appropriate U.S.-based startup with expertise in the communication technologies essential to the company.

- Needs: [E3] Komatsu's approach to identifying its technology needs is driven by a strong emphasis on its vision for the future. The CTO Office invests considerable effort in creating videos and computer graphics that visualize its vision for the next 5-10 years, targeting employees rather than customers. These visual aids help the employees understand the direction in which they should be working and clarify what needs to be developed internally and what should be acquired through open innovation. The company regards the vision as the primary factor for proceeding with open innovation projects.

- Channels: [F4] Komatsu actively engages in face-to-face networking with hub universities and venture capitalists to explore potential partnership opportunities around the world. The CTO Office staff, who are "connoisseurs" with a deep understanding of Komatsu's business, technology, and workplaces and who have diverse development experience, can constantly access such external hub parties to establish meaningful connections with high-potential external candidates for collaborative projects. In addition, the CTO Office also gathers information on the latest technologies from around the world, with team members building networks in Silicon Valley, the East Coast of the United States, Israel, and Europe [F2].

- External Partner Candidates: [G3] Komatsu focuses primarily on collaborating with promising startups through the use of universities and venture capitalists, emphasizing horizontal integration. In the United States, there is an abundance of startups emerging from university research labs, leading to rapid expansion of Komatsu's network through a domino effect. Komatsu also allows competition with its existing R&D departments when collaborating with external partners, fostering a dynamic and innovative environment, meaning that its partners can be categorized as horizontal relationships.

- Technology Assessment: [H3] Komatsu places great emphasis on conducting proof of concept (PoC) trials when assessing the potential of new technologies. By focusing on PoCs, the company can quickly evaluate the feasibility and practicality of integrating external technologies into its products and services. The PoCs also enable Komatsu to identify and address any challenges or limitations early in the evaluation process, ensuring that the selected technologies are aligned with the company's goals and can be effectively implemented in its offerings.

- Knowledge Management: [I2] While there is limited information available on Komatsu's knowledge management practices specifically related to open innovation, it can be inferred that the company employs a moderate level of knowledge management strategies based on its approach to patent protection during the development of its Komtrax system. In the development of Komtrax, Komatsu carefully and systematically secured patents throughout the development process by targeting these essential patents and actively pursuing rights through divisional applications, indicating a certain level of knowledge management competence.
- Project Budget: There is no publicly available information regarding Komatsu's specific approach to project budgets for open innovation initiatives.
- Project Timeline: [K2] Komatsu's open innovation efforts are primarily focused on collaborating with startups, and the company strongly emphasizes maintaining the flexibility to operate independently of existing development schedules. This approach allows Komatsu to fully respect the timelines of its collaboration partners, ensuring that the pace of innovation is not hindered by internal constraints. By prioritizing the preferences of its external partners, Komatsu can foster a more agile and adaptive environment for open innovation, enabling the company to respond quickly to new opportunities and rapidly integrate emerging technologies into its products and services.

(Performance)

Komatsu's approach to open innovation has yielded tangible results and successful collaborations, although the company does not publicly disclose specific metrics such as the number of successful open innovation projects or patents obtained through open innovation. One notable case is Komatsu's partnership with Skycatch, a Silicon Valley-based startup that develops drone image-processing platforms. In 2015, the two companies launched drone surveying as part of Komatsu's Smart Construction market launch, with Skycatch playing a critical role in visualizing and optimizing construction sites. Another example is the establishment of LANDLOG in 2017, a construction site management platform developed in collaboration with NTT DOCOMO, SAP Japan, and OPTIM. In summary, by leveraging external expertise and technologies, Komatsu has been able to introduce innovative solutions such as drone surveying and digital platforms, strengthening its position as a global leader in construction and mining equipment while delivering greater value to its customers.

### 5.6.5. Konica Minolta, Inc.

Konica Minolta, Inc. ("Konica Minolta") is recognized as a company actively engaged in open innovation initiatives, particularly in digital imaging and printing solutions. This case study examines Konica Minolta's architectural choices in implementing open innovation, drawing insights from various publicly available sources, including Konica Minolta's corporate documents, interview articles with executives and R&D staff, and case studies[95], [153], [154], [155], [156], [157], [158], [159], [160], [161], [162], [163], [164], [165], [166], [167], [168], [169], [170]. By examining how Konica Minolta selected different options for the previously defined architectural choices, this analysis provides a comprehensive understanding of the company's approach to open innovation and the key factors contributing to its success in leveraging external collaboration to drive innovation and growth.

(Basic Information)

Konica Minolta, Inc. was formed in 2003 through the merger of Konica Corporation and Minolta Co., Ltd., both companies with rich histories in the manufacture of photographic products, copiers, and other office equipment. The company's roots date back to 1873, when it was founded as a camera and photographic film company. Today, Konica Minolta leverages its expertise in imaging technology to focus on four core businesses: Digital Workplace Business (multifunctional peripherals and related services), Professional Print Business (digital printing systems and solutions), Healthcare Business (diagnostic imaging systems and medical industry solutions), and Industry Business (functional films, industrial inkjet printheads, and lenses). With 39,775 employees, consolidated net sales of 1,130 billion Japanese yen (as of 2023), and a strong global presence, Konica Minolta's research and development efforts are characterized by its unique "Imaging-IoT Technology," which combines four core technologies - imaging, materials, optics, and microfabrication - with the latest advances in information and communication technologies. Over the past decade, Konica Minolta's R&D intensity has consistently hovered around 7.5%, as shown in Figure 5-8. As the company aims to transform its business portfolio by 2025, it is shifting its R&D investment toward growth areas while focusing on improving efficiency in recent years. According to government statistics, the R&D intensity of the Japanese electronic applications and electrical measuring instruments manufacturing industry is 7.5-10.7%, and that of other electrical machinery and equipment manufacturing industries is 6.0-9.3%[99]. These averages suggest Konica Minolta's R&D investment is on par with its industry peers.

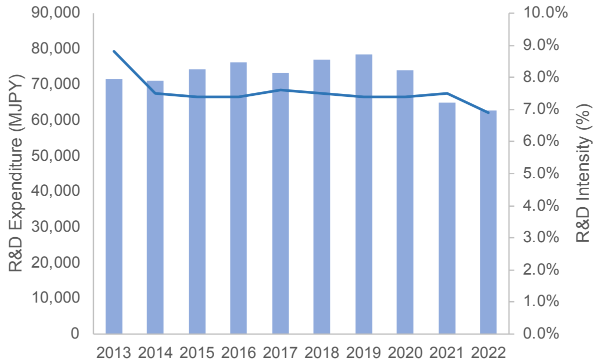


**Figure 5-8 R&D expenditures and R&D intensity (Konica Minolta)**

(External Landscape)

Konica Minolta faced a major challenge in 2006 when it lost its founding businesses in film and cameras due to the decline of the industry, forcing the company to adapt and leverage its technologies in other business areas. Then, in the early 2010s, the widespread shift to paperless offices began, raising concerns in the industry about the potential shrinkage of the copier business on a global scale. With 80% of its sales dependent on the copier business, Konica Minolta's management became increasingly aware of the impending crisis. At that time, Konica Minolta's core technologies in the areas of imaging materials, optics, and image processing were highly self-sufficient and closed in nature. This realization led to a growing emphasis on the need for open innovation.

(Architectural Decision)

Below is a table summarizing the architectural decision choices made by Konica Minolta, accompanied by in-depth descriptions:

Table 5-9 Architectural decision options (Konica Minolta)

| Decision Variable | Selected Decision Option |
|---|---|
| Strategy | [A1] Published Long-term Strategy |
| Purpose | [B6] Upgrade Final Products<br>Sub: [B2] Accelerate R&D |
| Organizational Structure* | [C1] New Dedicated Team |
| Learning Culture | [D2] Bottom-Up |
| Needs* | [E1] R&D Identifies Needs |
| Channels | [F2] Investigating Existing Business Partners |
| External Partner Candidates | [G3] Vertical Multiple Partners |
| Technology Assessment | [H3] Proof of Concepts |
| Knowledge Management | [I2] Moderate Knowledge Management Capabilities |
| Project Budget | [J1] Both Phases Funded |
| Project Timeline | No Data |

* Architectural decisions prioritized by Konica Minolta

- Strategy: [A1] Konica Minolta's commitment to open innovation is clearly reflected in its published long-term strategies. In 2014, the company launched its medium-term business plan, "TRANSFORM 2016," which included establishing the Business Innovation Center (BIC) Japan as one of the key initiatives to drive the creation of next-generation businesses and open innovation initiatives. The subsequent medium-term business plan, "SHINKA2019," announced in 2017, further reinforced the company's goal of continuously creating new value for the development of business and human society, which focused on some collaborative projects such as the IoT platform built. While the medium-term business plan "DX2022," began in 2020, did not explicitly mention open innovation, it emphasized the realization of a business portfolio that was not dependent on the office business and aims to promote strategic new businesses. In addition, the newest mid-term plan, began in 2023, focuses on further strengthening business profitability by actively reallocating resources to improved businesses.

- Purpose: [B6] Konica Minolta's primary purpose for engaging in open innovation is to improve its final products and services by gaining a deep understanding of customer needs. The company views the BIC as a starting point for understanding customer needs, recognizing that its previous R&D efforts prioritizes quality improvement over understanding customer needs. Then, Konica Minolta believes that with the establishment of the BIC, the company can actively collaborate with internal and external partners to acquire the necessary technologies to meet customer needs. In addition to improving end products and services, Konica Minolta aims to accelerate R&D[B2] by fostering a culture of rapid prototyping and customer validation, enabling a rapid and iterative development process.

- Organizational Structure: [C1] As described, Konica Minolta established the BIC as a dedicated organization to promote open innovation and create new businesses. This variable is Konica Minolta's primary decision. The company's experience influenced the decision to establish the BIC in collaborating with acquired U.S. companies, which highlights the need for a mechanism to incorporate external talent while promoting internal mindset change and generating new solutions on a global scale. The BIC has been established in five locations: Silicon Valley, London, Singapore, Shanghai, and Japan, with each center led by external hires to foster a new culture. BIC Japan operates in a hybrid structure, combining external hires with internally recruited talent. The focus of the BIC has evolved to include both local problem-solving and global market-oriented activities. Within the BIC, projects are executed by small teams: Incubation teams, which are dedicated to new business projects, and Support teams, which provide cross-functional support in areas such as technology, administration, and research activities. This structure creates a matrix of vertical project teams and horizontal support teams. It is important to note that as of March 31, 2023, the BIC has been integrated into the Technology Development Division.

- Learning Culture: [D2] Konica Minolta's learning culture is characterized by a bottom-up approach that is promoted by the initiatives of the BIC. They regard that the company has experienced a gradual shift in its corporate culture, with an increasing emphasis on constantly considering the value that customers provide or want to provide to their target audiences. This customer-centric mindset has permeated beyond the departments responsible for generating new business and services and has even reached the production sites in the factories.

- Needs: [E1] Konica Minolta identifies its technology needs through a combination of core technology assessment and R&D portfolio analysis. The company has a clear innovation portfolio and allocates resources in a balanced manner across three domains: "evolutionary domain" (close to existing businesses), "new domain" (far from existing businesses), and "revolutionary domain" (completely new areas) in a 40:40:20 ratio. In addition, the company emphasizes the concept of "Open-Close Architecture," which involves identifying differentiated technologies and filling all four quadrants of the 4B framework: Base, Build, Borrow and Buy. This approach helps the company determine whether to use other companies' technologies, secure exclusivity, make its own technologies open, or use them in a closed manner. These approaches ensure that the company does not focus solely on existing businesses or entirely new fields. Konica Minolta emphasizes the importance of differentiation and uses its core technologies to maintain high barriers to entry. By objectively assessing whether its core technologies are effectively used in each project, the company selects topics that align with its strengths and differentiate it from competitors. The company's primary decision is to make its portfolio strong.

- Channels: [F2] Konica Minolta's primary exploration channel for open innovation could be to investigate existing business partners. The company's open innovation projects are largely customer-focused, suggesting that the company primarily works with its current business partners to identify and address customer needs. However, there is limited information on the specific methods Konica Minolta uses to explore and identify potential partners compared to the case studies of other companies.

- External partner candidates: [G3] Konica Minolta cooperates with a wide range of external partners, including companies, universities, and government agencies, without specific restrictions. The company establishes confidentiality agreements with its partners and promotes open communication, sharing positive and negative information. This approach fosters a collaborative environment where partners can communicate effectively, enabling a holistic approach to manufacturing.

- Technology Assessment: [H3] Konica Minolta places great emphasis on conducting PoC trials when evaluating the potential of new technologies and solutions. The company's projects include researching customer needs, developing prototypes closely aligned with those needs, and consistently conducting test marketing. If a project is deemed suitable for commercialization based on test marketing results, it is transferred to the relevant internal business division to further develop quality and mass production systems. Konica Minolta adopts a lean startup approach, starting projects with a single member with strong problem awareness and gradually expanding resources as the project progresses toward commercialization.

- Knowledge Management: [I2] Konica Minolta's intellectual property strategy and activities are integrated into its value creation process, supporting brand building, strengthening the competitiveness of each business, and providing solutions to future social issues. While focusing primarily on building effective patent assets to protect technologies that create customer value, Konica Minolta also employs a mix of intellectual property strategies, including the protection of know-how and the establishment of contractual schemes for the use of data, tailored to the specific business formats and environments of its portfolio transformation.

- Project Budget: [J1] The BIC has the autonomy to decide which projects to pursue without significant input or guidance from the main Konica Minolta organization during the process. The director of the BIC has the discretion to allocate the budgeted funds within the given "framework," indicating that the center has secured budgets for both the exploration and assimilation phases of open innovation projects.
- Project Timeline: No specific data is available. Note that Konica Minolta primarily adopts a stage-gate approach to project management. The company is willing to promptly terminate projects that are deemed unfavorable, which may result in some developed products or services not being released to the market.

(Performance)

While Konica Minolta does not disclose specific metrics, such as the number of open innovation projects or patents generated through these initiatives, the company has reported several successful outcomes from its open innovation efforts. One notable example is the development of a new product called "Workplace Hub" and "FORXAI," an IoT platform that combines Konica Minolta's core technologies with solutions from external partners. This innovative offering, which provides a comprehensive IT infrastructure solution for small and medium-sized businesses, is made possible through collaborations fostered by the company's BICs around the world. Customers have well received the platform and contributed to Konica Minolta's growth in the IT services business. The company has also seen positive results from its open innovation activities in the healthcare sector. Through collaborations with startups and academic institutions, the company has developed an odor-measuring device for personal care and AI-based voice translation solutions for disease diagnosis. While the company does not provide specific financial figures directly attributable to open innovation, it has acknowledged the positive impact of these initiatives on its overall business performance.

### 5.6.6. Synthesis of Case Study Outcomes

The synthesis of case studies of five companies, leading to the critical factors of enhancing absorptive capacity and successful open innovation in large Japanese companies, are summarized in

Table 5-10. It shows each company's consolidated choice of architectural variables to analyze the common factors and differences.

**Table 5-10 Summary of architectural decision options**

| Company Name (Open Innovation Index) | Osaka Gas (38) | MCGC (19) | Toray (11) | Komatsu (16) | Konica Minolta (12) |
|---|---|---|---|---|---|
| Strategy | A1 | A1 | A1 | A1 | A1 |
| Purpose | B2 (B1, B6) | B2 (B1, B3) | B4 (B2, B6) | B6 (B2, B4) | B6 (B2) |
| Organizational Structure | C1 | C1 | C3 | C1 | **C1*** |
| Learning Culture | **D2*** | D1 | D1 | D2 | D2 |
| Needs Identification | **E1*** | **E1*** | **E2*** | **E3*** | **E1*** |
| Exploration Channels | F4 (F1, F3) | F4 (F2) | F2 (F4) | F4 (F2) | F2 |
| External Partner Candidates | G3 | G3 | **G1*** | G3 | G3 |
| Technology Assessment | H1 | H1 | H1 | H3 | H3 |
| Knowledge Management | - | I2 | I1 | I2 | I2 |
| Project Budget | - | - | - | - | J1 |
| Project Timeline | K1 | **K2*** | K2 | **K2*** | - |

**** Architectural decisions prioritized by each company***

**[Legend]**

Strategy: [A1] Published Long-term Strategy, [A2] Published Short-term Tactic, [A3] Internal Memo, [A4] No Strategic Stance
Purpose: [B1] Reduce Expenses (Financial Benefits), [B2] Accelerate R&D, [B3] Shorten Timelines Except for R&D, [B4] Enhance R&D Capabilities, [B5] Improve HR Efficiency, [B6] Upgrade Final Products/Services, [B7] Develop New Markets
Organizational Structure: [C1] New Dedicated Team, [C2] Subgroups Within R&D Division, [C3] Additional Responsibilities on Personnel
Learning Culture: [D1] Top-Down, [D2] Bottom-Up, [D3] Cross-Functional
Needs Identification: [E1] R&D Identifies Needs, [E2] Other Departments Identify Needs, [E3] Management Defines Vision
Exploration Channels: [F1] Searching Public Information, [F2] Investigating Existing Business Partners, [F3] Posting Needs Online, [F4] Hiring Agencies, [F5] Participating in Third-Party's Platforms, [F6] Attending Conferences
External Partner Candidates: [G1] Vertical Multiple Partners, [G2] Vertical Single Partner, [G3] Horizontal Multiple Partners, [G4] Horizontal Single Partner
Technology Assessment: [H1] Evaluated By R&D or Open Innovation Team, [H2] Use Third-Party, [H3] Proof of Concepts
Knowledge Management: [I1] High Capabilities, [I2] Moderate Capabilities, [I3] Low Capabilities
Project Budget: [J1] Both Phases Funded, [J2] Only Exploration Funded, [J3] Only Labor Costs (No Project Funds)
Project Timeline: [K1] Prioritized Internal Schedules, [K2] Prioritized Partner Preferences, [K3] Coordination

(Commonalities)

- Strategy [A]: All five companies clearly articulate their commitment to open innovation in their published long-term strategies, highlighting the importance of top management leadership and vision in driving open innovation initiatives. When implementing open innovation, companies need to communicate their openness externally. This leads to the announcement of open innovation policies in mid- to long-term management plans, which are the most proactive in demonstrating the company's strategy among various external announcement materials. In addition, top management's understanding and commitment are critical to driving open innovation efforts. To allocate human and financial resources, it is necessary for executives to actively define the importance of promoting open innovation and clarify it within the management strategy and vision.

- Organizational Structure [C]: Establishing dedicated organizational structures, such as new teams or offices, is a common approach to facilitating open innovation, serving as focal points for coordinating external collaborations and integrating acquired knowledge into the company's innovation ecosystem. Creating specialized departments to support open innovation proves that management, which has the authority to determine the organizational structure, strongly recognizes the need for open innovation. This not only allows for relatively smooth staffing and budgeting but also clarifies the responsibilities of open innovation projects. This contributes greatly to promoting awareness reform and advancing open innovation. As specialized departments achieve results, their recognition increases internally and externally, leading to the rationalization of open innovation.

- Exploration Channels [F] & External Partner Candidates [G]: Many companies collaborate with a variety of external partners, including startups, universities, and industry players, to leverage a wide range of expertise and capabilities. Rather than relying on one particular channel, they use multiple channels to conduct efficient and effective research. Adopting methods that utilize third parties with much expertise in external knowledge exploration, such as external venture capital firms and agencies specialized in open innovation, is often observed. To promote open innovation quickly and efficiently, it is important to establish the company's network for exploring suitable external partners and utilize specialized external intermediaries. Companies that incorporate diverse methods for exploring external partners tend to search for partners horizontally rather than vertically.

- Knowledge Management [I]: Each company demonstrates strong knowledge management capabilities and recognizes the importance of protecting core technologies while strategically leveraging external knowledge. To establish strategic partnerships with other companies that lead to commercialization, it is necessary to create a solid intellectual property portfolio and link it to rights acquisition. Collaborations require a foundation for secure protection of proprietary technology based on an open-close strategy.

- Project Timeline [K]: When the collaboration partner is a startup, it is common for the large company to try to align the timeline with the startup because they understand that the slowness of the decision-making process in large companies can be an obstacle to collaboration. Recognizing the importance of two-way communication, it is possible to consider that the attitude of responding beyond the company's internal rules contributes to the success of open innovation.

(Differences)

- Purpose [B]: There is variation in the choice of architectural decision options, and it is not necessarily the case that companies must have a specific purpose. Although each company's choices are different, they all have a clear sense of purpose. In other words, companies do not start open innovation haphazardly, but rather have a clear recognition of issues as a company and set objectives in response to them, thus determining the overall direction of open innovation.
- Learning Culture [D]: A culture of learning is an important element in fostering understanding within the organization to sustain and grow open innovation efforts. However, it varies from company to company, with some adopting a top-down approach and others relying on a bottom-up approach. To foster open innovation, it is necessary to move away from the "not-invented-here" syndrome of researchers and the self-reliance of the organization, and to cultivate an organizational culture and climate that continuously generates new ideas and initiatives. While such a culture can be fostered through both top-down and bottom-up approaches, there is a tendency for companies with a bottom-up culture to actively embrace open innovation. The analysis shows that a success factor in promoting open innovation is the effective integration of top-down strategies and visions with bottom-up initiatives, supported by a long-term commitment from top management to the efforts of such bottom-up personnel.
- Needs Identification [E]: The methods used to identify technology needs vary among companies, with some emphasizing R&D-driven needs identification, while others involve multiple departments or rely on management-defined visions. Whichever option is chosen, it is necessary to clarify the needs and technologies sought externally after taking stock of internal technologies and extracting core technologies, as competition between external and internal resources is a common challenge in

open innovation. It is important to clarify the management resources to be acquired externally and to ensure that all stakeholders understand why external resources are needed. Companies can define the competition in a transparent and fair way to ensure that it is productive and includes decisions not to penalize those who don't succeed but can quickly move to a new project.

- Technology Assessment [H]: Technology assessment approaches vary among the companies surveyed, ranging from relying on internal R&D teams to conducting proof-of-concept trials. The choice of technology assessment approach may depend on the stage of the innovation process and the nature of the external collaboration. In general, early-stage exploratory collaborations may benefit from a more open-ended, proof-of-concept approach, while later-stage collaborations may require a more rigorous, internally-driven assessment process. Regardless of the approach, it is critical for companies to have a clear and systematic process for assessing the value and potential of external technologies.

It is also important to add that each case shows that external factors, such as rapid changes in the business environment, are important drivers for large companies to move away from self-reliance and toward open innovation. On the other hand, there is no consistent trend in R&D spending or R&D intensity among companies: Open innovation is pursued regardless of whether R&D spending is increasing or decreasing and whether R&D intensity is higher or lower than the industry average.

In summary, the architecture decision variables that are consistently selected across the five companies, namely Strategy [A], Organizational Structure [C], Exploration Channels [F], External Partner Candidates [G], Knowledge Management [I], and Project Timeline [K], are considered to play a critical role in the enhancement of absorptive capacity, leading to the success of open innovation. On the other hand, the choices for Purpose [B], Learning Culture [D], Needs Identification [E], and Technology Assessment [H] vary across companies. This pattern suggests that elements such as long-term commitment, establishment of specialized organizations, collaboration with diverse external partners, strategic management of intellectual property, and scheduling coordination with partners are universally important in strengthening the absorptive capacity for a company to promote open innovation. It also implies that some factors, such as the purpose of open innovation, organizational culture, needs identification methods, and technology assessment approaches, should be selected flexibly according to each company's circumstances.

However, it should be noted that the above discussion is based on the assumption that all variables are independent. In reality, the architectural decisions are interrelated, and it is essential to consider their respective importance. Therefore, in the next section, connectivity and sensitivity analyses are conducted to explore further the relationships between these variables and their impact on the overall absorptive capacity system.

## 5.7. Connectivity and Sensitivity Analysis

This section analyzes the connectivity and sensitivity of variables in architectural decision-making. This analysis supports navigation of the complex interdependencies between decisions and their impact on the systematic performance of open innovation absorptive capacity.

In general, architectural decisions are often highly coupled, meaning that the choice made for one decision can significantly constrain or influence the options available for other decisions. This coupling can arise from hard constraints, where choosing a particular value for one decision precludes certain values for another, or from softer dependencies related to system metrics and performance goals[83]. In addition, architectural decisions typically have varying degrees of sensitivity to performance goals. Some decisions may have a strong impact on key metrics, while others may have a more limited impact. By assessing the sensitivity of metrics to specific decisions and groups of decisions, the high-impact decisions that are likely to drive total system performance can be identified[83]. In summary, the analysis of coupling and sensitivity in architectural decisions aims to develop a clearer understanding of the decision landscape of open innovation absorptive capacity in the enterprise as a system.

In analyzing the couplings between architectural decision variables [A] through [K], a Design Structure Matrix (DSM) approach is adopted to assess the connectivity between decisions. The DSM is a square matrix that captures the relationships and dependencies between architectural decisions. In this matrix, variables are represented along both the rows and columns, and the off-diagonal elements indicate the presence and strength of couplings between pairs of decision variables[83]. Concretely, in this thesis, the variables in the rows are the influencing factors, while the variables in the columns are the ones being influenced. When a variable in a row affects a variable in a column, they are considered to be coupled. To populate the DSM, the influential dependencies between each pair of decisions are examined based on the information provided and sourced in the five case studies. For each pair of decision variables, the direction and strength of the coupling is assessed and categorized as strong, weak, or no coupling. The strength of the coupling is determined according to the following rules:

- Strong coupling: If a coupling is suggested in all five case studies or in four of the five case studies, it is considered a strong coupling. Strong couplings are identified when the choice made for one decision significantly limits or influences the options available for another decision.

- Weak coupling: If a coupling is suggested in one to three case studies, it is considered weak. Weak couplings are noted when the decisions have limited direct influence on each other.

- No coupling: If a coupling is not suggested in any of the five case studies, it is assigned no coupling. No coupling indicates that the decisions are found to be independent.

The architectural decisions with the greatest impact on the overall system architecture are then identified by weighting and summing the coupling for each variable.

Table 5-11 shows the DSM followed by detailed explanations:

**Table 5-11 DSM representing the interconnection of architectural decisions**

| Architectural Decision Variable | | A | B | C | D | E | F | G | H | I | J | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Strategy | A | - | S | S | | | | | | | W | |
| Purpose | B | W | - | S | | W | W | | | | | |
| Organizational Structure | C | | | - | S | S | | | W | | W | |
| Learning Culture | D | | W | S | - | | | | | | | |
| Needs Identification | E | | | W | | - | W | W | | | | |
| Exploration Channels | F | | | | | | - | S | W | | W | W |
| External Partner Candidates | G | | | | | | S | - | W | | | |
| Technology Assessment | H | | | | | | | | - | W | | W |
| Knowledge Management | I | | | | | W | | | | - | | W |
| Project Budget | J | | | | | | W | | | | - | S |
| Project Timeline | K | | | | | | W | | | | S | - |

S: Strong Coupling, W: Weak Coupling

(Strong Coupling)

- Strategy [A] to Purpose [B]: In all five case studies, the companies' long-term strategies emphasizing open innovation directly shape their primary goals for open innovation. Based on each company's strategy, the objectives of open innovation projects at Osaka Gas and MCGC emphasize accelerating R&D, Toray aims to improve R&D capabilities, and Komatsu and Konica Minolta prioritize improving end products and accelerating R&D. The strong alignment between strategy and goals is consistent across all five companies, highlighting the critical role of strategic direction in guiding open innovation initiatives.

- Strategy [A] to Organizational Structure [C]: The strategic importance of open innovation determined the most appropriate organizational structure in all five case studies. Osaka Gas creates a dedicated open innovation office, MCGC establishes the Frontier & Open Innovation Headquarters within the Innovation Division, Komatsu creates the CTO Office, and Konica Minolta establishes the Business Innovation Center. This strong link between strategy and organizational structure is common to all five companies, underscoring the significant impact of strategic priorities on the design of open innovation frameworks.

- Purpose [B] to Organizational Structure [C]: The goals and objectives of open innovation play a critical role in determining the most appropriate organizational structure in all five case studies. Every company clearly defines the roles of the open innovation project team or personnel to achieve their goals through the projects, which affects the organizational structures in each company. For example, the acceleration of R&D can be achieved by a dedicated team, as they can review and change some routine R&D processes with an external force. Such strong coupling is consistently observed in all five case studies, highlighting the significant impact of open innovation goals on organizational structure.

- Organizational Structure [C] and Learning Culture [D] (bi-directional): The organizational structure chosen to support open innovation and the learning culture within the organization has a strong, bidirectional influence in four of the five case studies. Osaka Gas's dedicates open innovation office fostered a bottom-up learning culture encouraging collaboration and knowledge sharing. Conversely, MCGC's top-down learning culture is reinforced by top management's strategic definition of focus areas. Toray's assignment of additional responsibilities to existing R&D staff is influenced by its top-down learning culture. Komatsu's CTO office promotes a bottom-up learning culture driven by the company's "gemba" philosophy. This strong bidirectional coupling was evident in most of the case studies, highlighting the interdependence between organizational structure and learning culture in open innovation.

- Organizational Structure [C] to Needs [E]: The organizational structure chosen to support open innovation has a significant impact on the methods used to identify technology needs in four of the five case studies. Osaka Gas's Open Innovation Office actively collaborates with R&D departments to identify technology gaps, MCGC's Frontier & Open Innovation Headquarters works closely with business units to identify strategic technology needs, Komatsu's CTO Office collaborates with various departments to identify technology needs, and Konica Minolta's Business Innovation Center works with internal stakeholders to identify customer needs. This strong coupling was evident in most of the case studies, underscoring the impact of organizational structure on needs identification methods.
- Exploration Channel [F] and External Partner Candidates [G] (bi-directional): The channels used to source external knowledge strongly influence the choice of external partners in all five case studies. Osaka Gas's use of specialized agencies enables it to engage with various partners, including startups and universities. MCGC's corporate venture capital investments and partnerships influence its engagement with startups and academic institutions. Toray's emphasis on working with existing business partners shapes its focus on vertical partnerships within the supply chain. Komatsu's global networks with universities and venture capitalists drive its partnerships with startups. Konica Minolta's collaboration with existing business partners guides its selection of external partners. Conversely, the preferred partner types also shaped the companies' choice of sourcing channels. This strong bidirectional coupling was consistently observed across all five case studies, underscoring the interplay between sourcing channels and partner selection.
- Project Budget [J] and Project Timeline [K] (bi-directional): Although the case studies provide limited information on the specific budgetary aspects of the open innovation projects, making it difficult to definitively establish the coupling between project budgets and timelines based on the case studies, it is clear from the basic principles of project management, in particular the constraints triangle, that these two variables are strongly interrelated and have a significant influence on each other.

(Weak Coupling)

- Strategy [A] to Project Budget [J]: The choice of open innovation strategy may have some influence on the allocation of project budgets. For example, Konica Minolta's Business Innovation Center has the autonomy to allocate budgeted funds within the given framework in accordance with its open innovation strategy. The strategic emphasis on open innovation can guide the prioritization and distribution of resources to support open innovation initiatives.

- Purpose [B] to Strategy [A]: The purpose and goals of open innovation have a limited impact on the overall strategy. For example, Komatsu's goal of improving end products through open innovation projects partially contributed to the company's strategic focus. While the specific objectives may influence the strategic direction, the overarching strategy is primarily driven by overarching factors such as the competitive landscape and long-term vision.

- Purpose [B] to Needs [E]: The rationale for pursuing open innovation can, to some extent, shape how technology needs are identified. For example, Osaka Gas's primary goal of accelerating R&D through open innovation may encourage a more proactive approach to identifying technology gaps by relying on its R&D department. Konica Minolta's goal of improving end products led to a customer-centric approach to identifying needs in its collaborative projects.

- Purpose [B] to Exploration Channel [F]: The goals and objectives of open innovation may influence the channels used to acquire external knowledge. For example, Toray's emphasis on improving R&D capabilities may lead to a greater focus on collaborating with existing partners. Konica Minolta's goal of improving end products influenced its decision to explore existing business partners for open innovation primarily.

- Organizational Structure [C] to Technology Assessment [H]: The organizational structure chosen to support open innovation has some impact on the methods used to evaluate external technologies. The presence of dedicated teams with diverse expertise, such as Osaka Gas' Open Innovation Office, can enable a more comprehensive and efficient evaluation process.

- Organizational Structure [C] to Project Budget [J]: The organizational structure chosen to support open innovation has some impact on the allocation of project budgets. The presence of dedicated teams or specialized units facilitates the budgeting process for open innovation initiatives. Konica Minolta's Business Innovation Center has the autonomy to decide which projects to pursue and allocate budget accordingly, ensuring a clear link between organizational structure and budget allocation.

- Learning Culture [D] to Purpose [B]: The learning culture has a limited impact on the fundamental reasons for pursuing open innovation, but it can influence how the goals are communicated and embraced. In the case of Toray, the company's initial top-down approach to promoting open innovation helped overcome the "not-invented-here" syndrome and activate the company's purpose for open innovation.

- Needs [E] to Organizational Structure [C]: The methods used to identify technology needs have a limited influence on the organizational structure for open innovation. The division that has ownership to identify the needs may be responsible for the open innovation projects, implying that the activity can dictate the organizational setup for a company. In Osaka Gas, the R&D department's role in identifying needs contributed to its responsibility for open innovation projects, making them to communicate with the dedicated team well.

- Needs [E] to Exploration Channel [F]: The methods used to identify technology needs have a strong influence on the channels used to obtain external knowledge. For example, as shown in the case studies, Komatsu's reliance on management vision to identify needs drove the use of global networks with universities and venture capitalists to explore partnership opportunities.

- Needs [E] to External Partner Candidates [G]: The ways to identify technology needs can guide the selection of external partners with relevant capabilities and expertise. In the case studies, Osaka Gas's approach of relying on R&D departments to identify technology gaps lead to a focus on partners with specialized technical expertise, such as startups or universities. Toray's emphasis on gathering input from non-R&D departments results in a stronger interest in collaborating with customers or suppliers.

- Exploration Channel [F] to Technology Assessment [H]: The channels used to obtain external knowledge have a limited impact on the methods used to evaluate external technologies. The specific channels used, such as hiring agencies for Osaka Gas or working with existing partners for Komatsu, can provide some context for the evaluation process, internal evaluations, or PoC trials, respectively.

- Exploration Channel [F] to Project Budget [J]/ Project Timeline [K]: The channels used to source external knowledge impact the allocation of project budgets/timelines to some extent. The specific channels, such as hiring external agencies, can need additional budgetary allocations or limit some timelines as shown in the example of MCGC and Konica Minolta.

- External Partner Candidates [G] to Technology Assessment [H]: The types of partners selected can guide the selection of assessment techniques best suited to evaluate their technologies and capabilities. For example, Komatsu's focus on working with multiple vertical startups led to a strong emphasis on conducting proof-of-concept trials to quickly assess the feasibility and potential of new technologies.

- Technology Assessment [H] to Knowledge Management [I]: The choice of evaluation techniques may require different approaches to managing and protecting the knowledge and intellectual property generated during the evaluation process. Konica Minolta's use of proof-of-concept studies may require tailored knowledge management practices to protect the knowledge generated during the evaluation phase.

- Technology Assessment [H] to Project Timeline [K]: The methods used to evaluate external technologies have some influence on the determination of the project schedule. The choice of evaluation techniques, such as PoC trials, may have different time requirements. Komatsu's emphasis on proof-of-concept trials influenced the time requirements for its open innovation projects.

- Knowledge Management [I] to Needs [E]: The knowledge management capabilities within the organization impact on the ways to identify technology needs to some extent. In general, using the ability to manage and protect IP and know-how may lead to the efficient identification of the deficit in the organization's technological capabilities.

- Knowledge Management [I] to Project Timeline [K]: The knowledge management capabilities within the organization can impact the determination of open innovation project timelines. Effective knowledge management practices can support the efficient sharing and use of knowledge, potentially accelerating certain aspects of the open innovation project, as demonstrated by Toray's strong knowledge management practices.

- Project Budget [J]/Project Timeline [K] to Exploration Channel [F]: The allocation of project budgets and the setting of project timelines have some influence on the channels used to source external knowledge. Available financial resources may determine the feasibility and scope of working with certain partners or using certain sourcing methods, and the urgency and duration of the project may also dictate the need for more rapid or targeted sourcing approaches. In the case of Osaka Gas, the urgency of the project influences the decision to use external agencies for rapid and targeted sourcing of external knowledge.

As analyzed in Section 5.3, the architectural decisions correspond to the level 2 functions that make up an organization's open innovation absorptive capacity. When the level 1 functions are scoped out, the variables [A] to [D] can be classified under the management capability, [E] to [H] under the recognition capability, and [I] to [K] under the assimilation capability. This categorization can help interpret the DSM shown in Table 5-11, which captures the couplings between the system's architectural decisions. Specifically, the DSM shows that the couplings between the variables exhibit a certain degree of clustering along the lines of the level 1 functions. In other words, the interactions between variables tend to be more concentrated within each of the three capability groups - Management, Recognition, and Assimilation. This observation suggests that architectural decisions within each capability group are more tightly intertwined and have a stronger influence on each other than decisions across different groups. In addition, the DSM analysis shows that the management capability, represented by decision variables [A] through [D], significantly impacts the other two capabilities compared to other capabilities. This insight can be derived from the fact that variables [A] through [D] are more frequently coupled with variables belonging to the recognition and assimilation capabilities. The prevalence of these cross-capability couplings underscores the central role of management capability in shaping and coordinating the overall absorptive capacity system for open innovation in an organization. The strategic decisions made at the management level, such as the choice of open innovation strategy and the definition of goals, set the direction and priorities for the entire organization. These decisions have cascading effects on how technology needs are identified (recognition capability) and how external knowledge is acquired (assimilation capability). Second, the organizational structure and learning culture established by management create the framework within which the recognition and assimilation capabilities operate. The presence of dedicated teams, the allocation of resources, and the fostering of a collaborative environment all shape the effectiveness of these capabilities.

Next, to quantify the importance of each architectural decision based on the coupling analysis, a scoring system can be used as follows. It assigns points to each variable based on the strength of its couplings with other variables with the following scoring scheme: strong coupling receives 2 points, weak coupling receives 1 point, and no coupling receives zero. For each architectural decision ([A] through [K]), the points are summed based on the couplings they form with other variables, as shown in Table 5-12. Variables with higher total scores are considered to have a greater impact on the overall open innovation architecture because they are more strongly connected to other decision variables. That is, this total score represents the overall importance or influence of that particular variable within the open innovation architecture.

**Table 5-12 Coupling score of each architectural decision**

| Decision Variable | # of Strong Couplings | # of Weak Couplings | Score |
|---|---|---|---|
| [A] Strategy | 2 | 1 | 5 |
| [B] Purpose | 1 | 3 | 5 |
| [C] Organizational Structure | 2 | 2 | 6 |
| [D] Learning Culture | 1 | 1 | 3 |
| [E] Needs | 0 | 3 | 3 |
| [F] Exploration Channels | 1 | 3 | 5 |
| [G] External Partner Candidates | 1 | 1 | 3 |
| [H] Technology Assessment | 0 | 2 | 2 |
| [I] Knowledge Management | 0 | 2 | 2 |
| [J] Project Budget | 1 | 1 | 3 |
| [K] Project Timeline | 1 | 1 | 3 |

The scoring analysis of the architectural decisions based on their couplings provides implications on the interconnectedness and potential influence of each variable within the open innovation absorptive capacity system. The high scores primarily reflect the strong interconnectedness and potential influence of certain variables on others. As shown in Table 5-12, the variable [C] Organizational Structure has the highest score, highlighting the central role of organizational design in shaping the absorptive capacity of firms as it sets the framework for learning culture, knowledge sharing, needs identification, and evaluation processes. Similarly, the high scores for [A] Strategy and [B] Purpose underscore their potential to influence a wide range of other variables. A clear and focused open innovation strategy and well-defined open innovation goals can guide the selection of exploration channels, shape the culture, and influence project constraints. In addition, the strong connectivity of the variable [F] Exploration Channels highlights the potential influence of knowledge-sourcing methods on variables. The choice of channels can determine the type and quality of partners engaged and the evaluation approaches used. These results correspond with the previous clustering results, saying that the management capability exerts a significant influence on the other two capabilities, recognition and assimilation capabilities, systematically for the absorptive capacity of a company.

It is noted that in this case the strength of the couplings is evaluated in two stages: strong and weak, resulting in the simple assignment of 2 points and 1 point, respectively. In general, when using Quality Function Deployment (QFD), especially the House of Quality approach, a scoring system using a scale of 1 (weak relationship), 3 (moderate relationship), and 9 (strong relationship) is often used to indicate the strength of the relationship between customer requirements and product or system characteristics. This scoring method also helps the development team prioritize which technical characteristics to focus on to most effectively meet customer needs[171], [172]. If this scoring method were applied to this case, the results would be consistent with the trends described above. In other words, variables [C] Organizational Structure, [A] Strategy, [B] Purpose, and [F] Exploration Channels would still emerge as the most influential factors in the same rank of order to shape the absorptive capacity of firms in the context of open innovation.

Next, sensitivity analysis in architectural decisions typically involves quantifying the impact of each decision on specific performance metrics. One approach to measuring this sensitivity is to compute the main effect, which assesses the average change in system-wide properties produced by changing a binary variable in a decision problem[83]. However, in the context of open innovation absorptive capacity, performing such an ordinal sensitivity analysis proves challenging due to the difficulty of establishing quantifiable metrics as described in Section 2.4 and Section 5.5. Objectively measuring the system performance of absorptive capacity is not very feasible because open innovation is intertwined with a company's broader perspectives. The case studies also implicitly show that the performance metrics of open innovation are complex and ambiguous as summarized in Section 5.6.

Given these limitations, an alternative approach to sensitivity analysis is taken that leverages the available case study data. Each case study has already identified two primary architectural decisions, as summarized in Table 5-10, providing a basis for assessing their impact on absorptive capacity and open innovation performance. In addition, the Open Innovation Index score for each company is defined in Section 5.5, allowing for a weighted calculation of sensitivity scores. The detailed steps are as follows: First, each primary architectural decision identified in the case studies is assigned a binary value: 1 for primary and 0 for non-primary variables. Then, each firm's Open Innovation Index score is multiplied by the binary value assigned to each primary variable. This step weights the impact of the variable based on the company's open innovation performance, assuming it is reflected in the Open Innovation Index score. Finally, the weighted scores for each primary variable are divided by the number of cases to obtain the final sensitivity score for that variable. These steps can be formulated mathematically as follows (assuming $n$ cases and variable $i$ in firm $j$ are considered):

$$(Sensitivity\ Score)_i = \frac{1}{n}\sum_{j=1}^{n} p_{ij} * (Open\ Innovation\ Index)_j$$

$p_{ij}$; 1 for primary variables and 0 otherwise in firm $j$

This approach to sensitivity analysis, while not as granular as the ordinal method[83], provides a practical way to assess the relative impact of primary architectural decisions on system performance. Table 5-13 shows the result, and some insight is followed into the key drivers of absorptive capacity in the context of open innovation.

**Table 5-13 Sensitivity score of each architectural decision**

| Decision Variable | Companies with Primary Designation | Score |
|---|---|---|
| [A] Strategy | NA | 0 |
| [B] Purpose | NA | 0 |
| [C] Organizational Structure | Konica Minolta | 2.4 |
| [D] Learning Culture | Osaka Gas | 7.6 |
| [E] Needs | All companies | 19.2 |
| [F] Exploration Channels | NA | 0 |
| [G] External Partner Candidates | TORAY | 2.2 |
| [H] Technology Assessment | NA | 0 |
| [I] Knowledge Management | NA | 0 |
| [J] Project Budget | NA | 0 |
| [K] Project Timeline | MCGC, Komatsu | 7 |

As a result, the highest sensitivity score for Needs underscores the critical importance of accurately defining and understanding the technological and market needs that open innovation efforts should address. This variable is consistently emphasized in all five case studies. For example, some R&D departments actively identify technology gaps based on the challenges they face in their daily R&D activities, leading to effective scope definitions for their open innovation project. The second highest sensitivity score for learning culture highlights the critical role that organizational learning plays in increasing absorptive capacity. A strong learning culture characterized by openness to new ideas creates an environment conducive to the effective assimilation and application of external knowledge. The relatively high sensitivity of project timelines underscores the importance of effective project management in open innovation contexts. It suggests that companies should focus on developing the ability to define clear milestones, allocate resources effectively, and manage stakeholder expectations, especially when collaborating with startups that pursue flexible timelines.

In summary, by prioritizing needs assessment, fostering a strong learning culture, and ensuring effective project management, companies can lay a solid foundation for the absorptive capacity of open innovation initiatives. However, it is important to recognize that this approach has limitations. The sensitivity scores are based on a limited number of case studies and may not capture the full complexity of open innovation dynamics. In addition, the binary classification of variables as primary or non-primary may oversimplify the nuances of their impact on absorptive capacity.

## 5.8. Framework of Absorptive Capacity

This section closely follows the insights and implications derived from the detailed system architecture analysis in the previous sections to propose a framework for the absorptive capacity system in promoting open innovation in Japanese firms.

A framework is based on the consolidation of the initial sections of this chapter as follows: The absorptive capacity system, which scopes outside-in (inbound) open innovation in this thesis, aims to effectively utilize valuable external knowledge and integrate it into the existing mechanisms of the enterprise by utilizing various types of capabilities within the enterprise. Focusing on the boundaries between stakeholders of the system, key internal ones, such as executives and R&D departments, prioritize revenue growth, competitiveness, and access to external innovation, while external ones, including startups and academics, seek resources, commercialization pathways, and industry visibility. A functional analysis of absorptive capacity, which breaks down the system into its constituent functions, **identifies key internal capabilities** in detail: **Management** Capability, which includes strategically positioning open innovation, setting goals, and establishing appropriate structures; **Recognition** Capability, which includes identifying areas where external resources are needed, exploring technologies, and selecting partners; **Assimilation** Capability, which includes project management and integrating external knowledge; and **Exploitation** Capability, which includes determining applications of assimilated knowledge, updating the company's portfolio, and translating results into new projects and business models. **These four capabilities form the foundation of the absorptive capacity system**, enabling large Japanese companies to effectively identify, acquire, assimilate, and exploit external knowledge and innovation through outside-in open innovation initiatives.

However, the functional decomposition alone is not sufficient to fully capture the interactions and dynamics of the absorptive capacity system in open innovation practice. **The absorptive capacity is not merely a hierarchical structure but a network of interconnected elements that function dynamically, leading to the emergence of the**

**overall system function.** Then, mapping level 2 capabilities to specific architectural decisions then provides a tangible link between the theoretical understanding of absorptive capacity and the practical choices firms make in designing their open innovation as a system. This mapping identifies **eleven key architectural decisions**. The Strategy, Purpose, Organizational Structure, and Learning Culture variables are related to Management Capability because they involve strategic positioning, goal setting, and establishing appropriate structures and culture for open innovation. The Needs, Exploration Channels, External Partner Candidates, and Technology Assessment variables are related to the Recognition Capability because they involve identifying areas where external resources are needed, exploring technologies, and selecting partners. The Knowledge Management, Project Budget, and Project Timeline variables are related to the Assimilation Capability because they involve project management and the integration of external knowledge.

All of these decisions represent the critical building blocks that fundamentally shape the design of open innovation absorptive capacity systems. Each of these architectural decisions has multiple options, reflecting the different choices organizations can make when implementing open innovation initiatives. These options range from high-level strategic decisions to operational-level choices, all of which help shape the overall structure and effectiveness of the absorptive capacity systems framework. Taken together, these architectural decisions and their associated options form the basic framework for the absorptive capacity system in open innovation.

Next, as shown in the second half of the sections of this chapter, the application of the framework to real cases is expected to provide a comprehensive understanding of how absorptive capacity systems are structured and optimized. In this thesis, five companies from different industries were selected as case studies: Osaka Gas, Mitsubishi Chemical Group Corporation, Toray, Komatsu, and Konica Minolta. The selection is guided by an Open Innovation Index, a scoring system based on their inclusion in various public documents and recognition in national awards related to open innovation. Every case suggests that the pursuit of open innovation appears to be independent of trends in R&D spending or intensity, with companies implementing open innovation strategies regardless of the direction of their R&D investments or their relative position in the industry. Rapid external environment changes, such as technological disruptions or market shifts, emerge as significant catalysts for firms to move away from self-reliance and embrace collaborative innovation.

The synthesis of the case studies, including connectivity and sensitivity analyses, provides insights into the architectural decisions that shape their absorptive capacity systems. Based on the synthesis, Figure 5-9 provides a concise overview of the absorptive capacity framework, which aligns eleven key architectural decisions as identified above. The gray links represent the key interactions and influences between these elements, as revealed by the connectivity analysis. The size of each variable indicates its relative significance in driving absorptive capacity, based on the sensitivity analysis.

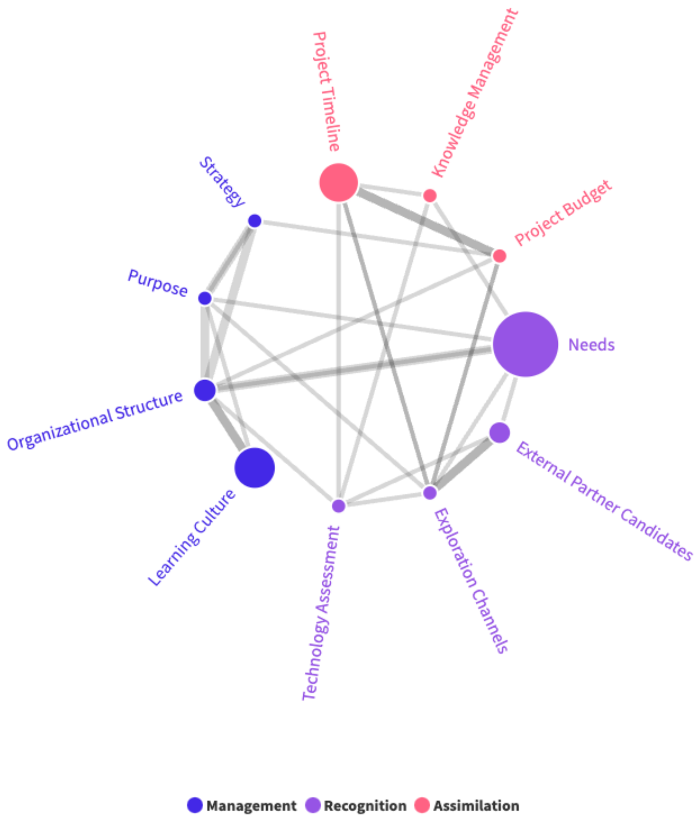


**Figure 5-9 Visualized absorptive capacity framework**

Most importantly, **the architectural decision variables are not all uniformly selected, equally weighted, or sequentially determined**. The results of the analysis suggest that companies should carefully consider the interdependencies and relative importance of each decision in their specific context and tailor their approach accordingly. In particular, the coupling analysis shows that **organizational structure plays a central role in shaping a company's absorptive capacity**. It also implies that firms should prioritize establishing appropriate organizational structures, such as dedicated open innovation teams or offices, as a foundation for their open innovation efforts. The presence of these specialized structures facilitates the coordination of external collaborations, the integration of acquired knowledge, and the cultivation of a supportive learning culture.

The coupling analysis also shows that **management capability variables, such as strategy, purpose, and learning culture, significantly influence recognition and assimilation capabilities**. This finding underscores the importance of strategic alignment, clear purpose, and top management commitment to open innovation success. These variables must be addressed in the early stages of open innovation adoption. Companies should ensure that their open innovation initiatives are firmly grounded in their overall strategy and that goals are well-defined and communicated throughout the organization.

In addition, the sensitivity analysis shows that **needs identification is the most critical driver of absorptive capacity, meaning that it is important to accurately identify and prioritize the technology and market needs that open innovation efforts should address.** Companies should invest in robust processes for gathering and analyzing internal and external input to ensure that their open innovation initiatives are focused on the most pressing and promising opportunities. Fostering an appropriate learning culture and adjusting project timelines can also be key variables in the sensitivity analysis, highlighting the importance of organizational learning and effective project management in open innovation contexts. Companies should foster a culture of openness and collaboration to facilitate the assimilation and application of external knowledge. They should also develop project management skills, including setting clear milestones and managing stakeholder expectations, especially when working with startups that operate on different timelines. The findings suggest that these variables require ongoing attention and refinement throughout open innovation projects. Companies should carefully consider the relative importance of each variable in their specific context and tailor their approach accordingly.

Therefore, the system architecting analysis and case studies have enabled a deeper understanding of absorptive capacity as a system, capturing its dynamics and interactions beyond the deterministic nature of past research. In conclusion, this chapter has presented a comprehensive systems framework for understanding and designing absorptive capacity in the context of open innovation in Japanese companies. **The framework, derived from the analysis of architectural decisions and case studies, highlights the importance of adopting a systems approach that recognizes the interconnectedness and relative importance of architectural decisions.** Not only by prioritizing key variables but also by refining their approach based on systems architecture analysis, companies can develop their absorptive capacity-optimized for their unique challenges and opportunities. Then companies will perform better to make innovations through their outside-in open innovation projects.

# 6. Discussion

## 6.1. Hypothesis Validation

The primary motivation for this thesis stems from the current state of innovation in Japan, the challenges facing the Japanese industry, and the potential role of collaborative R&D activities between large Japanese firms and other actors as a catalyst to drive innovation. This thesis focuses on the transformation of Japanese firms to adopt more openness and sets out to address the primary research question: *What are the critical levers to activate collaborative R&D activities in large Japanese enterprises?*

To answer this question, the literature review reveals the importance of absorptive capacity, the ability to recognize, assimilate, and utilize external knowledge, as a key factor in the successful implementation of open innovation. However, the exact components of absorptive capacity needed to optimize open innovation outcomes remained unclear. The literature review also identified the gaps between academic research and real-world examples of open innovation implementation within firms. This led to the development of the following sub-questions and hypotheses:

Research Sub-Questions:

*Q1. How can absorptive capacity be depicted as a framework to express the mechanism of open innovation practices?*

*Q2. What decisions, those related to the absorptive capacity of the firm, are significant for the successful implementation of open innovation in large Japanese companies? Given these decisions, how can the firm optimize their absorptive capacity to maximize their innovation performance?*

Hypotheses:

*H1. Absorptive capacity for open innovation is not only composed of three proven capabilities - recognition, assimilation, and exploitation - but also includes strategic, organizational, and cultural factors that go beyond technical capabilities.*

*H2. Identifying technological needs for open innovation projects is the fundamental basis for a company's feasible openness and its absorptive capacity.*

*H3. Effective organizational structures increase a firm's openness and improve its absorptive capacity.*

The results presented in Chapter 5 provide substantial evidence to validate these hypotheses and answer the research sub-questions.

**Regarding the first hypothesis**, the functional decomposition of absorptive capacity in Section 5.3 shows that absorptive capacity consists of four main capabilities: Management Capability, Recognition Capability, Assimilation Capability, and Exploitation Capability. The management capability includes strategic factors, such as positioning open innovation within long-term plans and setting clear goals; organizational factors, such as establishing dedicated structures; and cultural factors, such as fostering a supportive learning culture. The decomposition confirms that absorptive capacity surpasses the technical capabilities of recognition, assimilation, and exploitation of external knowledge. Furthermore, the case studies presented in Section 5.6 demonstrate the critical role of management capability in shaping the absorptive capacity framework, highlighting that all five companies clearly articulate their commitment to open innovation in their published long-term strategies, underscoring the importance of top management leadership and vision in driving open innovation initiatives. In addition, the coupling analysis in Section 5.7 shows that management capability variables, such as strategy, purpose, and learning culture, significantly influence recognition and assimilation capabilities. These findings strongly suggest the importance of strategic alignment, clear purpose, and top management commitment in driving open innovation success. In summary, the evidence from the functional decomposition, case studies, and coupling analysis supports the first hypothesis and confirms that absorptive capacity encompasses strategic, organizational, and cultural factors beyond technical capabilities.

**The second hypothesis** is mainly supported by the sensitivity analysis in Section 5.7, which identifies the accurate definition and understanding of technological and market needs as the most critical driver of absorptive capacity. This variable is consistently highlighted in all five case studies presented in Section 5.6, which shows that in some companies, R&D departments actively identify technology gaps based on the challenges they face in their daily R&D activities, leading to effective scope definitions for their open innovation projects. This finding is consistent with several previous reports and research clarifying the importance of accurately identifying and prioritizing the technology and market needs that R&D efforts should address[18], [19]. For R&D departments to achieve more efficient and effective results, it is essential to correctly create a portfolio of the company's technological capabilities and research and development areas. It is also necessary to clarify the company's core competencies and identify areas where external resources are needed. Therefore, by thoroughly evaluating their internal technologies and extracting core competencies, companies can more effectively identify the needs and technologies that should be sought externally, leading to more successful open innovation projects. In short, by prioritizing the accurate definition of technology and market needs and aligning them with the company's core competencies and strategic goals, Japanese companies can increase their absorptive capacity and improve the efficiency and effectiveness of their R&D efforts.

**The third hypothesis** is confirmed by the commonalities identified in the synthesis of the case study findings in Section 5.6 and the coupling analysis in Section 5.7. Most of the case study companies create special organizational structures, such as new teams or offices, to facilitate open innovation, which helps each company increase its absorptive capacity for openness. The coupling analysis also shows that organizational structure plays a central role in shaping a firm's absorptive capacity by setting the framework for learning culture, knowledge sharing, needs identification, and evaluation processes. The high coupling values for organizational structure underscore its potential to influence a wide range of other variables, such as strategy, purpose, and learning culture. These findings are consistent with previous research highlighting the importance of organizational structure for the success of open innovation projects. They show that organizational change is perceived as the most significant challenge in implementing open innovation and that the creation of dedicated open innovation teams and the adaptation of organizational structures are the key factors influencing the successful implementation of open innovation[33], [92]. The results of this thesis also confirm that effective organizational structures are crucial for increasing the openness of a company and improving its absorptive capacity in open innovation mechanisms.

**In summary, the results and analyses presented in Chapter 5 provide sufficient evidence to validate the three hypotheses and answer the research subquestions.** The results show that absorptive capacity is a multidimensional construct that includes strategic, organizational, and cultural factors beyond technical capabilities. Furthermore, the identification of technological needs and the establishment of effective organizational structures are identified as critical levers for the successful implementation of open innovation in large Japanese firms.

## 6.2. Insights for Enterprises and Public Policy

This thesis aims to present the absorptive capacity framework to provide a comprehensive and actionable guide for Japanese firms and policymakers seeking to successfully implement open innovation strategies in large Japanese firms. By understanding the key components of absorptive capacity and their interrelationships, companies and policymakers can optimize their approach to open innovation: companies can improve their ability to identify, acquire, assimilate, and exploit external knowledge, and policymakers can consider public policies that remove barriers to open innovation for firms.

First, companies can use this framework by carefully evaluating the options for each architectural decision and determining which options best fit their specific context and goals to gain a holistic view of their open innovation initiatives. First and foremost, the case studies in this thesis demonstrate that there is no one-size-fits-all approach to selecting architectural decision options. The specific options chosen varied depending on each company's unique circumstances, suggesting that companies should not feel obligated to adopt a particular option simply because it has been successful for others. For example, despite differences in learning cultures - top-down or bottom-up - each company in the case studies is able to successfully implement open innovation by ensuring that their chosen options work together effectively across various variables.

Instead, companies should carefully consider the interdependencies and interactions between variables, as revealed by this thesis's coupling and sensitivity analysis, and choose options that create a coherent and mutually reinforcing system for their specific context. Based on this insight, the first prominent implication of this thesis is that **to expand absorptive capacity, companies should prioritize the creation of a dedicated open innovation unit with a clear mandate to drive open innovation initiatives**. The unit should be given the necessary resources, including budget, staff, and decision-making authority, to effectively coordinate external collaborations and integrate acquired knowledge into the company's innovation processes. The unit should also be positioned to work closely with R&D, business units, and top management to ensure alignment with the company's overall strategy and goals.

The second implication is that **to effectively identify and prioritize their technology needs for implementing open innovation, companies should establish a robust and systematic process that involves close collaboration between R&D and business units, including the open innovation unit**. This process should include regular technology scouting and a clear set of criteria for evaluating and ranking identified needs. By involving multiple stakeholders and leveraging multiple sources of information, companies can ensure that their open innovation efforts are focused on the most pressing and promising opportunities.

Interestingly, the case study results also suggest that **some actions may be less critical or have a more limited impact on open innovation success than commonly expected**. As indicated by the low sensitivity scores, companies may not need to invest too heavily in knowledge management systems and project budgeting processes. Instead, companies should focus their resources on the other key drivers of absorptive capacity, such as fostering a supportive learning culture to cultivate a mindset of openness, collaboration, and experimentation.

Most importantly for companies, this framework is not intended to be a prescriptive set of guidelines or a one-size-fits-all solution to open innovation success. Rather, **it should be viewed as a systems-thinking framework that helps companies identify the key dimensions and decision points they need to consider when designing and implementing their open innovation strategies**. The framework is intended to provide a structured way to break down the complex challenge of open innovation into more manageable components, allowing companies to systematically assess their strengths and weaknesses and make informed decisions about where to focus their efforts. In addition, companies can continuously refine and adapt their approach based on their experience and the evolving business landscape by using the framework as a basis for continuous learning and improvement.

Next, in terms of insights into public policy, our literature review highlights typical innovation policy instruments, such as R&D subsidies and tax incentives, that have been used to promote open innovation. Although the case studies do not directly provide examples of such public policies supporting the firm's open innovation initiatives, it is reasonable to assume that these policy instruments can effectively stimulate open innovation activities among large Japanese firms. R&D subsidies that target collaborative projects between firms and external partners can provide the financial incentives needed to overcome the risks and costs associated with open innovation. Tax incentives that provide preferential treatment for open innovation activities can encourage firms to invest more resources in external collaboration and knowledge acquisition.

However, the results of this study also suggest that public policy initiatives should go beyond such financial incentives. The absorptive capacity framework derived from our work can provide guidance for designing targeted policy interventions that address the key drivers of open innovation success. Based on the framework, one potential policy recommendation is to support the development of robust processes for identifying and prioritizing technology and market needs. The case studies show that a systematic approach to needs identification, involving collaboration between R&D, business units, and open innovation teams, is essential to ensure that open innovation efforts are focused on the most promising opportunities. Policymakers can help by providing guidance on developing technology roadmaps and market intelligence reports that provide companies with valuable insights into emerging trends and customer needs. For example, the National Aeronautics and Space Administration (NASA), an independent agency of the U.S. government, has developed the Technology Readiness Level framework, a systematic metric for assessing the maturity of a given technology, and also published the "Technology Readiness Assessment Best Practice Guide" to help companies effectively assess and manage their technology development processes[173]. The Japanese government could adopt similar approaches to help companies identify and prioritize their technology needs for open innovation. The government has already published several "Model Contracts for Promoting Open Innovation," scoping on non-disclosure agreements, proof of concept contracts, and joint R&D contracts, which are expected to play a key role in reducing administrative barriers, simplifying collaborative agreement procedures and streamlining approval processes for joint projects[174]. By creating some guidelines scoping technology perspectives, public policy can support the effective needs identifications by companies and help reduce uncertainties that often discourage companies from pursuing open innovation. In addition, like the United States, the Japanese government can establish reliable platforms or networks that facilitate knowledge sharing and collaboration among companies, universities, and research institutions, allowing for a more efficient flow of information about technological advances and market needs[80].

It is important to note that the Japanese government has actively taken several symbolic steps with some strong messages to promote open innovation. One prominent example is the Japan Open Innovation Prize since 2018 to recognize companies and universities implementing groundbreaking open innovation initiatives. This strong message from the government can support open innovation and help spread best practices and success stories across organizations[175]. In addition, the government's "Startup Development Five-Year Plan," published in 2022, also emphasizes the promotion of open innovation as a key pillar and outlines strategies to encourage investment in startups by large corporations in Japan. These developments are expected to create a more conducive environment for large Japanese companies to engage in more collaborative innovation activities[176].

A final note is that policymakers need to recognize that the effectiveness of these policies may vary depending on the specific context and needs of individual firms. Just as the case studies show that there is no one-size-fits-all approach to open innovation at the firm level, no universal policy formula will work for all firms. **Policymakers should, therefore, see their role not only as providing one-off support or incentives but also as creating an ongoing innovation ecosystem that supports and encourages open innovation over the long term.** This requires a shift from a transactional to a more collaborative approach, where policymakers work closely with companies and other stakeholders to continuously identify and address evolving barriers to open innovation. In summary, policymakers should see their role as long-term partners in the open innovation journey, working closely with companies to create a vibrant and sustainable environment for innovation and growth.

## 6.3. Research Limitation and Future Works

While this thesis is expected to provide insights and a comprehensive framework for understanding absorptive capacity and open innovation in large Japanese companies, this section summarizes the limitations of the research approach and findings, and suggests future work to address these limitations.

(System Architecture Approach)

One of the main limitations of this approach is the potential lack of comprehensiveness in the selection of architectural decisions within the system architecting approach. The absorptive capacity framework developed in this thesis is based on functional decomposition, architectural decision analysis, and case studies that focus on the interconnectedness and relative importance of specific variables. While this systems architecture approach provides a structured holistic way to understand the dynamics of open innovation, it may not capture all of the relevant factors and dynamics that influence open innovation success in the Japanese context.

The functional decompositions and the architectural decisions identified in this study are objectively derived from a review of academic literature, books, national reports, etc. However, the process may be subject to limitations in terms of the breadth and depth of the sources considered. The categorization of architectural decisions based on the system functions into four main capabilities-management, detection, assimilation, and exploration-may not be the most comprehensive or optimal way to structure the problem. In addition, there may be additional external variables or factors that are not adequately represented in the existing literature but play a significant role in shaping open innovation practices and outcomes in Japanese firms. For example, cultural factors such as the emphasis on consensus building and long-term relationships, or the regulatory environment surrounding technology transfer and economic security perspectives, could have a significant impact on the effectiveness of open innovation strategies for firms.

To address these limitations, future research could take a more exploratory approach to identifying and validating the architectural decisions. This could include using modeling techniques to statistically test the relationships between the variables and their underlying constructs, as well as to visualize the dynamics of the absorptive capacity system. As discussed in Section 2.4, there are trade-offs in open innovation, where excessive openness can lead to diminishing returns or even negative impacts on innovation performance. These findings imply the presence of both positive and negative feedback loops within the absorptive capacity system, highlighting the importance of capturing the dynamics of open innovation in future modeling efforts. By subjecting the absorptive capacity framework to more rigorous empirical testing, future research could refine and strengthen the theoretical underpinnings of the model. It could also take a more holistic approach, examining how internal absorptive capacity factors interact with external enablers and barriers to open innovation in order to refine the systems framework and generalize it to a wider range of settings.

(Case Study Approach and Selection)

Ideally, well-defined multi-attribute utilities to assess system performance would serve as the most objective and reliable metrics. However, as discussed in Section 5.5, measuring the innovation outcomes of large organizations in a consistent manner is much difficult due to the complex interplay of multiple internal and external factors, making it difficult to isolate and discuss the impact of open innovation alone. This lack of established quantitative metrics for measuring the performance of absorptive capacity as a system for open innovation may also introduce subjectivity into the selection of case studies.

The Open Innovation Index used to identify the companies for case studies is based on a scoring system that takes into account various publicly available documents. While this approach provides a relatively systematic way to identify companies that are actively engaged in open innovation, it may not fully capture the effectiveness or impact of their open innovation efforts. The index may favor companies that are more successful in communicating externally about their open innovation initiatives or that have received public recognition, potentially overlooking companies that have achieved significant success through more discreet or internal open innovation practices. This bias toward companies with better external communication can be seen in the relatively low Open

Innovation Index scores of pharmaceutical companies, despite their significant investments in R&D and active engagement in open innovation, as indicated in the literature review. Furthermore, the index does not take into account the specific types of open innovation or the maturity of individual cases, although the system scope of this research focuses on outside-in, technology-driven open innovation.

To address these limitations and ensure greater objectivity in the selection of case studies, one potential method of ensuring objectivity in future research could be to conduct a comprehensive questionnaire survey of Japanese companies to identify those that are implementing open innovation most effectively. Such a survey could provide valuable insights into the specific practices, challenges, and outcomes of open innovation initiatives across a wide range of companies. However, it should be noted that even the extensive questionnaire surveys conducted by the Japanese government have focused primarily on identifying the challenges of open innovation rather than assessing its effectiveness, as shown in the literature review[61]. Future research could build on these existing surveys by incorporating some metrics to evaluate the performance of open innovation initiatives and using some econometric approaches as conducted in European national projects by using the European Community Innovation Survey, as discussed in Section 5.3.

(Limitations of Case Studies)

One of the major limitations of this research is the relatively small sample size of the case studies. Although the five companies selected for in-depth analysis represent diverse industries and have notable open innovation practices, due to the limits of publicly available information, they may not fully capture the full range of open innovation experiences among large Japanese companies. The limited number of case studies may not account for potential differences in approaches and outcomes in different industries with different business models, as this research only covers manufacturing industries. To enhance the generalizability of the absorptive capacity framework, future research could expand the sample size to include a broader range of firms from different sectors and have a case as a baseline, thus ensuring a more comprehensive representation of the Japanese business landscape.

The main limitation of the case studies is that this approach relies heavily on publicly available information, such as corporate documents, interviews with executives and R&D staff, and secondary sources, such as national working papers and books. While these sources are inherently scattered and their restructuring and consolidation provide insights, they may not always provide a complete picture of the internal dynamics and decision-making processes within each company. The information presented in these sources may be subject to various biases, such as self-promotion or selective disclosure, which could affect the analysis and conclusions drawn from the case studies. Future research could mitigate this limitation by conducting primary interviews with key stakeholders involved in open innovation initiatives, allowing for a more nuanced understanding of the challenges, trade-offs, and success factors associated with implementing open innovation strategies. In addition, soliciting objective reviews of the case studies from third-party experts could help validate the findings and provide additional perspectives on the open innovation practices of the selected companies.

Furthermore, in line with the objective of clarifying the absorptive capacity framework, this research focuses on a specific type of open innovation and does not differentiate between different methods of implementing open innovation. As discussed in the literature review and case studies, there are various forms of outside-in open innovation, such as technology collaborations, venture capital investments, the establishment of corporate venture capital, mergers and acquisitions, and the implementation of acceleration programs. Future research could explore these different methods in more detail by surveying cases that specifically examine each approach. By categorizing and analyzing open innovation initiatives based on their specific methods, future studies could provide a more detailed understanding of the factors that influence the success of different types of open innovation practices in the Japanese context. This could include comparing the absorptive capacity factors and outcomes associated with each method, as well as identifying the unique challenges and best practices for effectively implementing each approach.

(Connectivity and Sensitivity Analysis)

The connectivity analysis in this study has some limitations due to the method used to determine the strength of couplings between architectural decisions. The couplings are categorized as strong, weak, or no coupling based on their occurrence in the five case studies. The limited number of case studies may not provide a sufficiently robust basis for determining the strength of couplings between variables. With only five case studies, the presence or absence of a coupling in one or two cases can significantly affect the categorization of the coupling as strong or weak. In addition, the binary classification of couplings as either strong or weak may rely on the relatively subjective interpretation of the case study results and may oversimplify the complexity of the interactions between architectural decisions. In reality, the impact of one variable on another may depend on the specific context and conditions of each case. Future research could mitigate this limitation by increasing the number of case studies and defining rigid coupling criteria to assess the significance of the relationships between architectural decisions.

The sensitivity analysis conducted in this study also has limitations due to the challenges of establishing quantifiable metrics for open innovation performance. The analysis relies on a binary classification of architectural decisions as primary or non-primary, which may oversimplify the nuances of their impact on absorptive capacity. This limitation also stems from the lack of quantitative metrics to assess system performance. Future research could explore more sophisticated methods for assessing the sensitivity of open innovation performance to different variables, such as linking the results of stakeholder analysis with the identified needs of each stakeholder, using multi-criteria decision analysis, or developing composite indicators that capture the multidimensional nature of open innovation success.

In summary, the research limitations in this thesis primarily arise from the potential lack of comprehensiveness in the selection of architectural decisions, the subjectivity in case study selection, the reliance on publicly available information in case studies, and the simplification of connectivity and sensitivity analyses. We expect that future research could address these limitations to update our framework for understanding absorptive capacity for open innovation through system architecting.

# 7. Conclusion

Motivated by the current state of innovation in Japan and the challenges faced by Japanese industry, the thesis has focused on the potential role of collaborative R&D between large Japanese firms and other actors as a catalyst for driving innovation. Our literature review reveals the importance of *absorptive capacity* -- the ability to recognize, assimilate, and utilize external knowledge -- as a key factor in the successful implementation of open innovation in a firm. However, it also highlights gaps between academic research and real-world examples of open innovation implementation within firms. To address these gaps, the thesis developed a systems framework for understanding and designing absorptive capacity in the context of open innovation in Japanese firms.

Through a systems architecture approach with case studies, **the research identified four main capabilities that constitute absorptive capacity: management, recognition, assimilation, and exploitation capabilities**:

- management capability, which includes strategically positioning open innovation, setting goals, and establishing appropriate structures;
- recognition capability, which includes identifying areas where external resources are needed, exploring technologies, and selecting partners;
- assimilation capability, which includes project management and integrating external knowledge; and
- exploitation capability, which includes determining applications of assimilated knowledge, updating the company's portfolio, and translating results into new projects and business models.

**The framework maps these capabilities to specific architectural decisions and options, providing a tangible link between the theoretical understanding of absorptive capacity and companies' practical choices in designing their open innovation systems.**

The case studies of five prominent Japanese companies from diverse industries provide insights into the architectural options shaping their absorptive capacity systems. Each company's pursuit of open innovation appears to be independent of trends in its R&D spending or intensity. Instead, rapid changes in the external environment, such as technological disruptions or market shifts, emerge as significant catalysts for firms to move away from self-reliance and embrace collaborative innovation.

The synthesis of these case studies, including connectivity and sensitivity analyses, demonstrates the importance of a systems approach that recognizes the interconnectedness and relative importance of architectural decisions. In particular, **organizational structure plays a central role in shaping a firm's absorptive capacity, while management capability variables significantly influence recognition and assimilation capabilities.** Moreover, accurate definitions and understanding of technology and market needs are the most critical drivers of absorptive capacity. **These findings underscore the importance of prioritizing needs assessment and aligning open innovation efforts with the organization's core competencies and strategic goals.**

In conclusion, **this thesis presents a comprehensive systems framework for understanding and designing absorptive capacity in Japanese firms' open innovation context**. The framework emphasizes the importance of a holistic approach considering strategic, organizational, and cultural factors beyond technical capabilities. By prioritizing key variables and refining their approach based on system architecture analysis, companies can develop absorptive capacity optimized for their unique challenges and opportunities. These insights will enable companies to perform better through their outside-in open innovation projects.

We expect the results of this research to contribute to both the academic discourse and the practical implementation of open innovation strategies. For academics, the framework extends previous perspectives on absorptive capacity by integrating insights from real-world open innovation practices. For practitioners, including policymakers, the framework provides actionable guidance for designing and managing open innovation initiatives. By providing a systems framework for understanding and designing absorptive capacity, this thesis will lead to the development of a more vibrant and competitive innovation ecosystem in Japan that fosters collaboration and knowledge exchange among diverse actors.

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