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An Empirical Study Regarding Radical Innovation, Research and Development Management, and Leadership

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Abstract

The objective of this research is to empirically compare the management that is most suitable for radical innovation with that needed for incremental innovation. The relationship between the results of research and development and management styles was surveyed using a questionnaire. Respondents included research and development leaders in Japanese manufacturing, with special attention given to the differences between radical innovation and incremental innovation. Results verified, in an integrated way, the management and leadership factors, taking into consideration the differences arising from the object under analysis and the environmental factors.

Keywords: radical innovation, incremental innovation, research and development management, leadership, size of the firm, technology life cycle, kinds of goods

Introduction

The objective of this research is to empirically compare the management that is most suitable for radical innovation with that which is needed for incremental innovation.

Conventionally, many Japanese manufacturers have excelled at incremental innovation (e.g., Lam, 2005). However, the research and development (R&D) management that is appropriate for incremental innovation is not always effective for radical innovation. The traits of Japanese R&D organisations are often compared to rugby (Nonaka et al., 1995): all of the members move forward, little by little, in a horizontal line in cooperation, with no one moving ahead of the others. On the other hand, radical innovation may resemble American football. It is innovation using an idea that is not bound in the past, and it efficiently uses a star's personality and projected capabilities. Therefore, the leadership of an R&D team may be important. There may be a close relationship between the realisation of outstanding innovation and the organisation and its human resource management.

However, as described later in section 2, the findings regarding the relationships between the results of innovation and management styles have not been uniform in previous research study. The causes of this inconsistency include the variations in the R&D results and the mixture of the goods at issue. Furthermore, various

factors are considered to be related to the success or failure of R&D (Griffin & Page, 1993). Similarly, the success or failure of a management style may change as a result of differences in specific industries, products, technologies, and other aspects of the business environment. Therefore, in analysing the optimal relationship between the results of innovation and management styles, classifying various influences, such as the specific companies, technologies, and environments, is important.

As the research question of this research, the relationship between the results of R&D and management styles was surveyed using a questionnaire answered by R&D leaders in Japanese manufacturing, with special attention given to the differences between radical and incremental innovation. The questionnaire items were designed using prior research on R&D management.

Prior Research

After surveying the literature on radical innovation, the prior research on the relationship between innovation and management and leadership was surveyed. Since radical innovation is considered relevant for venture businesses, the size of the firms and their life cycles were given particular attention. In addition, the differences between the types of goods, such as those aimed at consumers and those designed for companies, were noted.

Radical innovation and incremental innovation

Innovation is classified into incremental innovation and radical innovation depending on its degree of newness. (e.g., Dewar et al., 1986). According to Govindarajan et al. (2005), four organisational factors of an existing business are the mastery of operational employees, hierarchical structure, a fixed accountability system, and a risk-hedge corporate culture. Meanwhile, four organisational factors of new businesses are creativity, a flat organisational structure, a system with a flexible ability to learn, and a risk-tolerant corporate culture. Macher (2004) stated that acquisitions are needed for an existing company that is initiating disruptive innovation, because the management for disruptive innovation is different from that for incremental innovation.

Radical innovation and R&D management

Regarding the relationship between management and innovation, Tushman et al. (1980) asserted that an R&D division must consider various directions, such as external technology and the market environment, head-office strategies and intentions, and collaboration between the sales and production departments. According to Morton (1971), by optimising the barriers and bonds of an organisation, a technician can develop his creative power freely and can cooperate well with other technicians. For example, a central laboratory is appropriate for radical innovation in comparison with a division laboratory (O'Connor et al., 2005). In order for a creative group to generate significant results, it is necessary to vary the thinking style and the special capabilities in a group and combine them appropriately (Luecke et al., 2003). According to James (2002), the factors that provide the most motivation to engineers and scientists are their interest and the degree of freedom they are granted.

Radical innovation and leadership

Regarding the relationship between leadership and innovation, today's technical managers are required both to have clear, objective proposals and orientations and to consider the delegation of power, education, and an attractive environment (Farris et al., 2002). Amabile et al. (2004) and Tierney et al. (2004) found a relationship between supportive leadership and creativity. Furthermore, Shin et al. (2003) found a positive relationship between transformative leadership and creativity. According to Cooper (1998), an important role for managers in product innovation is the determination of the go/kill points and the priority of a project. According to Dyer et al. (2011), five skills are needed for a disruptive innovator: associating, questioning, observing, networking, and experimenting.

Radical innovation and the scale of a company

Utterback (2005) argued that innovation occurs in small technical companies and is adopted by large-scale corporations. In large-scale corporations, incremental innovation with economies of scale is dominant. Marcati et al. (2008) found that an entrepreneur's personality is key in the innovation of smaller enterprises. Meanwhile, Revilla et al. (2012) indicated that the relationship between the productivity of R&D and the size of a firm is not constant but is influenced by management methods.

Radical innovation and the different kinds of goods

Problems regarding the objects of the analyses can be considered as one reason why the results of the preceding research on the success factors of product development have not been uniform. For example, Iansiti (1993) showed that the scale and diversity of research activities in the initial development phase are effective in order to evaluate and

select various technologies, based on the analysis of the development project for a mainframe computer. With respect to the research scale, Barnett et al. (1998) showed that the accumulation of knowledge about technological assessments through past experiences was effective in the product development of the chemical industry. Meanwhile, in the case of consumption goods, it is necessary for developers to anticipate potential needs in advance and propose new concepts (Clark et al., 1991).

Radical innovation and the life cycle

Abernathy et al. (1983) considered the maturation of the industry based on the evolutionary patterns of a product's technology and indicated that it moved from the early stage, which is centred on radical product innovations, to a mature phase, which is centred on incremental process innovations. When there are transformations in the external environment, such as changes in technology and consumer preferences, the technology moves to the de-maturity (new growth) phase. According to Tushman et al. (1997), the innovation in a cycle of discontinuous change is produced as a result of the unpredictability of entrepreneurial organisations. Meanwhile, the organisational models in a cycle of incremental change are characterised by formulated roles and responsibilities, intensive processes, an efficiency-oriented culture, a sufficiently designed work process, and a strong manufacturing and selling capability.

Survey Hypotheses and Research Design

Survey hypotheses

The questionnaire was designed to clarify the traits of R&D management for the creation of radical innovations in contrast to those necessary for incremental innovation. The fundamental framework of the research design was based on the above-mentioned prior research and is shown in Figure 1.

Here, the objective variable is the result of radical or incremental innovation.

The explanatory variables are R&D management and leadership. The control variables are the management environments, such as the size of the firm, the kinds of goods, and the life cycle of the company or the product. The cause-effect relationships were thought to be as follows: the optimal organisational management changes with the strategic goals and the business environment, and the optimal leadership changes with the strategic goals, the business environment, and the organisational management. The following survey hypotheses were formulated based on the above framework:

H1. The management of R&D needed to bring about radical innovation differs from the management needed to bring about incremental innovation.

H2. The R&D leadership needed to bring about radical innovation differs from the leadership needed to bring about incremental innovation.

H3. The relationship of the results of innovation, R&D management, and leadership is affected by the scale of a company.

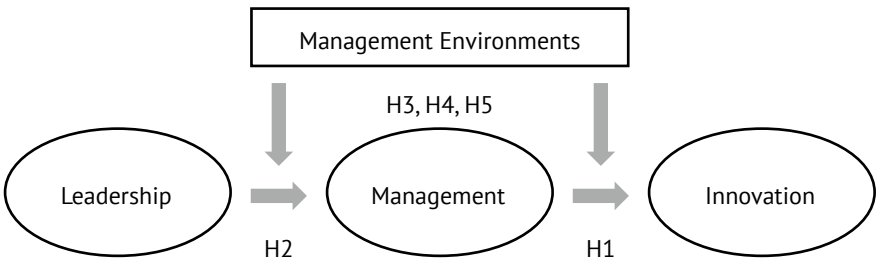
H4. The relationship of the results of innovation, R&D management, and leadership is affected by the kinds of goods involved in this relationship.

H5. The relationship of the results of innovation, R&D management, and leadership is affected by the life cycle of the company and the product.

Methodology and data

The items on the questionnaire were created based on the above-mentioned hypotheses. In addition to the evaluation of the product, which is the final result of the R&D, a patent and academic society publication was adopted as a proxy variable for the R&D process evaluation regarding the

Figure 1. The fundamental framework of the research design



result of the innovation, which is the objective variable. The number of items and the degree of innovation were evaluated. All of the questionnaire items were rated on a 5-point Likert-type scale (Strongly disagree, Disagree, Neither agree nor disagree, Agree, Strongly agree). The manufacturers' R&D managers were set as the targets for the survey. The questionnaires were distributed and collected by active businesspeople who are students at the business school that the author heads, as well as over social networks. The survey period took place during October 2015. A total of 100 responses to the questionnaire were received (39 students and 61 respondents over social networks). As a result of the performance of an evaluation of the deficit value or the abnormal value, an evaluation of the ceiling and the floor effect, a reliability assessment, and so forth, the final number of effective responses was 81. With respect to the effective responses to the questionnaire, in order to verify each hypothesis, the following statistical analyses were conducted. SPSS by International Business Machines (Ver. 23) was used to perform the statistical procedures.

Results

Factor analysis results

First, two or more questionnaire items were collected into groups based on the hypotheses, and a factor analysis was conducted. The major factors (with an eigenvalue of one or more) for each group were extracted using the principal factor method (promax rotation).

Two factors were extracted as a result of the factor analysis of the questionnaire items regarding the results of the innovation, which are the objective variables.

The first factor consists of the questionnaire items regarding the numbers of products or the results of the research; this was called the incremental innovation factor. The second factor consists of questionnaire items regarding the degree of the new-product ratio in the product portfolio, or the novelty; this was called the radical innovation factor.

Next, among the explanatory variables, first, as a result of the factor analysis of the questionnaire items regarding the organisational operation of R&D management, three factors were extracted. The first factor consists of questionnaire items regarding personnel exchanges between sections, internal and external interchange, and so one; this was called the personnel-exchanges factor. The second factor consists of questionnaire items regarding the scale of an R&D group; this was called the research scale factor. The third factor consists of questionnaire items regarding the differentiation of the team for original and radical research; this was called the original factor.

Next, three factors were extracted as a result of the factor analysis of the questionnaire items regarding research management in R&D management. The first factor consists of questionnaire items regarding the formation of a new technology-oriented team, industry-university cooperation, and so on; this was called the technical-oriented factor. The second factor consists of questionnaire items regarding a long R&D time period, a stage administration, and so one; this was called the long-term-oriented factor. The third factor consists of questionnaire items regarding the formation of a market-oriented team, the high frequency of performance appraisals, and so on; this was called the market-oriented factor.

Next, one factor was extracted as a result of the factor analysis of the questionnaire items regarding the research diversity in R&D management. It consists of the questionnaire items regarding diversity, such as the specialised fields of study and age, and it was called the research diversity factor.

Next, one factor was extracted as a result of the factor analysis of the questionnaire items regarding the culture of R&D management. It consists of questionnaire items regarding a researcher's discretion, personal respect, and so on; this was called the cultural factor.

Next, two factors were extracted as a result of the factor analysis of the questionnaire items regarding leadership in management. The first factor consists of questionnaire items regarding the flexible business solutions for a project, negotiations, and so on; this was called the flexible factor. The second factor consists of questionnaire items regarding the assignment of work, progress management, control, and so on; this was called the process-oriented factor.

Next, two factors were extracted as a result of the factor analysis of the questionnaire items regarding leadership. The first factor consists of questionnaire items regarding the presentation of a vision and a scheme to followers; this was called the structure factor. The second factor consists of questionnaire items regarding the fiduciary relationship with followers, mental support, and so on; this was called the consideration factor.

Next, one factor was extracted as a result of the factor analysis of the questionnaire items regarding decision making in leadership. It consists of questionnaire items regarding decisions in complicated situations, the participation of followers in decision making, and so on; this was called the decision-making factor.

Next, one factor was extracted as a result of the factor analysis of the questionnaire items regarding individual capabilities in leadership. It consists of questionnaire items regarding networking ability, presentation ability, and so on; this was called the individual-capabilities factor.

Test statistics for each factor analysis are shown in Table 1.

Regression analysis results

With respect to the factor score for each factor, based on the hypotheses, the regression analysis was applied for each hypothesis, and the relationship was verified. First, each innovation result factor was made into an objective variable, and each R&D management-related factor was made into

Table 1: The test statistics for each factor analysis

	T1	T2	T3	T4	T5
Results of the innovation	.518	.000	74.215	56.618	.804
Organisational operation of R&D	.576	.000	74.215	56.618	.750
Research management in R&D	.752	.000	63.000	48.077	.806
Diversity in R&D management	.814	.000	53.474	43.675	.754
Culture of R&D management	.764	.000	60.078	50.975	.825
Leadership in management	.555	.000	53.097	43.568	.795
Leadership	.624	.001	66.015	49.850	.757
Decision making in leadership	.507	.001	54.153	44.964	.761
Individual capabilities in leadership	.583	.006	46.663	30.046	.717

(T1: Kaiser-Meyer-Olkin (KMO), T2: Bartlett's test of sphericity (%), T3: Eigenvalues with cumulative variance (%), T4: Extraction sums of squared loadings with cumulative percentage (%), T5: Cronbach's alpha).

Table 2: The multiple linear regression analysis results during a factor score

Environment	Innovation	Management	Leadership
Large-scale corporation	Incremental	Market oriented (.474*) [.256, .016**]	Process oriented (.442**) [.309, .007**]
	Radical	Personnel exchanges (.581*) [.274, .012**]	
Small and medium-size enterprises	Incremental	Originality (1.481**) [.572, .001**]	
	Radical	Culture (.717**) [.579, .001**]	Flexible (.788*) [.361, .014**]
Industry goods	Incremental	Research scale (.622*)	
		Research diversity (1.015**) [.871, 001**]	Process oriented (.421*) [.429, .040**]
	Radical	Technical oriented (.664*) [.556, .013**]	Structure (.645*) [.503, .022**]
Consumption goods	Incremental	Originality (.346*) [.239, .034**]	Decision making (.669*) [.249, 030**]
	Radical	Market oriented (.474**)	Decision making (.595*) [.239, .034**]
		Personnel exchanges (.375*) [.578, .001**]	
Growth phase	Incremental		
	Radical	Research scale (-1.086**)	
		Originality (1.236:*)	Individual capabilities (1.055*) [.662, .026**]
		Technical oriented (.873*) [.980, .005**]	Individual capabilities (.764*) [.671, .024**]
Mature phase	Incremental	Research scale (.605**) [.309, .009**]	Flexible (-. 688**) [.371, .003**]
	Radical	Long-term oriented (.477**)	Structure (-. 574*) [.215, .034**]
		Research diversity (.411**) [.748, 000**]	Process oriented (.407*) [.224, .030**]
Decline phase	Incremental	Long-term oriented (.628**)	
		Cultural (.410**) [.918, .003**]	Consideration (2.101*) [.975, .012**]
	Radical		

Note: Parentheses () indicate partial regression coefficients; square brackets [] indicate the determination coefficient and the significance probability of the F-test. (** Significant at .01; * Significant at .05.)

an explanatory variable. Subsequently, each R&D management related-factor was made into an objective variable, and each leadership-related factor was made into an explanatory variable.

In each analysis, a regression analysis was applied according to the size of the firm, the kinds of goods, and the life cycle. The size of the firm was measured by the yearly turnover; 100 billion yen (about 800 million euro, which was a near medium value of the samples) or more was classified as a large-scale corporation, while less than 100 billion yen was classified as a small or medium-size enterprise. About 59% of the responses to the questionnaire were from large-scale corporations, and about 41% were from small and medium-size enterprises. The kinds of goods were classified into industrial goods (including capital goods and construction goods) and consumption goods. About 51% of the responses of the questionnaire addressed industrial goods, and about 49% addressed consumption goods. The life cycle was classified into the growth phase, the mature phase, and the decline phase. About 22% of the respondents to the questionnaire were in the growth phase, about 65% were in the mature phase, and about 13% were in the decline phase. The regression analysis revealed only the factors with statistically significant relationships, using the stepwise procedure. The factors and the partial regression coefficients that were revealed are shown in Table 2.

Findings and Discussion

The different relationships between R&D management and leadership were extracted for radical innovation and incremental innovation, respectively, as a result of the statistical analysis of the questionnaire. In addition, those relationships were affected by environmental conditions, such as the size of the firm, company age, and the kinds of goods.

First, the size of the firm was considered. H1-3 belong to this section. In the case of a large-scale corporation, incremental innovation is created by market-oriented research with a leader management style. Large-scale corporations have abundant managerial resources (e.g., human and intellectual resources, R&D equipment, etc.) within the company, and it is considered that the incremental results of the research are steadily created, mass-produced and sold by managing the resources specifically for the market. On the other hand, radical innovation is created by diversified interchange within and outside a company. In order for a large-scale corporation to create radical technology and products, utilising external resources (e.g., a university or a venture business) or promoting the interchange of diverse, talented people in the company is thought to be effective. This result is consistent with the prior research (see 2-4).

Next, in the case of a small or medium-size enterprise or venture business, in contrast to a large-scale corporation, original research is important for incremental innovation. Unique research in a niche area can contribute to successful competition with with a large-scale corporation despite comparatively scarce managerial resources. Furthermore, with respect to radical innovation, a research-oriented culture with flexible leadership is important. This corporate style and culture, which are not present in large-scale corporations and existing enterprises, may induce original and disruptive products. This result is consistent with the prior research (see 2-4). Thus, H1-3 were accepted.

Next, the kinds of goods are considered. H1, H2, and H4 are relevant to this section. In the R&D of industrial goods, incremental innovations are created when the input of resources is increased for R&D and the leader appropriately manages diversity. In the case of industrial goods, it is thought that the customers are also professionals and the evaluation of technology is stringent. In order to create outstanding technology, a large amount of research (e.g., many trial experiments) is required, and the amount of research resources is considered to be important. This result is consistent with prior research (see 2-5). In addition, in order to properly assemble diverse team members, it may be important for the leader to appropriately manage each milestone in the research process. In addition, radical innovation is created in the pursuit of technology by a leader with a visionary style. In order to create radical technology, a leader's transcendent vision and beliefs may help to promote the research project.

Meanwhile, in the R&D of consumption goods, in incremental innovation, original research is useful. Further, a leader's decision-making ability promotes R&D. In the case of consumer goods (since, in general, consumers' needs are ambiguous and fickle), the manufacturing side may be required to positively change a product concept and make a novel proposal. In the case of industrial goods, the quality of a product can be measured by its technical specifications, but market surveys regarding the popularity of consumption goods may have limitations, and a decision from the sales side may be needed. This result coincides with those found in prior research (see 2-5). In addition, in radical innovation, dialogue with marketing or other sectors is useful. Further, a leader's decision-making ability promotes R&D for incremental innovation. In consumer-oriented product development, the proposal of solutions developed through cooperation between distributors and retailers, service companies, and so on may be important. Thus H1, H2, and H4 were accepted.

Finally, the differences arising from the product and corporation life cycles are considered. H1, H2, and H5 are

relevant to this section. First, in the case of the growth phase, the management factor was not extracted for incremental innovation. At the time that a product's market begins to extend, radicalism and novelty in research are considered to be important. With respect to radical innovation, the pursuit of original technology is more useful than the amount of resources injected into R&D. In addition, the results are dependent on an individual leader's capabilities. Research in an organisation in which independence without bondage is higher than in past experiences is considered to be effective in the growth phase. Giving priority to heightening technical capabilities above all other aspects is thought to create results, as are individuals who champion these types of research capabilities. These results coincide with those in prior research (see 2-6).

Next, in the case of the period of maturity, the research scale is important for incremental innovation, and a managing type of leader is more desirable than flexibility. During the period of maturity, in which the objective of R&D is converted from quality to quantity and competition intensifies, steadily improving the product, the production process, and so on is considered necessary to expand the market share and to improve productivity. On the other hand, for radical innovation, long-term research by a transfer-of-authority type of leader and the suitable management of diverse research and talented people are useful. When entering the period of maturity, in which many competitors are entering the market and price competition is intensifying, improvements in productivity and cost reductions are required. On the other side, R&D aimed towards the next phase (i.e., de-maturity) is required. In such long-term R&D, supportive type leaders who respect researchers' independence are thought to be more appropriate than the vision-oriented leaders of the growth phase. In addition, although the diversity of research can improve innovation, in order to assemble diverse, talented people, both within and outside the company, a leader who provides orderly management at each milestone of a process is required. These results coincide with those in prior research (see 2-6).

Lastly, long-term-oriented R&D by leaders with a consideration style is also useful for incremental innovation during the decline phase. In addition, the management factor was not extracted for radical innovation. In the decline phase, in which the protraction of the life cycle of the product serves as the objective, good communication with existing customers is required, rather than radical innovation. Thus, H1, H2, and H5 were accepted.

Conclusion

This research was aimed at empirically clarifying the types of R&D management and leadership that promote radical innovation in contrast to those that are needed for incremental innovation. Although a variety of actual evidence and results have been shown regarding innovation, management, and leadership in the prior research, those results have not been unified together. As a result, radical innovation and incremental innovation remained intermingled; the relationship between management factors and leadership factors remained unexplained; and the influence of environmental factors, such as the kinds of companies and goods at issue, remained ambiguous. One contribution of the present research is that it verified, in an integrated way, the management and leadership factors, taking into consideration the differences arising from the object under analysis and the environmental factors. As an implication of this research, it is expected that the minute positive results of the research will provide support for decision making by the R&D managers of companies. With respect to the limitations of this research, since the analysis of this research is limited to Japanese firms, it is possible that the research findings were influenced by environmental factors specific to Japanese firms. Future research should include the use of a larger number of samples and international comparative research. Also, the interaction among various environmental factors needs to be analysed.

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Appendix

Questionnaire items (translated)

Variables	Items	Scales
Objective variables	✓ Number of products ✓ Number of results of the research	1: 3 or fewer per year 2: 4-6 per year 3: 7-9 per year 4: 10-12 per year 5: 13 or more per year
	✓ Number of conference presentations	1: 5 or fewer per year 2: 6-15 per year 3: 16-30 per year 4: 31-50 per year 5: 51 or more per year
	✓ A large new-product ratio in the product portfolio ✓ Novelty of the products	1: Strongly disagree 2: Disagree 3: Neither agree nor disagree 4: Agree 5: Strongly agree

Variables	Items	Scales
Explanatory variables (Management)	✓ Frequent personnel exchanges between sections ✓ Frequent internal interchanges ✓ Frequent external interchanges ✓ Large-scale R&D groups ✓ Many R&D groups ✓ Existence of a team for original and radical research ✓ Differentiation of tasks of R&D groups ✓ Existence of a new technology-oriented team ✓ Active industry-university cooperation ✓ Evaluation of technology-oriented performance ✓ Long R&D time period ✓ Rigidness of a stage administration ✓ Large ratio of research expense ✓ Priority of the technology road map ✓ Existence of a market-oriented team ✓ Priority of customer needs ✓ High frequency of performance appraisals ✓ Great diversity of specialised fields of study ✓ Great diversity of age ✓ Great diversity of backgrounds ✓ Great diversity of members in a project team ✓ Researcher's much discretion ✓ Great respect for researcher's autonomy ✓ Great independence of the research organization ✓ Flat organization	1: Strongly disagree 2: Disagree 3: Neither agree nor disagree 4: Agree 5: Strongly agree
Explanatory variables (Leadership)	✓ Flexible in business solutions for a project ✓ Excel in negotiation capability ✓ Excel in problem solving ability ✓ Excel in the appropriate assignment of work ✓ Excel in progress management ✓ Excel in process control procedure ✓ Active in the presentation of a vision and a scheme to followers ✓ Acutely conscious of mission ✓ Strong fiduciary relationship with followers ✓ Active in mental support ✓ Active in empowerment ✓ Excel in decisions in complicated situations ✓ Active adoption of followers in decision making ✓ Good under pressure ✓ Excel in networking ability ✓ Excel in presentation ability ✓ Strong intellectual inquiry	1: Strongly disagree 2: Disagree 3: Neither agree nor disagree 4: Agree 5: Strongly agree
Environment variables	✓ Category of industry	1: Manufacturing 2: Other
	✓ Type of occupation	1: R&D manager 2: Other
	✓ Yearly turnover (yen)	1: 100 million or less 2: 100 million – 5 billion 3: 5-10 billion 4: 10-100 billion 5: 100-500 billion 6: 500 billion -1 trillion 7: 1 trillion or more
	✓ Type of goods	1: Industry goods 2: Consumption goods
	✓ Life cycle of the company and the product	1: Growth phase 2: Mature phase 3: Decline phase

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Empirična študija radikalnih inovacij, upravljanja raziskav in razvoja ter vodenja

Izvleček

Cilj raziskave je empirično primerjati upravljanje, ki je najprimernejše za radikalne inovacije, potrebne za postopne inovacije. Kar zadeva metodologijo, smo z anketiranjem vodij raziskav in razvoja v japonski industriji ugotavljali povezavo med rezultati raziskav in razvoja ter stili upravljanja s posebnim poudarkom na razlikah med radikalnimi in postopnimi inovacijami. Raziskava je potrdila povezanost dejavnikov upravljanja in vodenja, upoštevajoč razlike, ki izhajajo iz predmeta analize in okoljskih dejavnikov.

Ključne besede: radikalne inovacije, postopne inovacije, upravljanje raziskav in razvoja, vodenje, velikost podjetja, življenjski cikel tehnologije, vrsta blaga.