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- Determining Jigsaw Puzzle Type or Puzzle Links Type for Managerial Decision Making

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J-L Puzzle Theory - Determining Jigsaw Puzzle Type or Puzzle Links Type for Managerial Decision Making

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ABSTRACT

The challenge of this paper is to validate whether perceptions toward technology typically shared by engineers can be theorized as J/L classification. J-type is where desired output can be achieved given sufficient investment in people, money, resources, and time. L-type is where desired output is uncertain and risks are involved. A jigsaw puzzle (J) is a suitable metaphor for the former. Even though it might require time and resources, there is a high degree of confidence in advance; therefore, a resolution can be achieved somehow. A puzzle link (L) could be a metaphor for the second. It might be untangled in the blink of an eye or it might require considerable patience and still result in failure. According to the findings of this research conducted within an organization, J/L classifications indicated the differences between technical and non-technical (administration/business) employees with regard to their perceptions toward technology, as well as differences among the managerial layers within the organization. These differences should have a significant impact on management decision-making. Management decision-making would be completely altered depending on whether the decision maker perceives or assumes the differences in the perceptions toward technology between technical and non-technical (administration/business) employees or among the managerial layers within the organization. Conventional classifications of research and development fail to provide this kind of criterion for judgment.

Key Words：research, development, breakthrough, resource, decision

PREFACE

This study was inspired by a casual lunch-hour chats with a veteran engineer at Company X.

People in the R&D and technology divisions claim they were the first in the industry to develop a consumer-grade piece of large-scale equipment, but anyone can do that with a sufficient number of personnel. The technical standards of consumer-grade, large-scale equipment were established primarily by an industry-led organization, so you could say they just happened to be the first ones assigned to implement it. To produce what meet the standards, they only needed someone to do the work, and making it happen was only a matter of putting a certain number of people on the job.

To an outsider interpreting this kind of comment like, "a company's Research and Development division employs an ample number of engineers, which results in the very first product within the industry," it may appear that it is because of a breakthrough. However, the veteran engineer remarked that this interpretation projects a stereotype, rather, in reality, the completion of these projects is possible when an adequate number of people are assigned the task. The inference we can draw from his observation is that certain projects among large-scale, cutting-edge technology projects can succeed on the condition that people, resources, and money are allocated to them. Such circumstances do not qualify for the simple definition of "development." The following research questions encompass the critical factors for success or failure of this "theory on-site"

- What types of technology projects can be accomplished by merely investing people, resources, and money?
- Can these project outcomes be associated with different perceptions of technology?
- How are these perceptions toward technology shared, or not shared, within an organization?
- If perceptions toward technology could be unified, then what types of problems could be solved, given current organizational circumstances?

DEFINITIONS

Types of General Research and Development

The Ministry of Internal Affairs and Communications's website (2014) features categories of research characteristics based on the *Report on the Survey of Research and Development* (a Science and Technology White Paper) that in turn may be based on classifications used by the Organization for Economic Cooperation and Development (OECD). This study showcases a combination of these classification concepts in basic and applied research categories. Similarly, research and development herein is assumed to be the equivalent of development (Table 1).

TABLE 1

Comparison of Ministry of Internal Affairs and Communications's and the OECD's Definitions with the Concepts of this Study

Ministry of Internal Affairs and Communications OECD(2002) Definitions		
Basic Research*	**Applied Research**	**Research & Development**
Theoretical or experimental research conducted to gain new knowledge regarding phenomena and observable facts or to form hypotheses and theories without directly considering special applications or uses.	Research to set goals and determine the possibility of commercializing knowledge or to seek out new ways to apply existing knowledge discovered in basic research.	Research that uses knowledge gained through basic research, applied research, or actual experience with the aim of introducing new materials, devices, products, systems, or processes, or the improvement of such things as they al- ready exist.
Research		**Development**
Concepts in this Study		

*Most basic research is not currently conducted at private enterprises.

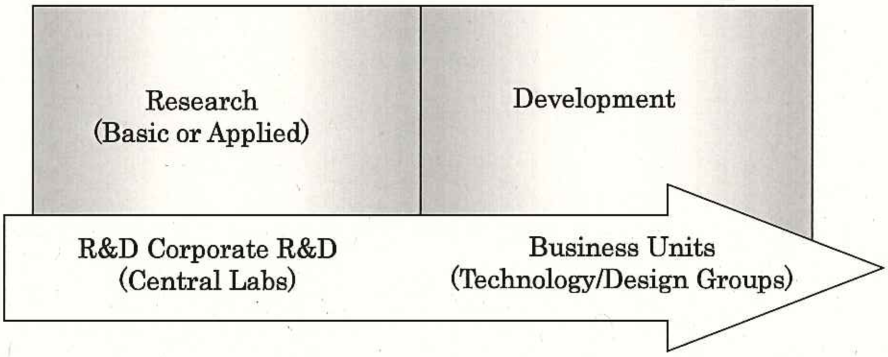
Furthermore, the model presented as Figure 1 was developed, with classification names in the rectangles and arrows denoting the group responsible for each activity within a corporation. Wherever possible, we used the following simple definitions for research and development:

Research: Theoretical studies and experiments conducted to gain new knowledge or to search for new applications.

Development: Using knowledge gained through research or actual experimentation.

FIGURE 1

General Model of Research & Development (R&D) from Basic or Applied through to Design and Development



Classifications Reflecting "Perceptions Toward Technology"

We now define classifications unique to this study, in contrast to the general classifications mentioned earlier. Investing human and capital resources into a project, as suggested by our veteran engineer, presents a challenge that is not unlike a jigsaw puzzle. Regardless of the number of pieces, sufficient time and patience will ensure completion.

Conversely, since the investment of resources does not always guarantee a successful outcome, projects can be regarded as puzzle links; that is, they may appear to be a combination of simple links, but they require special knowledge (i.e., "breakthrough") to realize the solution. That point of realization could occur in an instant or may take a lifetime.

In terms familiar to traditional management decision-making, these classifications can also be expressed as follows:

J-type: investment of people, money, and resources ensures output.

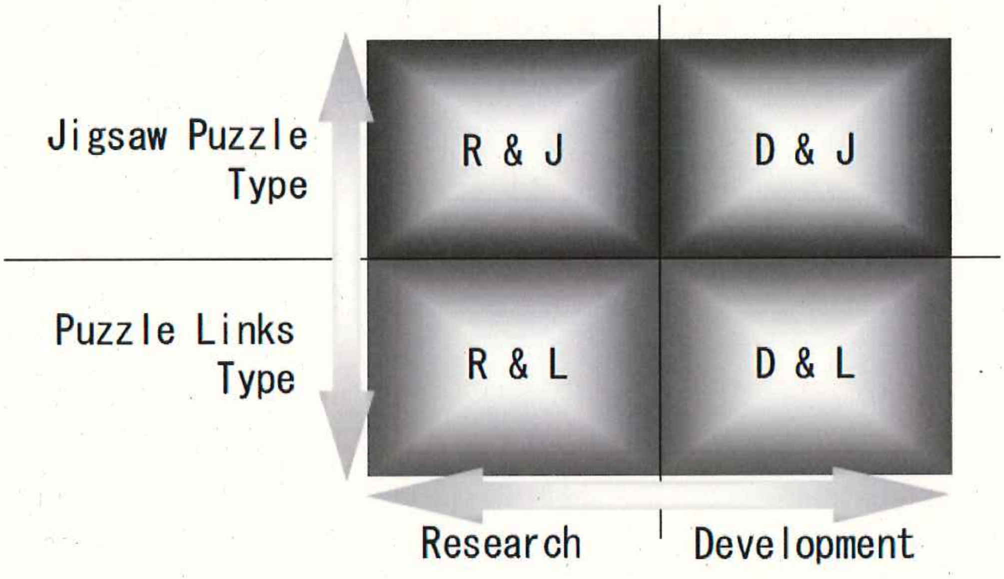
L-type: investment of people, money, and resources does NOT ensure output

J/L Classifications and their Relationships with Research and Development

Research and development can be visualized as a one-dimensional flow, from upstream to downstream (or from left to right as in Figure 2). Placing this concept within the context of this study, we obtain the relationships shown in Figure 2. When research and development are placed horizontally adjacent to each other, J- and L-types can be placed vertically alongside them, resulting in the cells illustrated in Figure 2.

FIGURE 2

Relations hips between Research / Development and Jigsaw Puzzles / Puzzle Links



Conventional definitions of research focus on theory and experimentation or on exploring new methodologies, whereas development considers solely the application of knowledge. Those definitions and the premise of this study (that success or failure depends on whether breakthroughs are required) are concepts that represent fundamentally different axes. The former classification is time-based, or has a relative focus on sequenced problems. The latter involves technology projects at a specific point in time.

In Figure 2, the two cells, R&L (bottom left: success or failure depends on whether breakthroughs are required) and D&J (top right: development that only needs resources), seem familiar to us. One of the contributions made by the puzzle theory is, however, highlighting R&J (top left: research that only needs resources) and D&L (bottom right: development that requires breakthroughs) as part of the matrix.

As an example of R&J, let us consider a state-of-the-art system such as that presented in the veteran engineer's comment. Consumer goods developed using state-of-the-art technologies are usually not readily available on the market and are less likely to be mass produced; therefore, these projects are often handled by basic research labs. The basis behind state-of-the-art systems (obtained during the "breakthrough" phase) have already been developed, and projects currently in progress have completed specific applications for which no mass production is planned. Therefore, these projects represent the refinement of applied technologies. This falls under the definition of "applied research" presented in Table 1, i.e., the scope of applied research is "to set goals and determine the possibility of commercializing knowledge or to seek out new ways to apply existing knowledge discovered in basic research." Moreover, this category entails the "turning of one's attention to acquiring technological knowledge" for "setting specific practical goals or applications," and can be categorized as research within the framework of the OECD classifications. That is, in the context of a "knowledge acquisition" phase rather than "business production," we can consider these activities to be research and not development. However, it requires no breakthroughs, and one can expect results and output commensurate with the invested resources.

There may be some objections to R&J, which are related to how we define research in this paper. An objection may assert that it cannot recognize research as something "achievable through the investment of resources" or "that does not require breakthroughs." This is reasonable, both intuitively and rationally. However, the private sector is currently experiencing difficulty in recognizing the economic significance of conducting basic research, which results in research labs working on what the Ministry of Internal Affairs and Communications calls "applied research, or research that sets specific goals and determines the possibility of commercializing knowledge, or to seek out new ways to apply existing knowledge discovered in basic research." In addition, if we were to attempt a definition by paradoxically working backwards from the research projects of private companies, we may find that research labs can manage "any technology projects prior to productization or mass production."

The next category is D&L, which is unrelated to historical background or changes in business methods. It is a phenomenon that can exist in any technological activity, which means that however slight a technological development may appear, it will require someone to notice it or make a decision regarding it, and managers must be aware of the possibility of "small" projects being derailed without breakthroughs, or the risks of having no output. "Algorithm development" (written tersely and succinctly) and "weight reduction" (above a certain limit) are examples in this category.

Working backwards from our objective and the research question posed in our introduction, classifications can be assumed to be useful in decision-making. The requirements below prepare us for these classifications while we provide an overview of extant research in the following sections.

1. Do these classifications fill the gap left behind by conventional classifications for research and development?
2. Do these classifications have new business creation in their purview, or do they confine the discussion to product development?
3. Do these classifications enable proactive work with technology projects rather than merely explaining innovation after the fact, or is the *a priori* judgment of those involved in the project crucial to its success?

4.

The third point can be explained in greater detail. If for certain technology projects, common sense can be employed by anyone to classify these projects using publicly available information, then the management of that particular technology project using classifications loses all value, even if that technology can be understood holistically and a macro-level discussion can be developed. To paraphrase, proposals that are developed through classifications are limited to extremely common sense items. In contrast, if a classification respects the judgment of those involved by using novel standards, then decision-makers can find management measures specific to those technology projects, and such a classification may become deeply significant.

PREVIOUS RESEARCHES

Radical Innovation and Incremental Innovation

Several researchers have debated over radical innovation and incremental innovation and the respective classifications that are derived from these two styles of innovation. Table 2 presents a synopsis of definitions developed by Leifer et al. (2000) and indicates the classifications of radical and incremental innovations to be largely unchanged in meaning from those developed by the Ministry of Internal Affairs and Communications, as explained earlier in the section on J/L Classifications and their relationships with research and development.

There are innumerable examples of classifications resulting from small changes such as subdivisions or from determining whether the essence of something is identical with the classifications for research and development. For example, Allen, Tushman, and Lee (1979) asserted that classification standards can be defined at four levels on the basis of three criteria: (1) time periods until feedback was received, (2) whether the problem to be solved was special or general, and (3) whether it used an accumulation of new knowledge or existing knowledge. The four levels at which these standards are defined include basic research, general research, development, and technical service. We will refrain from going into detail here, but this nomenclature denotes more detailed subdivisions than research and development. A similar example is the classifications created by Wheelwright and Clark (1992a; 1992b) regarding product development projects.

TABLE 2

	Incremental Innovation	Radical Innovation
Project duration	• Short-term (6 months to 2 years)	• Long-term (normally 10 or more years)
Process	• Structured	• Because of uncertainty, structured processes manifest their true value in the later development stage.
Examples	• Relatively low uncertainty • Perfect, detailed plans	• Business models are created by studying facts about technology and markets.
Organizational structure	• Cross-functional teams	• Commences within an R&D group to be passed on to another organization before achieving its project goals.
Divisional involvement	• Divisions are involved from the beginning.	• Premature involvement of divisions may introduce constraints and should be avoided.

(Source: Created by author using excerpts from Leifer et al. (2000))

2x2 Matrix of Technological Innovation and Market Innovation Competence-destroying and Competence-enhancing, and Architectural Innovation

Abernathy and Clark (1985) proposed a two-dimensional framework that adds a market/customer axis to the technology/product axis (Figure 3). Although these classifications appear to be similar to the classifications applied in this study, there are actually several key differences. First, by introducing the concept of market/customer, we narrow the range of research and development, which results in the horizontal axis showing the level of novelty in the scope of development. Thus, although these classifications can be used in discussions of new model development, they are not meant for discussions of research or new business creation. Next, there is nothing unexpected in the implications of these classifications; even if we do not use the type of framework proposed herein, we can probably make a determination through intuition. In other words, this matrix does not answer the third condition: "Do these classifications enable proactive work with technology projects rather than merely explaining innovation after the fact, or is the *a priori* judgment of those involved crucial to the project's success?" It is in this context that we conclude that these two-dimensional classifications result from the classifications of incremental and technical innovation.

In addition, it is easy to visually understand these concepts using the 2x2 matrices of Tushman and Anderson (1986) in the classifications of competence- destruction / discontinuity and competence-enhancement/discontinuity, and of Henderson and Clark (1990) in architectural innovation. However, these have similar limitations.

FIGURE 3

Abernathy and Clark's Matrix of Technology/Product Innovation and Market/Customer Innovation

Market/Customer Axis

	Continuous	Radical
Radical	Niche Innovations	Architectural Innovations
Continuous	Regular Innovations	Revolutionary Innovations

Technology/Product Axis

(Source: Abernathy & Clark, 1985; matrix created by the author.)

Frontier Development and Routine Development

In classifying technology projects, opinions regarding standards similar to those in this study can be found in the extremely practical realm of nothing out of the ordinary. Table 3 presents an example of "frontier development" and "routine development" classifications, published on a software company's website (Software Buhin Development Co. Ltd, 2014). These classifications have been traditionally limited to software companies; however, the distinctions between frontier development and routine development are drawn from a practical perspective. As the table reports, frontier development comprises "unknown areas, with no development experience" and, therefore, "has a risk of failure requiring risk management." This is certainly the same perspective of the L-type projects presented in this study (i.e., output is uncertain and the project is risky), and carries the possibility of project failure with no output. In contrast, routine development has "known themes with past experience." The risk of failure "is low, with management focusing on cost and time." This definition corresponds with this study's focus on J-type projects (output is certain given the allocation of people, money, resources, and time).

TABLE 3

Frontier Development and Routine Development Classifications Created by Software Company

		Frontier Development	Routine Development
Requirements	Subjects	Unknown areas, with no development experience.	Known themes, with past experience.
	Risks	Risk of failure; risk management required.	Low risk of failure; management focus on cost and time.
	Cost development time	Cost is difficult to forecast, and budget estimates are typically very inaccurate. Long development times are typically required.	Ample precedence for budgeting; projects can be completed cheaply. Development time can also be extremely short.

(Source: BSS Co., Ltd. website.)

The classifications in Table 3 decidedly part ways with the present study's assertions in the description of development time, as can be seen in the lowest row. In frontier development, "long development times are typically required." However, in specifically demonstrating the viewpoint that this relies on breakthroughs, we cannot simultaneously incorporate a time dimension if we believe that serendipitous discoveries are crucial in solving problems. One can possibly argue that, although in some cases lady luck may smile on us and we find answers to problems, in other cases, lifetimes may pass with projects generating no results. At the same time, Table 3 depicts routine development times as often being "extremely short;" however, the critical issue is whether there is "ample precedence for budgeting." Whether development times are long or short, they are inherently more readily predictable.

Future-minded and Present-minded

Kanei(1991) found that "even within the same research lab, a surprising amount of differentiation in contrasting basic concepts can be seen within corporate research" (Kanai, 1991, p.188). Furthermore, Kanei(1991) also noted that "basic ideas created 'systems of research philosophies' that are internally self-consistent" and contrasted these "cosmologies" (Table 4).

TABLE 4

Contrasting Cosmologies of Research Leaders

	Cosmology I (future-minded)	Cosmology II (present-minded)
Role of research groups	Active researchers should strive for the accumulation of basic technology that cannot be expected in other groups.	Because these research groups belong to corporate research labs, they must generate results tied to products and make proposals that lead to corporate profit.
Relationship with manufacturing division	Maintain autonomy from the manufacturing division. Sufficiently developed knowledge will flow into manufacturing division.	Relationship with the manufacturing division should be close. At the idea stage, concepts can come from the manufacturing division.
Research satisfaction and remuneration	Accomplish own goals as it is self-fulfilling. Move forward by creating abundant knowledge that appeals to users (customers) beyond the manufacturing division, and do not be distracted by short-term internal pressures.	Create technology that can be applied to products with development results that can be used in many areas, and create things that will please the manufacturing group in a business division.
Researcher development	Take responsibility for technologies and develop projects.	Grasp the essence of technology by responding to the manufacturing division.
Effective leadership	Respect autonomy and provide general guidelines. Discontinue research that would not develop a knowledgebase.	Decide on a schedule and maintain efforts and pressure. Focus on developing capabilities to support the manufacturing division when they are in trouble.

(Source: Kanei, 1991, p. 183.)

Table 4 indicates that Cosmology I (future-minded) appears to be research- oriented, whereas Cosmology II (present-minded) appears to be development-oriented. It is true in terms of what each of the cosmologies is actually oriented to. However, we must take special note of the following statement: "A comparison of knowledgebase and agile models does not necessarily correspond with traditional categorizations of basic research and applied research. Thirty-eight percent of research managers in one group in the agile model were doing basic research" (Kanei, 1991: 189). When comparing the internal roles of researchers and designers, Kanei notes that "Cosmology I is not specific to researchers, and Cosmology II is not specific to designers" (1991:). These are individual "perceptions toward technology" that go beyond the formal organizational frameworks to which an individual belongs. Although the aforementioned example may not correspond with the technology theme in this study, the implications derived from our classifications, as we state below, are applicable to such "perceptions toward technology."

DIFFERENCES IN PERCEPTION WITHIN ORGANIZATIONS

Comparison of Engineers and Non-engineers

Six engineers and six non-engineers were chosen to classify each project in terms of J/L classifications on the basis of summaries (a few sentences per project) of 25 projects in Company X,

FIGURE 4
Differences in Awareness between Engineering and Non-engineers regarding J/L Classifications

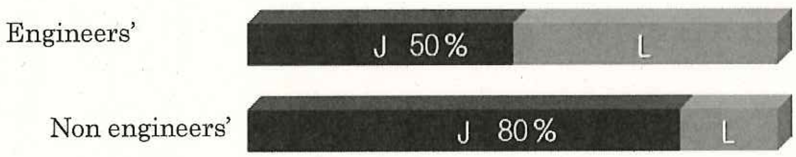


Figure 4 depicts significant differences in perception between engineers' and non-engineers' even though these interpretations come from the same 25 project summaries. Engineers classify projects equally among the two types (specifically, of the 150 total projects [6 people x 25 projects], 82 were classified as J-type), clearly distinguishing between J- and L-type projects. Non-engineers, however, classified 80% of technology projects (likewise, 118 of the 150 projects) as J-type, apparently noting little value in the J/L classifications.

One reason for the striking difference in opinions regarding these two types may stem from how much information the two groups have. That is, engineers can examine projects in greater detail, as if they were actually responsible for them. Another factor is somewhat of a *raison d'être* : that non-engineers imagine that "engineers spend money in their work, and results should naturally be expected." One of the comments from the manager of human resource department took this attitude to an extreme: "Researchers are in no way conducting Nobel prize-worthy research," thus revealing that non-engineers feel that L-type projects should be "Nobel-level." This response may suggest a clear feeling about where business responsibility lies.

Perception across Levels in an Organization

In reality, engineers exhibit little awareness of J/L type of their own projects. When touched off, however, they can determine the type of a project for which they are responsible. This demonstrates that J/L classifications represent "perceptions toward technology;" interpretations of a certain technology may differ, and the opinions of engineers do not necessarily coincide at all time. It is also certainly possible for the opinions of engineers in the same roles to diverge.

A section chief can make a determination just as engineers can, if given an opportunity to evaluate factors based on certain triggers. With a little deliberation, lower-level managers can conclude whether the work of their subordinates is a J- or L-type project. However, these managers rarely receive incentives and opportunities to think in such a manner. When it comes to department-level managers, the recognition of lower level engineers' work categories (J-type or L-type) becomes quite precarious. Unfortunately, engineers' important judgment of the risks (i.e., J/L classifications) of a certain project are rarely delivered to the upper-level management.

IMPLICATIONS

Many cases can be listed as decision making processes regarding investments differ fundamentally between engineers and non-engineers. For example, in the intra-organizational decision-making process for a technology project, an engineer proposing the project may actually be cognizant of whether the project is L-type and thus entails some risk (i.e., the project might not generate results). However, the engineer will attempt to gain the acceptance of non-engineers or management by expressing an optimistic determination to "finish the project on schedule," as if it were a J-type project. Non-engineers or managers will, therefore, perceive this as a J-type project, requiring only resources to be successful.

In a different scenario, the pressures imposed by customers or the market hoping for a new product launch sometimes discourage engineers from stating that their projects are L-type.

To avoid such situations, in-house protocols are needed to relay the intuitive judgment of the engineers to upper-level managers. Lacking these functions within an organization, or if any malfunction of them, is not unique to Japanese companies. For example, it can be difficult to argue logically when executives give such a pep talk: "We know this is a difficult project, and to the best of my knowledge, engineers and mid-level managers are responsible for making projects successful at all costs." The issue is whether projects are rationally explained to management as "difficult," meaning that they will require considerable people, resources, and money to complete (similar to a jigsaw puzzle), or whether projects entail the risk of not finding a solution (similar to a puzzle link), regardless of the emotional content of the appeal. Even where the final decision remains unchanged, executives' awareness of J/L classifications will change the nature of their preparations.

Of course, although non-engineers and executives may intuitively sense risk, they may still approve projects for the purpose of extracting the proposing party's (i.e., engineer's) commitment. The following example describes the recollection of an executive whose background was finance during a management meeting of Company Y:

> Whenever we heard proposals from engineers, for infrastructure investment in particular, I always cheeked three data points: volume, averages, and variances. The engineers' goal was always money (to buy equipment), so they would never mention any weak points or anything inconvenient to them. This wasn't academic research, so if they could convince me on those three data points, I didn't think it was important to worry about outliers or finding the causes of exceptions (Maegawa, 2011: 28).

SUMMARY

J/L classifications illustrate differences in how engineers and non-engineers view technology, and differences in perception within different layers of an organization. Knowing about, or assuming, these perceptual differences, or differences in perception toward technology, can completely change executives' decisions. These differences have a definitive impact on executive-level decision-making and directly affect corporate risk exposure and estimations of uncertainty; thus, risk cannot simply be understood using conventional classifications of research and development.

However, the J/L classifications apply beyond technology; they can also serve as criteria for decision-making in everyday life.

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