Knowledge Transfer in R&D Project Management: Application to Business-academia Collaboration Project

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***Abstract*--This paper proposes a method of project management knowledge transfer in order to increase the success probability of R&D projects. Our method consists of knowledge externalization and knowledge internalization. "Structured project analysis" is a method of knowledge externalization that reviews a finished project and produces a structured project case. "Internalization workshop" is a method enabling managers to internalize the project management knowledge based on the analogical transfer approach. The method selects success and failure scenarios (future chance and risk items) from the structured project cases that have some similarities to the ongoing target project. Then, the method prompts the managers to imagine and analyze future scenarios of their target project by analogy and take action concerning them. We apply this method to an ongoing business-academia collaborative project in which Toshiba, Shimizu Corporation, and the Japan Advanced Institute of Science and Technology (JAIST) are developing an innovative healthcare information system. We qualitatively evaluate the effectiveness of the proposed knowledge transfer method and show how to fill the project management knowledge gaps among project team members drawn from business and academia.**

I. INTRODUCTION

The ineffectiveness of research and development is recognized as a priority issue in Japanese manufacturing companies. There are several reasons for the ineffectiveness, including inability to meet the structural change of innovation and to gain exclusive profit from innovative technology. Quality of project management also affects the effectiveness of R&D. This paper focuses on project management knowledge of R&D managers and proposes a method of project management knowledge transfer in order to increase the success probability of R&D projects.

Several management tools, such as stage gate and phase review, have been introduced in R&D project management. However, they tend to become a dead letter if managers lack sufficient skill and knowledge to utilize these tools. In fact, it is not easy to gain experience because each manager participates in a limited number of projects. Therefore, we have been developing a knowledge transfer method and tools for R&D project management to overcome this limitation [1][2][3].

Some kind of open innovation has become inevitable in much corporate R&D recently and there are many collaborative R&D projects. Therefore, we try to apply this method to collaborative projects involving project team members drawn from academia and the private sector and show its effectiveness in the collaborative projects.

The remainder of the paper is organized as follows. In section II, we clarify difficulties in R&D project management. Section III reviews the literature on knowledge transfer in R&D project management. A knowledge transfer model and procedure are introduced in section IV. We apply it to a collaborative project in section V and present our conclusions in section VI.

II. DIFFICULTIES IN R&D PROJECT MANAGEMENT

We identify what we consider to be the principal difficulties encountered in R&D project management.

A. R&D project managers do not necessarily have great experience

For the following reasons, project managers in corporate R&D divisions do not necessarily have great experience and this is particularly so in Japan.

(1) Project terms are long: The average project term in corporate R&D divisions may be more than 6 years. Consequently, managers can only participate in a limited number of projects.

(2) Projects vary greatly: Research topics in corporate R&D divisions are often novel. Past experiences may be irrelevant.

(3) Projects are subject to high risk: Since project risk is high in corporate R&D divisions, managers are more likely to experience failure than success.

(4) Mobility of managers is low: Japanese companies recruit few managers in mid-career.

Therefore, organizational learning is necessary to compensate for managers' lack of experience. However, organizational leaning of R&D project management has not yet to be systematized because project management is dependent on individual skills. Whereas technical knowledge transfer, using technical reports and patents, tends to be well established in organizations, the importance of management knowledge transfer tends not to be fully recognized. The post-project review is one of the few tools for management knowledge transfer. According to Zedtwitz, 80% of the R&D projects that he investigated lacked a post-project review system, and moreover, the post-project review systems that do exist tend to be unsystematic [4].

B. Project phase review does not necessarily work

Project phase review methods are widely used worldwide [5][6]. Project phase review methods have two functions: project selection and project quality control (different from product quality control). In the case of new product development by electronics manufacturers and automobile manufacturers, the project quality control function is particularly important because the product development typically involves the integration of many technologies. However, the project quality control function often becomes a dead letter in routine operation because inexperienced managers cannot understand the real meaning of the checklist used in the phase review. Project management knowledge transfer is necessary in order to ensure that the project quality control function works effectively in the project phase review.

C. Difficulties in business-academia collaborative projects

Many publicly funded business-academia collaborative projects have been conducted recently in order to create new businesses and new industries. In comparison to project management in a single organization, business-academia collaborative project management involves additional difficulties, including gaps between project team members in terms of background, purpose, and managerial knowledge. Therefore, managers of business-academia collaborative projects require systematic methods capable of filling these gaps.

III. LITERATURE REVIEW

Since knowledge of new technology and product development is recognized as a core competence in manufacturing companies, there is much research on knowledge transfer [7][8][9]. However, most of this research focuses on knowledge transfer of technology and there are few reports on project management knowledge transfer. Project management knowledge is structured and standardized as PMBOK (Project Management Body of Knowledge). But PMBOK does not mention the knowledge transfer procedure, especially in regard to knowledge internalization.

Niwa and his colleagues proposed a knowledge transfer support system for large plant construction project management where useful project management knowledge is codified in an expert system [10]. Aoshima and Nobeoka introduced “project knowledge” and considered knowledge transfer in automobile manufacturers [11]. Compared with project management in plant construction and automotive development in which the target product requirement is clear, R&D projects involve many uncertainties and risks, and therefore additional considerations are required.

Ramchandani mentioned that the phase review process was found to be effective for project management knowledge transfer in new product development at Xerox [12]. In Japan, The New Energy and Industrial Technology Development Organization (NEDO) has investigated its past projects through post-project review and developed “NEDO R&D Management Guidelines” in which the reviewed past project cases are linked to a project management checklist [13]. These activities are a step in the right direction but they do not amount to the concrete procedure of a knowledge transfer process.

The literature includes many reports on the difficulties involved in business-academia collaborative project management, but few knowledge transfer approaches have been proposed to overcome these difficulties.

IV. KNOWLEDGE TRANSFER MODEL

A. Knowledge transfer model for R&D project management

Figure 1 represents the proposed knowledge transfer model consisting of knowledge externalization and knowledge internalization. The senders of knowledge externalize their knowledge as boundary objects. The receivers internalize the knowledge through boundary objects. A boundary object is a codified medium of knowledge transfer [14] and boundary objects are structured using the structure of organizational knowledge.

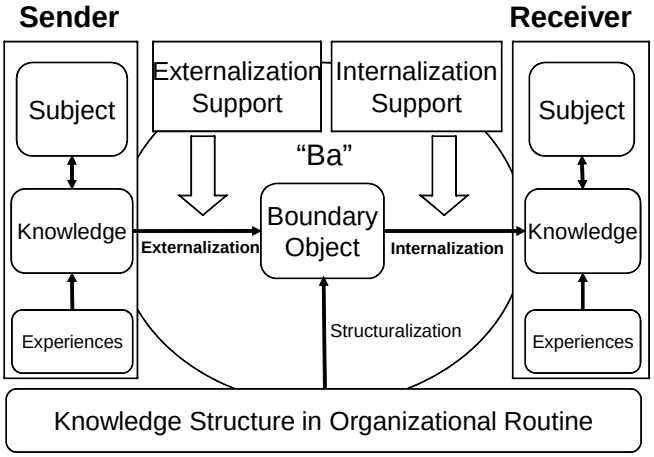

Fig. 1: Knowledge transfer model with boundary object

Figure 2 shows the knowledge transfer process in R&D project management based on the model. This process consists of post-project review and project phase review (Table 1). "Structured project analysis" is a method of knowledge externalization that reviews a finished project and produces a structured project case in the post-project review. The structured project analysis clarifies success and failure factors of the project by using some structures mentioned below. This structured project case is utilized as a boundary object in the context of knowledge transfer.

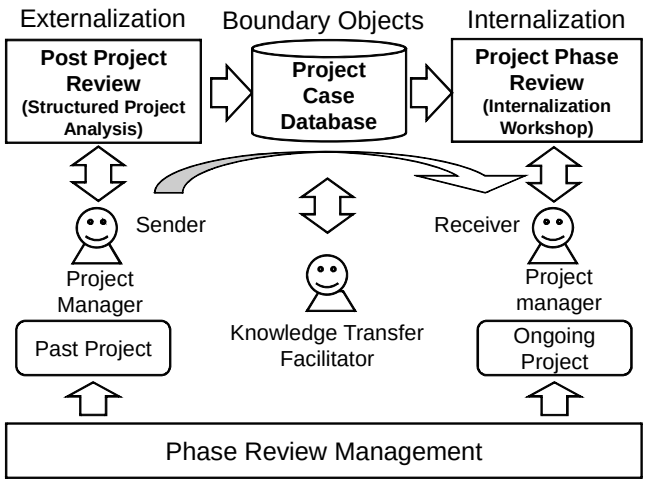

Fig. 2: Knowledge transfer process in R&D project management

TABLE 1: POST-PROJECT REVIEW AND PROJECT PHASE REVIEW

	Post Project Review (PPR)	Project Phase Review (PHR)
Target	Finished past project	Ongoing project
Purpose	Externalization of knowledge which should be learned from the past project.	(1) Recognition and sharing of future chance and risk items and action items to improve the project. (2)Decision-making in project management using results of (1).
Timing	When the project has finished.	When the project is reviewed in phase transition.
Participants	Project manager, project members, facilitator.	Project manager, project members, stakeholders, facilitator.
Method	Structured project analysis	Internalization workshop

The extracted project management knowledge is stored in a project case database. However, it is not trivial for project managers to internalize the knowledge using the case database. We also propose the "internalization workshop" method for managers to internalize the project management knowledge based on the analogical transfer approach. The method selects success and failure scenarios from the case database that have some similarities to the ongoing target project and shows them to the managers. Then, the method prompts the managers to imagine and analyze future scenarios (future chance and risk items) of their target ongoing project by analogy and take action concerning them. The internalization workshop is held in the first half of the project phase review ((1) in Table 1). Table 2 shows the correspondence between the proposed model and the implemented process.

Well-structured project cases can improve quality and motivation of project phase reviews. Good project phase reviews leave qualified records of projects, which improve post-project reviews. As shown in Fig. 3, the combination of post-project review and project phase review utilizing the knowledge transfer method can create a virtuous cycle. It can improve R&D project management quality, and then improve the success probability of R&D projects.

TABLE 2: CORRESPONDENCE OF MODEL AND IMPLEMENTATION

Model	Implemented process
Sender	Project manager of past project
Receiver	Project manager of ongoing project
Boundary object	Structured project case
Knowledge structure in organizational routine	Project management system based on phase review
Externalization support	Structured project analysis
Internalization support	Internalization workshop

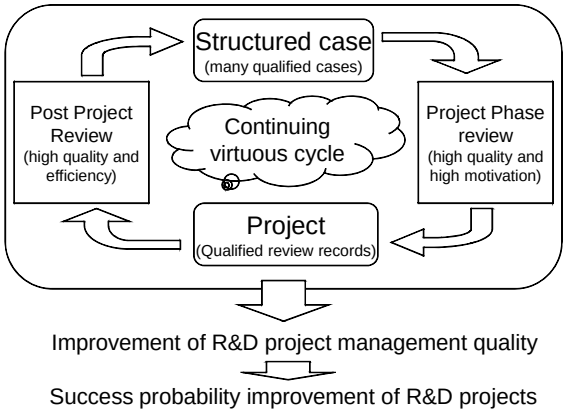

Fig.3: Virtuous cycle in R&D project management

B. Structured project analysis

"Structured project analysis" is a method of knowledge externalization that reviews a finished project and produces a structured project case. Figure 4 shows a structured project case in which we introduce three types of structures to the traditional text-based cases:

(1) Phase review framework:
7-phase structure (idea discovery, concept generation, feasibility study, development, testing and validation, product production and launch, and product support).

(2) Review checkpoint areas:
4 areas (technology, market, business, human resources and organization) of the review checklist. Table 2 shows an example of checklists consisting of 22 items classified into 4 areas. This checklist has been used in project phase reviews in the R&D organization which one of authors belongs to.

(3) Cause-and-effect relations

The structured project analysis clarifies success and failure factors of the project with these structures.

The proposed structured project analysis consists of the following 4 steps.

Step1: Organize records relating to past projects (project plan, weekly reports, design documents, phase review documents, etc.).

Step2: Enter project events (activities) in the matrix of the phase review process and review checkpoint areas (Fig. 4).

Step3: Analyze success factors and failure factors using cause-and-effect relations.

Step4: Summarize analysis and store the structured project case in the project case database as an outcome of the analysis.

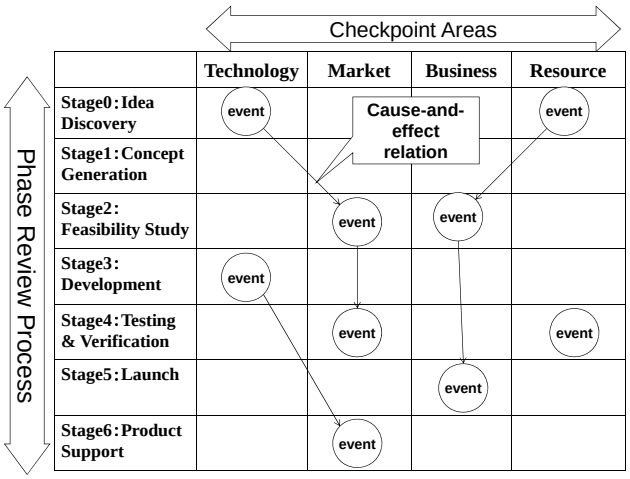

Fig.4: Structured project case

TABLE 3: CHECKLIST FOR PROJECT PHASE REVIEW

	Area	Check Point
1	Technology	Strong core technologies
2	Technology	Robustness of core technologies
3	Technology	Sufficient system technologies
4	Technology	Sufficient process technologies
5	Technology	Standardization & Regulation
6	Technology	Killer application
7	Technology	Unbiased consideration
8	Marketing	Future big market
9	Marketing	Changing point
10	Marketing	Real needs
11	Marketing	Competitor
12	Marketing	Alternative technologies
13	Marketing	Contextual consideration
14	Business	Responsible business unit
15	Business	Strategically fitness
16	Business	Utilization of business unit
17	Business	Sharing chance and risk with business unit
18	Resources	Communication among stakeholders
19	Resources	Strong leadership
20	Resources	Key person's support
21	Resources	Utilization of outside resource
22	Resources	Resource & risk management

C. *Internalization workshop*

The internalization workshop is a brainstorming process using structured project cases. In the workshop, a facilitator selects success and failure scenarios from the case database that have some similarities to the ongoing target project and shows them to the managers. Then, the managers imagine and analyze future risk and chance items (called FCR items) of their ongoing target project by analogy with similar cases (Fig. 5) and take actions concerning them. Table 4 shows an example of FCR items, which look like FMEA (Failure Mode and Effect Analysis), but FMEA deals only with risks and not with chances. Each FCR item can be classified with both phase review process and review check point area corresponding to the matrix in Figure 4. Without structured project cases, one can only imagine FCR items within one's experience. We contend that the number of FCR items not only increases but also the balance of FCR items is improved by using structured project cases as shown in Fig. 5. Balance is measured by cover ratio and variance of FCR items.

V. APPLICATION TO BUSINESS-ACADEMIA COLLABORATION PROJECT

A. *Project overview*

In recent years, the need to improve the efficiency of nursing and caregiving services has been widely recognized. However, conventional PC-based support tools are unsuitable for services involving physical tasks (we call them "intelligent physical services") such as nursing and caregiving because these tools impose great strain physically and mentally on nursing staff and caregivers. Therefore, new, less stressful, computer-human interaction technologies for intelligent physical services are required. Moreover, service design and evaluation methodologies for intelligent physical services are also necessary for improving these services step by step.

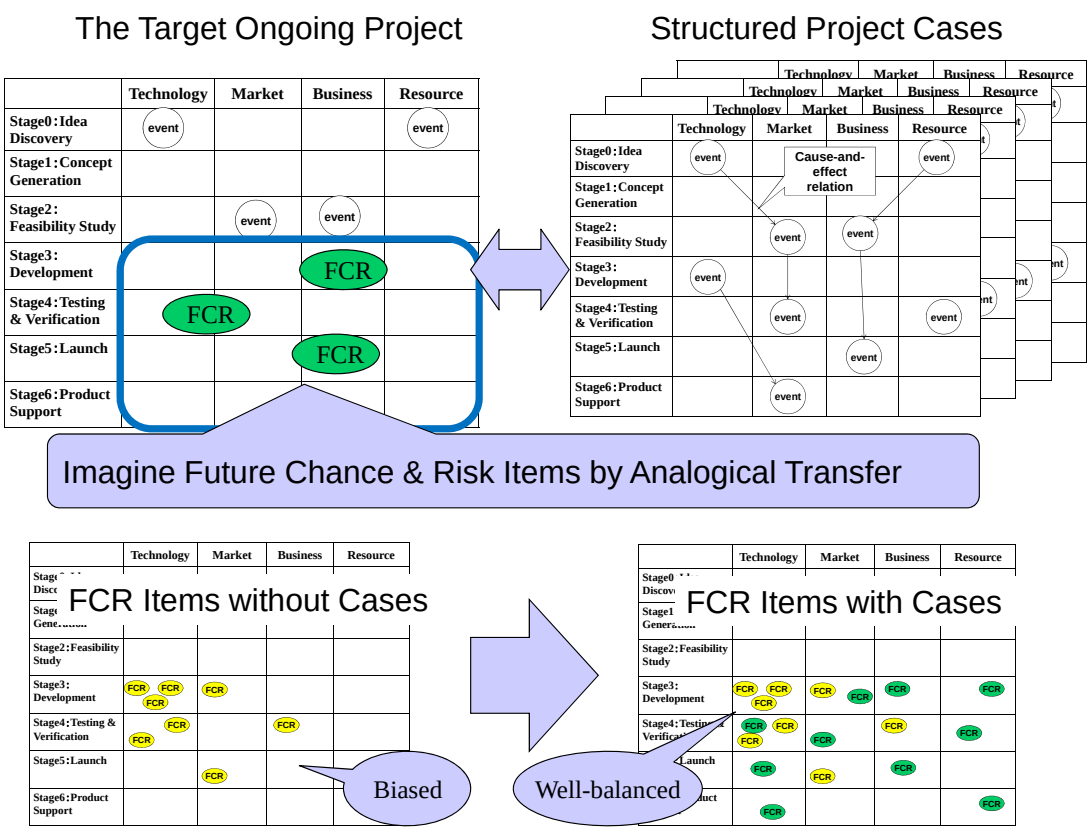

Fig.5: Internalization Workshop using Structured Project Case

TABLE 4: FUTURE CHANCE AND RISK ITEMS (EXAMPLE)

FCR Name	Phase	Area	Type	Cause	Effect
High-cost parts	development	business	risk	Use of particular kind of parts	High-cost product for niche market
Collaboration with market key person	testing & validation	resource	chance	Key person use it as a early adopter	Useful feedback from key person and promotion

To satisfy these requirements, we have been developing a novel temporal-spatial communication system utilizing hands-free smart voice messaging (Fig. 6). In our system, voice messages are adequately distributed among co-workers according to human behavior analysis. Based on interviews in a hospital, we find smart voice messaging not only increases the efficiency of nursing and caregiving, but also provides new value, that is, temporal-spatial collaboration "ba" (Nonaka & Takeuchi 1995), such as Twitter facilitates in cyberspace.

We have also been developing a visualization and evaluation tool for intelligent physical services that consists of traffic line evaluation, stress evaluation, and work efficiency evaluation (Fig. 7). We propose a service design methodology for the target service space (physical space + information space + workflow space design).

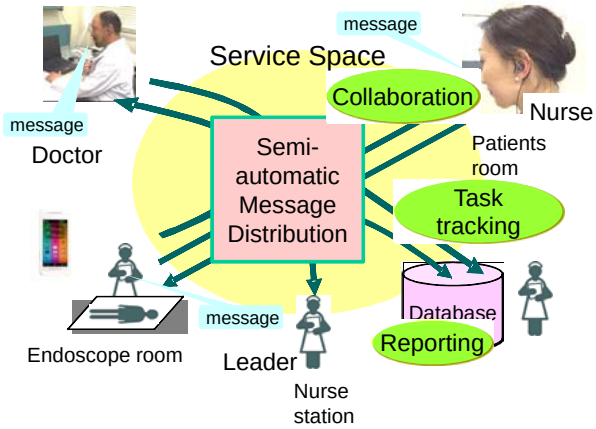

Fig.6: Concept of smart voice messaging

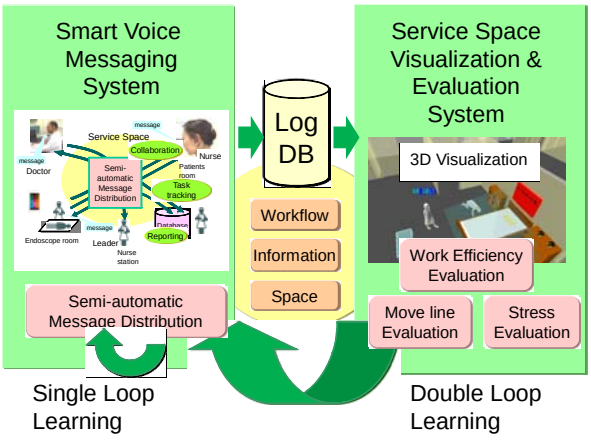

Fig.7: Service space evaluation system

This project started in October 2010 supported by the service science founding program in the Japan Science and Technology Agency (JST) (S3FIRE: Service Science, Solutions and Foundation Integrated Research Program). Our project consists of a company with expertise in healthcare information technology (Toshiba), a general construction company with considerable experience in hospital construction (Shimizu), system modeling and knowledge management researchers (JAIST), and a hospital (Toshiba Rinkan Hospital) and several care facilities. Since a project leader comes from company, not from academia, the project focuses on commercialization as well as academic contribution. In this situation, perception gaps among members of the project team drawn from academia and industry become critically important.

B. Knowledge transfer process (internalization workshop)

We have applied this method to four core members (two from companies: M1(Co), M2(Co) and two from academia: M3(Ac), M4(Ac)) of the project team. Since the four members are from different organizations, the in-house project case databases of the organizations cannot be used. Instead, we introduce structured project analysis in Step 3 for the past projects that the members have experienced. We focus on the project phase review (internalization) rather than the post-project review (externalization) as follows.

Step0: Define project scope

This project may be positioned as part of a larger target of each organization. Firstly, we define the common project scope and share it among the members.

Step1: Extract future chance and risk items (own experience)

Each member independently extracts future chance and risk items based on his own experiences.

Step2: Extract Future Chance and Risk Items (Checklist)

Each member independently modifies and adds future chance and risk items based on the project phase review checklist (Table 3).

Step3: Share past project experiences by structured project analysis

Each member refers to his own past project and analyzes it by applying the structured project analysis method. Table 5 shows analyzed and shared projects. Two projects provided by company members led to commercialization. The other two projects encountered management difficulties at universities. Members share the results of the analysis, which are externalized project management knowledge.

Step4: Extract future chance and risk items (project case)

Each member independently modifies and adds future chance and risk items based on the structured project cases provided in Step 3.

Step5: Extract action items

After sharing and classifying all of the extracted future chance and risk items through brainstorming, important future chance and risk items are extracted and future action items are derived. These action items are used in the phase review meeting.

TABLE 5: PAST PROJECTS

ID	Project	Organization	Characteristic Features
1	Credit information infrastructure project	Companies + University	Business-academia collaborative project. Outcome of the project was commercialized.
2	Commercialization project of verification tool for arrangement of bars	Companies	Companies collaborative project. Outcome of the project was commercialized.
3	Verifiable and evolvable e-society project	University + Companies	Big project having a lot of members who had varied interests.
4	MOT education course development project	University	University project whose stakeholders include company members.

C. Result

During the internalization workshop, 100 future chance and risk items were extracted by four members (Table 6). Since members are experienced managers, many items can be extracted in Step 1. Company members can utilize the checklist and project cases can be utilized by both academia and company members. Figures 8 and 9 represent transition of cover ratio and variance of FCR items for each member from Step 1 to Step 4. Here, the cover ratio is the ratio of the number of cells filled by FCR items divided by the number of cells in the matrix shown in Figure 4. The variance shows imbalance of FCR items over the matrix. Since structured project cases are represented by the same matrix, FCR items can be easily imagined according to the matrix. By using the checklist and structured project cases, the cover ratio and variance of FCR items were improved, which is interpreted as showing the effectiveness of the proposed method.

TABLE 6: EXTRACTED FUTURE CHANCE AND RISK ITEMS

	Own	CL	Case	Subtotal
M1(Co)	16	16	6	38
M2(Co)	12	3	3	18
M3(Ac)	13	1	3	17
M4(Ac)	18	0	9	27
			Total	100

Own: Using own experiences (Step 1)
CL: Using checklist (Step 2)
Case: Using project cases (Step 4)

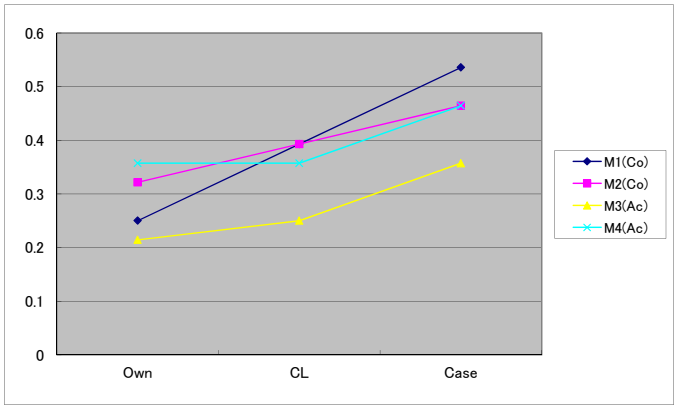

Figure 8: Transition of Cover Ratio

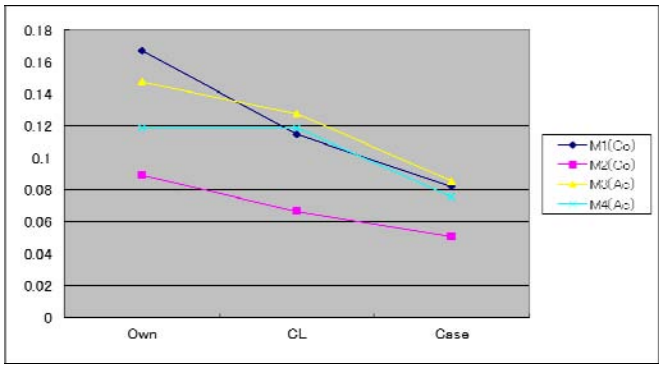

Figure 9: Transition of Variance

From the viewpoint of difference between academia and company members, the balance of FCR items among checkpoint areas (technology, market, business, human and organization) diverges drastically. Figure 10 shows that whereas company members extracted well-balanced FCR items, FCR items extracted by academia members are weighted toward technology and market. This is natural because academia members lack business experience. Our method can visualize this situation using some measures. Furthermore, academia members (M3(Ac) and M4(Ac)) can ameliorate their imbalance through the study of structured project cases (Figure 11).

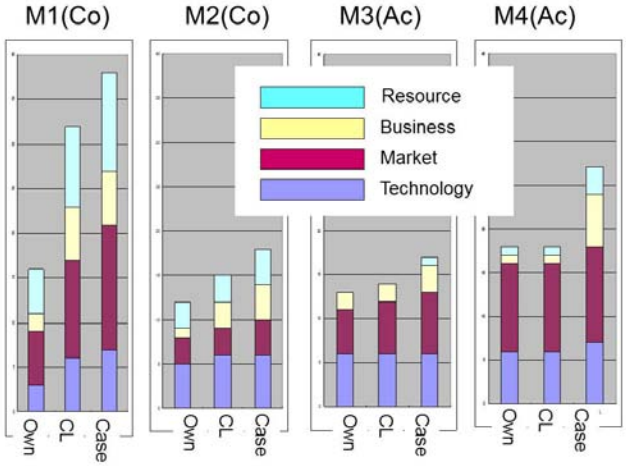

Figure 10: Transition of proportion among checkpoint areas

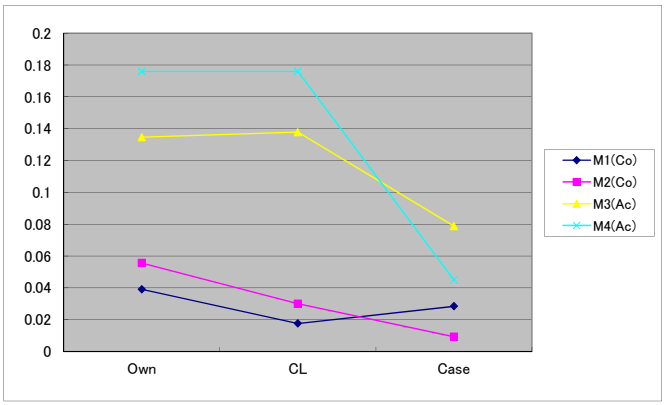

Figure 11: Transition of variance among checkpoint areas

Finally, in Step 5 we derive 6 action items from 100 FCR items. These action items are evenly extracted from all checkpoint areas. The most important item is clarification and sharing of the business model and commercialization process.

D. Discussion

For 3 members, it was their first experience of applying this method. We interviewed them to identify the method's merits and demerits. The merits include clarifying and sharing future chances and risks and gaps between academia and corporate members. Before the internalization workshop, project members in academia have interests in commercialization of their technology by the mind, but understand little about actual future risks and chances. The demerits include limited sharing of information on past projects among different organizations.

Analysis of past projects was found to be particularly useful for achieving mutual understanding. It involves not only sharing management knowledge among members but also understanding how their backgrounds and perspectives differ through the sharing of their life stories (narratives) as researchers and engineers. Narratives are thought to be effective for achieving mutual understanding [15].

VI. CONCLUSION

We have developed a knowledge transfer method for R&D project management that consists of structured project analysis (externalization) and an internalization workshop (internalization), and applied it to a business-academia collaboration project in which a healthcare information system has been developed. The uniqueness of the paper is that we show the effectiveness of the knowledge transfer method quantitatively by using several measures (cover ratio and variance of FCR items).

We intend to apply the method to other projects and confirm its effectiveness multilaterally because the method depends on the characteristics of the project and of the members.

In the application to the business-academia collaboration project, we find that narratives are effective for achieving mutual understanding when members have different backgrounds and are drawn from different organizations. In future work, we intend to explicitly introduce narratives in our method.

ACKNOWLEDGMENTS

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