Visualizing the Project of Design for Environment to Improve the Feasibility for Corporate Social Responsibility

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ABSTRACT

To improve the feasibility of accomplishing the superordinate concepts for corporate social responsibility (CSR), the person in charge must efficiently execute development processes. This study aims to make persons in charge recognize task importance by visualizing the value engineering process in automobile interior development, especially design for environment (DfE) process based on the Spiral model and V-model approach of system engineering. Therefore, a method for visualizing the entire DfE process is proposed through the assurance case. The effectiveness of the proposed method was examined through a survey of DfE project members.

Keywords: Assurance Case; Project Management; System Engineering; DfE.

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1. INTRODUCTION

In order to accomplish the superordinate concepts such as an engagement in social and environmental responsibility, it is one of issues to make the person in charge understand entire project and connection of tasks and evidences with accountability (Shibuya *et al*. 2020). According to the Stern Review on the Economics of Climate Change (Banerjee, S., 2007), The Economist (Barnett, M. L., 2007; Barnett *et al*., 2006), ecological sustainability could become the central social responsibility challenge for business. Thus, managers must be able to determine how their organizations can become more socially responsible, ecologically sustainable, and economically competitive (Orlitzky, M. *et al*., 2011).

At the view point of project visualization and planning, Browning described that process models can support ongoing project management by helping the project manager monitor interim results (Browning, T. R. *et al*., 2007) . Instead, visualizing the framework or the process helps project members effectively understand the entire work (Kobayashi *et al*., 2018a). Liebowitz and Megbolugbe examined the role of project managers in implementing knowledge management (Liebowitz, J. *et al*., 2003). Maryam and Leidner mentioned that a variety of knowledge management approaches and systems need to be employed in organizations to effectively deal with the diversity of knowledge types and attributes (Maryam, A. *et al*., 2001). As an approach to environmental, social, and governance investments and sustainable development

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goals (SDGs), the design for environment (DfE) needs to be implemented based on the guidelines of United Nations (United Nations, 2019) and METI (METI Japan, 2019). These guidelines recommend choosing DfE as a means of developing SDG initiatives from the product and service category. However, the specific process depends on the ingenuity of each company or organization and they did not describe the connection between the overall project and the tasks in DfE.

From the viewpoint of methodology in project management, Shirasaka *et al*. (2012) proposed a meta-process that coordinated the contents of the process based on the context and system. Krishnan *et al*. (2001) proposed a loosely structured approach to comprehensively survey the vast and expansive literature related to product development process modeling within a defined scope. Focusing on the DfE process and consensus making, Ameknassi *et al*. (2016) showed that the integrated approach includes a checklist and quality function deployment (QFD) to help designers effectively implement DfE activities. However, these studies did not clarify the necessary evidences, and the simultaneously satisfy both dependability and accountability (Matsuno, Y., 2010)

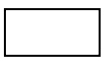
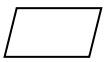
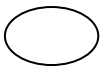
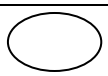
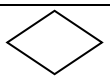
From above, the relevance of tasks to the overall project and the evidence required is recognized as issues because it is tacit knowledge that is not clearly stated. Therefore, this study aims to make project members recognize their tasks by visualizing the entire project process based on the Spiral model (Boehm, B, W., 1988) and V-model approaches (Harold, M. *et al*., 2014) of system engineering. Accordingly, a method for visualizing the entire DfE process is proposed by applying an assurance case. Furthermore, a survey was conducted before and after applying the method of combining a Spiral model and an assurance case to evaluate whether the member can understand the entire process and the corresponding task importance.

The remainder of this paper is organized as follows: In Section 2, previous studies are explained. In Section 3, the proposed method for DfE is presented. Section 4 presents the evaluation method, results, and discussion. Finally, Section 5 concludes this paper and discusses future research topics.

2. PREVIOUS STUDIES

The assurance case extends the scope of discussion to the overall quality, with an acceptable quality level among the stakeholders. This includes the "safety" that was targeted in the Safety Case (Menon, C. *et al*., 2009). In this study, the dependability-case (D-case), which is an extension of the description method called Goal Structuring Notation (GSN) proposed by Tim Kelly (Kelly, T. *et al*., 2004; GSN Community, 2011) is used as a description method.

Table 1. Six Nodes in Assurance Cases

Node	Figure	Explanation
Goal		Goal describes what to assure, with a combination of a subject and a predicate.
Strategy		Strategy describes how to break down the Goal into sub-goals, thus leading to the lower layer.
Context		Context describes the state, or environment and conditions, of the System, and shows ways to lead to the Goal and Strategy.
Evidence		Evidence eventually assures that we can reach the Goal, and shows the ways that lead to it.
Monitoring		Monitoring is intended to represent Evidence available at runtime, corresponding to the target values within the in-operation ranges.
Undeveloped		Undeveloped indicates the status that there is no Evidence or Monitoring, or discussion supporting the Goal.

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A requirement quality function development table can be utilized as a method for describing a business process (Akao, Y., 1972). The framework is organized by role and function. Compared with D-Case and GSN, both D-Case and GSN have dependability and accountability features (Matsuno, Y., 2010). Therefore, project managers cannot reliably confirm implementation. Herein, D-Case is used instead of GSN because it assumes the operation stage and adopts a node called "Monitor," which is prepared only for D-Case. We utilized the six nodes listed in Table 1.

3. METHOD OF COMBINED SPIRAL MODEL AND THE ASSURANCE CASE BASED ON V-MODEL IN VALUE ENGINEERING

In this section, we visualize the combined method by using the assurance case. This methodology is applied to value engineering in the development of automobile interiors. Figure 1 shows the phases of the project life cycle and the total expenditure profile (Forsberg, K. *et al*., 2005; Fabrycky *et al*., 1991) based on the systems engineering handbook (INCOSE, 2015). In this study, the schedule fitted to the project life cycle shown in figure 1 was planned for the development of an automobile interiors. DfE initiatives promoted in CSR are implemented in the initial development phase for front loading (Ohtomi, K., 2005). According to figure 1, We tried to apply the methodology in this study to the Concept Stage (INCOSE, 2015), which has a large effect of investment (Fabrycky *et al*., 1991).

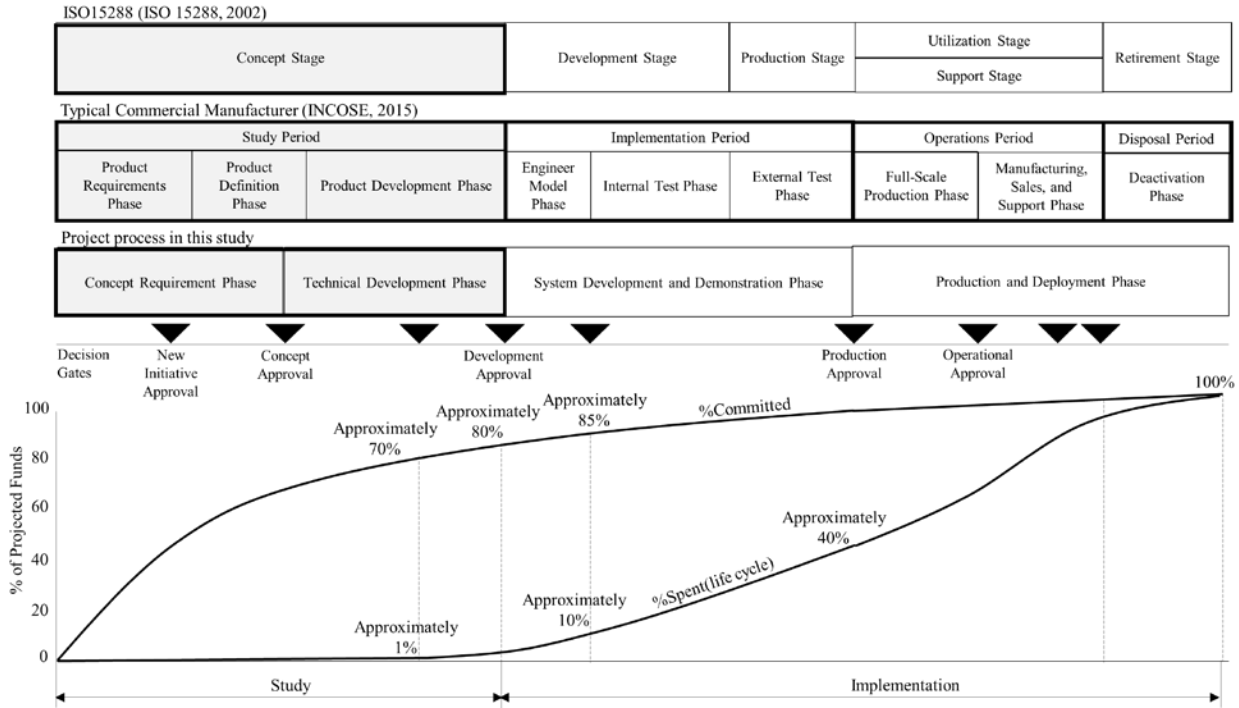

Figure 1. Project life cycle and typical expenditure profile (INCOSE, 2015), added project process in this study by the author

However, differences in the common language and understanding of development among the project members involved cause rework (Seki, K. *et al*., 2011). Therefore, the novelty of this study is to improve the feasibility of DfE by simultaneously having dependability, accountability and implementation confirmation,

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which are the feature of the assurance case (Matsuno, Y., 2010).

We visualized the entire DfE process using a biaxial diagram in the system design, as illustrated in Figure 2. This model is applied in Concept Stage (INCOSE, 2015). This diagram is related to the Spiral model (Boehm, B, W., 1988) in the project cycle. The horizontal axis represents the value and function required by the customer, and the vertical axis represents the planning and development, which is one of the phases of the process. The curved arrow in Figure. 2 represents building the process counterclockwise from Area1 to Area4, whereas the double-headed arrows indicate mutual confirmation. Herein, we propose to apply the assurance case in product development corresponding to Areas 3 and 4 in Figure. 2. This assurance case is applied based on the V-model. Furthermore, the description method of this assurance case uses the argument decomposition pattern (Bloomfield, R. *et al*., 2010; Masumoto, M. *et al*., 2013). Assuming that it is confirmed by all members involved in DfE, the D-Case of the DfE process is described based on the V-model in system engineering. In the requirement definition, based on IEEE1220 (IEEE, 2005), the process was shortened by considering time constraints (Yamamoto, S. *et al*., 2013).

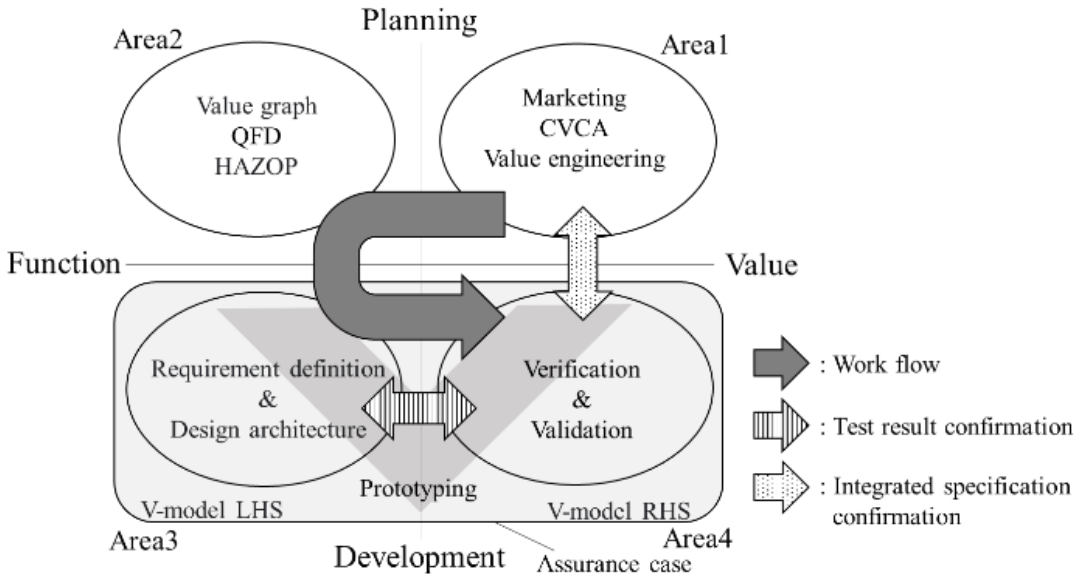

Figure 2. Combined Model

Figure. 3 and Figure. 4 depict the assurance case for DfE. Figure. 3 shows left-hand side of the V-model, whereas Figure. 4 shows its right-hand side. From the requirement definition viewpoint, the roadmap inside/outside of the company and its regulations were clarified, UI/UX design of the product was performed, and it was defined as a requirement specification. At this stage, the feasibility was confirmed to be consistent with the required specifications. In the architecture design, the process is divided into the adaption of eco-friendly materials and the detailed design document incorporating the parts. When adapting eco-friendly parts, fault tree analysis (FTA) was used to extract hazard factors from the developer's perspective. Moreover, failure mode and effect analysis (FMEA) was applied to the function of parts, weighting was applied considering the degree of risks, and finally, ecology materials are selected from the viewpoint of Reduce, Reuse, and Recycle. Finally, a detailed

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design was performed. In layout design, functional and structural parts were laid out considering interference of parts and design tolerances according to production equipment and quality standards, and finally, 3D CAD was presented. At this stage, the feasibility was confirmed to be consistent with 3D CAD data. Finally, we describe the description method of assurance case by D-Case for system reliability.

Herein, we first set the business system to achieve the top goal. We then divide it into "Left-hand side of the V-model (V-model LHS)" to define the requirement definition and the architecture design and "Right-hand side of the V-model (V-model RHS)" to define the verification and the validation in the strategy node. In "Left-hand side of the V-model," specification definition is the purpose of this work. Finally, the output of the work is described by an evidence node. Conversely, in "V-model RHS", the monitoring node is applied to the goal node. This is because we need to confirm "V-model LHS" as the implementation of the feasibility of customer requirements. Therefore, the evidence node was not used for the goal node in the validation for "V-model RHS". As shown in Figure. 3 and 4, the requirement specifications refer to the validation report, and the 3D CAD data refer to the verification results on "V-model LHS". Moreover, the monitoring node in "Right-hand side of the V-model" is connected to the evidence node in "V-model LHS" (Figure. 3 and Figure. 4 dotted arrow). This was done to judge whether to achieve the top goal based on the monitoring results. However, this description method has a limitation (Yamamoto, S., 2014) described as follows. First, we checked whether the required function was acquirable from the verification results. In addition, we confirmed whether the products matched the customer requirements in the validation process. The validation results were not constant because customer requirements were fluid. Second, the subject being monitored was not always constant. Third, the monitored results were not always necessary for evidence in "V-model LHS". Additionally, the proposed assurance case in this study was guaranteed by the agreement of the project member participants. The assurance case description procedure is presented in Table 2. Consequently, the monitoring results in the verification measure the architecture design achievement of a product using 3D CAD data. Additionally, they also measure the requirement definition achievement of a product using the requirement specifications.

Table 2. Method of Assurance Case Description

Step 1	Set Goal node.
Step 2	Set Context node as sub-goals by dividing the Goal into sub-goals. In addition, set priorities, if any, in the Context node when the priority of sub-goals is important.
Step 3	For Strategy node, divide the Goal into sub-goals (in prioritized order, if any).
Step 4	Set the sub-goals (in prioritized order if any) underneath the Strategy node. In addition, set Evidence nodes if the sub-goals need to be prioritized.
Step 5	Assume Step 4 to be Step 1, and repeat this process until the sub-goal nodes are completely deconstructed.
Step 6	Set Evidence node or Monitoring node until the goal cannot be divided any further.
Step 7	Confirm the relationship between the monitoring node and the evidence node.
Step 8	Connect the dotted arrow from the monitoring node to the evidence node according to the result of Step 7.

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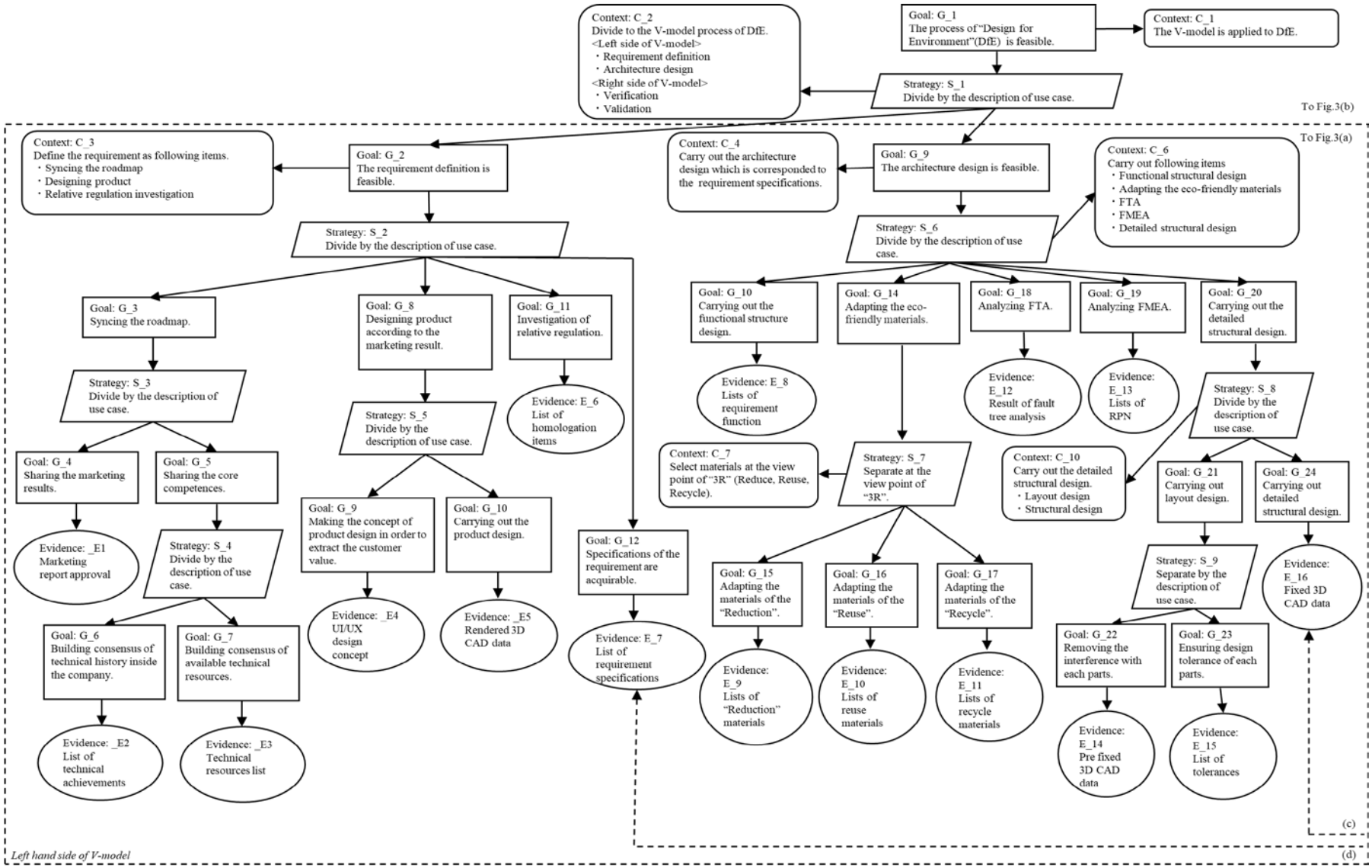

Figure 3. DfE Assurance Case in "Left-hand side of the V-model"

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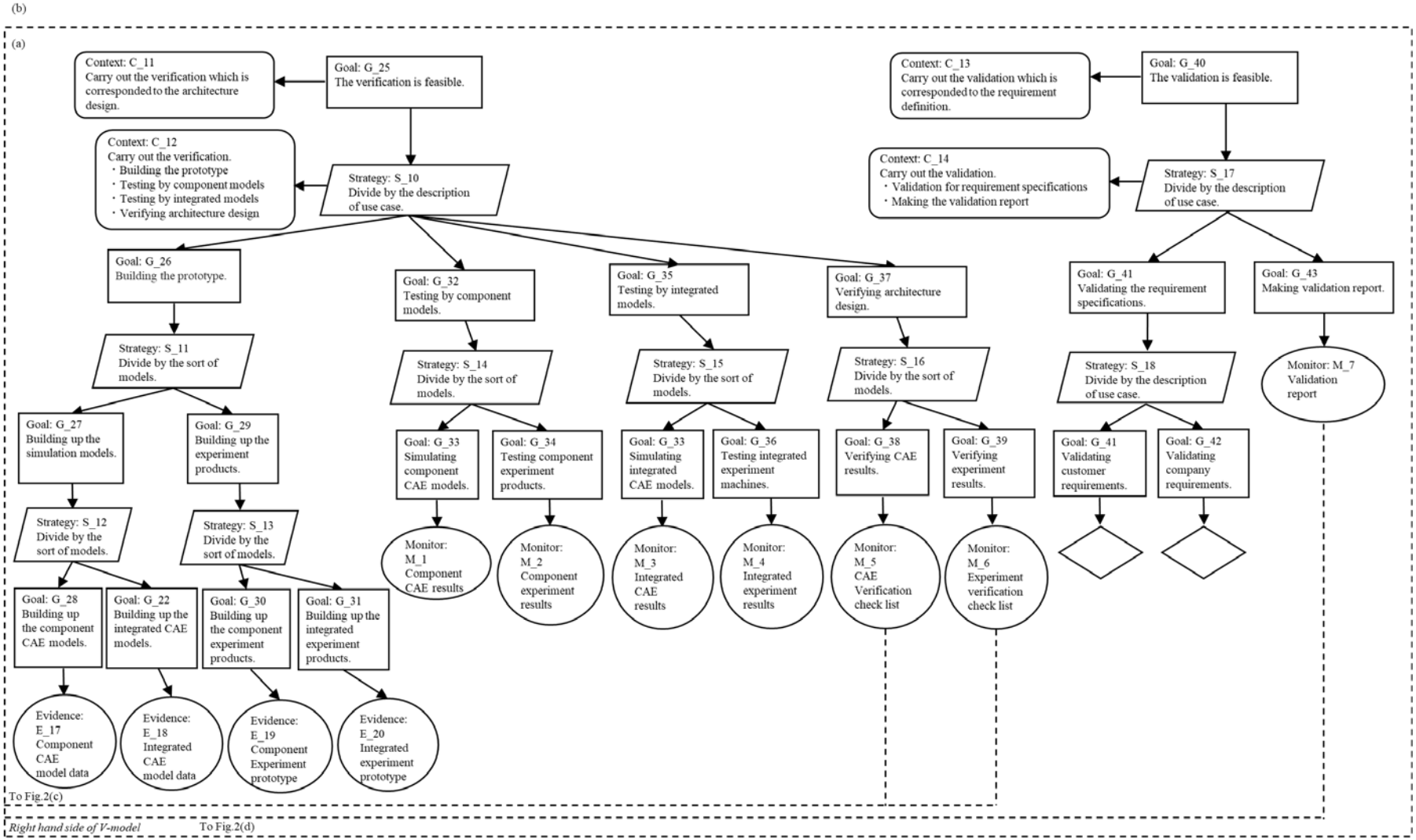

Figure 4. DfE Assurance Case in "Right-hand side of the V-model"

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4. EVALUATION

4.1. Evaluation Method

We surveyed DfE project members to verify this effect herein. Then, the target persons were designers, software engineers, structural design engineers, product planners, and quality control engineers. Herein, the evaluation methods were paired-samples t-test and open coding for each questionnaire, before and after applying the method of this study. This was done to confirm whether each member in charge is aware of the entire DfE process from the viewpoints of quantitative and qualitative analysis. Table 3 lists the questionnaire for the project members in this study. In this study, the relevance of tasks to the overall project and the evidence required is recognized as a issues because it is tacit knowledge that is not clearly stated. Therefore, the questionnaires are designed to ensure that the issues are addressed by the features of the assurance case. With regard to qualitative analysis, responses were given on a five-point ordinal scale, ranging from -2-“disagree,” to +2-“agree,” with 0 representing "neither agree nor disagree." Scores from +1 to +2 were assumed to be valid for business improvement. Moreover, we confirmed whether respondents could repeat and point after applying the proposed method to respondents (Kobayashi *et al.*, 2018a).

Table 3. Questionnaires for the Project Members

No.	Questionnaires
Q1	Do you understand the entire DfE process?
Q2	Do you understand the positioning of your task in this process?
Q3	Do you understand the relationship between the task connections and the evidences in this process?

Table 4. Open Coding Procedure

Step 1	The free description of the questionnaire survey and the verbatim comments are extracted, and the viewpoint of categorizing the Affinity Diagram is determined by using the KJ method (Scupin, R., 1997).
Step 2	Based on the viewpoint set in Step 1, the comments of the respondents are sorted according to the Affinity Diagram.
Step 3	Using the results sorted in Step 2, the participants are asked to summarize the main points of the group and describe the title of each group.
Step 4	The number of descriptions related to the open coding results is counted.

Conversely, with regard to the qualitative data analysis, free descriptive answers were used as data. Further, these data were analyzed using the procedure provided in Table 4 utilizing the qualitative coding methods provided in Strauss *et al*. (2008) .

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Lastly, to confirm the purpose of this study, which is described in Section 1, we set the viewpoint to understand the entire DfE project.

4.2. Evaluation Results

We surveyed before and after applying the method used in this study. A total of 20 individuals participated in our survey. In this study, the members who had participated in the DfE project as a person in charge were the target.

Table 5. Result of Paired t-test

	Q1		Q2		Q3	
No.	Before	After	Before	After	Before	After
1	-2	1	-1	0	-1	0
2	-1	0	-1	0	-1	0
3	0	1	1	1	0	1
4	-2	2	1	1	0	1
5	-1	1	0	1	0	1
6	-1	1	-1	0	-1	0
7	0	1	0	1	0	1
8	0	1	-1	1	-1	1
9	1	2	0	1	0	2
10	-1	2	-1	2	-2	1
11	-1	2	-2	1	-2	1
12	-2	1	-2	2	-1	2
13	-2	-1	-2	-2	-2	-2
14	-1	-1	-1	-1	-1	-1
15	-2	-1	-2	-2	-2	-2
16	-2	-1	-2	-2	-2	-2
17	-2	-1	-2	-2	-2	-1
18	-1	0	-1	0	-1	0
19	-1	1	0	0	0	0
20	-1	1	-1	0	-1	0
Sample number	20					
Degree of freedom	19					
Standard deviation	0.73	1.20	0.94	1.67	0.63	1.50
P-values (Both side)	0.000 (≤0.05)		0.001 (≤0.05)		0.000 (≤0.05)	

Table 5 presents the results of the paired t-test. Accordingly, before and after applying the method proposed herein, p-values were 0.000, 0.001, and 0.000 for each questionnaire, all of which are smaller than 0.05. Therefore, we rejected the null hypothesis, which means that there is a difference between before and after

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applying this method. In other words, by applying this method, the person in charge can understand the entire DfE process, positioning of their tasks, and the relationship between their tasks and other related divisions.

Table 6 provides the results of open coding. The results show the purpose of this study described in Section 1, "project members recognize their task by visualizing entire DfE process" is achieved. To ensure the reliability of the open coding results, we confirmed the analysis results in Table 6 with the respondents; all of them agreed with the analysis results (Kobayashi, N. *et al*., 2019; Kobayashi, N. *et al*., 2018b). In addition, the reliability of the analysis results was confirmed by an expert researcher who had verification experience in using qualitative surveys (Golafshani, N., 2003). Furthermore, we confirmed whether respondents could repeat and point after applying the proposed method (Kobayashi *et al*., 2018a). Consequently, all 13 respondents were able to repeat and point. This result shows that the method proposed in this study enables the recognition of the entire DfE process.

Hence, we concluded that this method is effective in making project members recognize the entire DfE process and their tasks.

Table 6. Results of Open Coding

No.	Open cording results	Counts
1	Since project process and work flow is visualized, the person in charge can understand the whole outline and schedule.	23
2	Since personal work is based on a written framework, the person in charge can understand needed evidences and carry it out.	15
3	The person in charge can understand and discuss business processes and output timing required for DfE.	12
4	Be aware of the positioning of own work in the DfE process.	5

4.3. Discussion

From the results of the paired t-test in Table 5, it can be seen that the proposed method accomplished the following goals: "person in charge can understand the entire DfE process," "person in charge can understand the positioning of their tasks," and "individual designers can understand the relationship between the task connections and evidences." The results are as follows: Kobayashi *et al*. (2017) indicated that the person in charge recognizes the task importance proposed by Hackman *et al*. (1980) by applying the assurance case. In fact, herein, from the open coding first result in Table 6, the respondents answered, "Since DfE process is visualized, we can understand the complete outline of the DfE." To recognize the entire DfE process, the proposed method is effective as a tool for grasping the complete process, which is considered to contribute to the recognition of task

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importance. In addition, the open coding second result in Table 6 indicates that the tacit knowledge, which is the personalized experience in the DfE, is converted into formal knowledge. Specifically, the open coding third result in Table 6 shows that the persons in charge can reconcile the recognition of tasks in the DfE. In other words, we consider that this contributes to the recognition of task importance. Finally, the open coding forth result in Table 6 indicates that the persons in charge were aware of each phase, and thus had the consciousness of positioning in the development process. This was because each designer understood the phase of overall development and the position of each person's work. Therefore, each person in charge can understand the entire DfE process by grasping the tailored process and outputs and the awareness of the work positioning of each phase. In conclusion, visualization of the DfE process using the proposed method is effective for DfE feasibility.

5 . CONCLUSION

Herein, we proposed a combined method for the DfE process to make project members recognize the task to visualize the DfE process, which assures that they will perform that task. The result of the paired t-test shows that there is a significant difference between before and after applying the proposed method; in other words, the persons in charge can understand the entire DfE process, positioning of their tasks, and the relationship between the task connections and evidences by applying the proposed method. Furthermore, based on the open coding results, it was observed that the proposed method is effective. From the foregoing, the method of this study is effective in addressing the issues described in Section 1. Therefore, we applied this method to the Concept Stage (INCOSE, 2015) and totally incorporated it into the development schedule. In future research, first, the development of a method for analyzing value creation linked to the proposed method is desired. This is because project managers and leaders perform their roles to succeed in the project. Second, future research needs to link ways to encourage innovation. A desirable method is a framework for finding "meaningful multi-viewpoints" that work reliably and guide insights. In other words, it should be a method that helps understand the characteristics of each option by quantitatively comparing multiple candidate ideas. Such methods would guide the insights and make it possible to innovate in a project. Third, future research needs to be conducted to drive the project smoothly. In other words, a method of converting ideas and concepts into concrete stories, telling them, and sharing them with project members and audiences is desired because

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persons in charge must share ideas, culture, and knowledge.

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