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REQUIREMENT-DEFINITION-CONFIRMATION MODELING APPROACH FOR IDENTIFYING UNCERTAINTIES IN PRODUCT DESIGN PROCESSES

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ABSTRACT

Product design consists of multiple work elements and their interrelations, but it is often a tacit process in a practical design environment. In order to capture and formalize the work elements and their interrelations, it is useful to introduce a process modeling methodology and to analyze and synthesize the design process in an adequate way. This paper proposes a novel Requirement - Definition – Confirmation (RDC) Model for this purpose. The RDC Model describes a design process as the interrelation of three types of design elements: requirement, definition and confirmation. Use of this description can facilitate visualization of iterations, conflicts and uncertainties in the product design process. Such design qualities are often related to engineering risks, and can be used for supporting engineering decisions. We applied our RDC Model framework to automobile design and showed that RDC models effectively visualize the process quality and engineering risks.

1. INTRODUCTION

The reformation of the product design process in order to improve the product quality and the productivity is always one of the main issues in manufacturing companies. However, the complexity of the processes may prevent companies from achieving the reformation.

Product design may include chaotic and ad hoc processes due to tacit sequences structured in the brains of design engineers. When facing design engineering issues, design engineers create processes to find solutions, relying on their experience, knowledge and, sometimes, their inspirations. Such processes may vary according to the specific design engineers and the conditions of the design issues. This characteristically limits the way in which companies visualize their design processes. Consequently, they may try a number of measures to improve the processes when the real aspects of the processes have not been understood. The result is that they may not reap adequate benefits from such measures. For example, Japanese automotive companies continuously improve their product design processes using both conventional techniques, such as design standardization, check lists, design review, etc., and modern techniques such as 3D CAD/CAE applications. However, the number of recalls the companies report every year has been increasing, as shown in Figure 1.

Engineering risks tend to grow as the product design processes increase in complexity. Hence, companies have begun to recognize that leaving the product design processes invisible and uncontrollable is unacceptable. Nowadays, many companies look for ways to control the product design

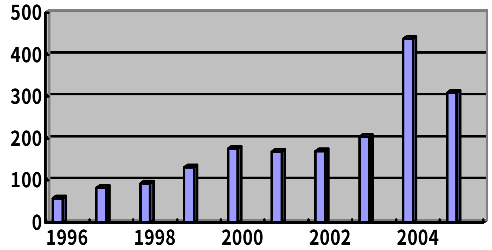

Figure 1: Number of recalls per year in the Japanese automobile market (Ministry of Land Infrastructure and Transport of Japan 2006)

processes to ensure the quality of the final products and to reduce risks. Product design process modeling is one of the most promising answers.

Product design process modeling is a methodology for capturing the parameters of the product design process and visualizing useful aspects of the process. Today, there are several product design process modeling methodologies that have been used in a number of companies. The aspects to visualize and parameters to capture are dependent upon the objectives of the methodologies.

In the following section, we take examples of typical modeling methodologies and compare the features of their approaches. In section 3, we describe a novel modeling methodology focuses on three types of activities, which are requirements, definitions and confirmations, in the product design process. We try this methodology to an automotive component in section 4. Finally, we conclude with an examination of present conditions of our study in section5.

2. EXISTING MODELING METHODOLOGIES

The Gantt chart has been used for managing the scheduling of product design for many years. As a scheduling technique the Gantt chart can be considered as a kind of modeling methodology of the product design process. It focuses on design activities and the duration of the activities of product design, and visualizes them in chronological order by showing horizontal bars on the timing chart. When dependencies between activities have to be emphasized, an arrowhead is used to clarify input and output between activities (Figure 2).

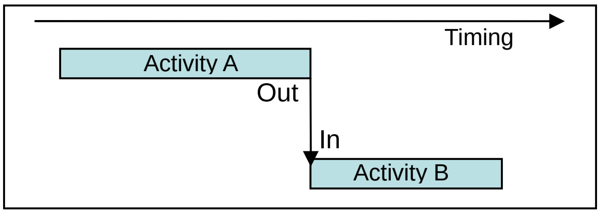

Figure 2: Gantt chart

The Program Evaluation and Review Technique (PERT) captures design activities, durations of activities and dependencies between activities using nodes or boxes on a network diagram. By following the arrows between the activities in a PERT diagram, we discover the work order of the product design process. Each arrow has attributes of work durations, so that we can calculate the lead time between any two selected activities and, consequently find the longest path between the activities (the critical path) and its lead time.

Although iterations between activities often characterize the performances of product design processes, the above two methodologies do not represent iterations adequately. The Design Structure Matrix (DSM) (Steward 1981, Smith and Eppinger 1995) is a powerful tool for visualizing such iterations in product design processes. DSM captures design activities and dependencies between the activities in an $m \times m$ matrix, and visualizes iterations via symbols of the dependencies on the upper triangular of the matrix. This visualization is useful for reducing the probabilities of reworks and finding an ideal execution sequence of activities (Browning 1998).

Business modeling methodologies such as the Unified Modeling Language (UML) (Jacobson, Booch and Rumbaugh 1999), have been developed for visualizing multiple aspects of business processes. Integration Definition language (IDEF) is an example of a business modeling methodology that captures and visualizes the product design process. Among the existing 16 IDEF methodologies, IDEF0 describes the structure of design activities by capturing the flows of information and resources including input / output, function, control and mechanism, through the process (The National Institute of Standard and Technology of USA 1993). IDEF3 visualizes work sequences by representing a context of activities (Mayer et al 1995). IDEF methodologies have been enhancing as a risk assessment tool in the concurrent engineering environment as shown by Kusiak and co-workers (1994, 1996, 2002).

The above examples of methodologies are intended to capture product design processes as they are. In contrast to these process capturing approaches, there are other approaches that standardize product design processes. These methodologies provide frameworks for the processes. The most well-known example of the standardized framework is the "systematic approach" proposed by Pahl & Beitz (1995). This approach provides a precise guideline for implementing an ideal product design procedure for mechanical products.

A simpler but more practical application of the standardized framework approach is the Gate Model, which sets a number of quality gates in the product design process. Consequently, this approach broadly standardizes activities between the quality gates. A number of studies of the Gate Model have been reported, such as "The Product Realization Process" by Wesner et al.(1995), "Stage-Gate process" by Cooper (2001), "ABB Gate Model", "GE Toolgate Review", "Lucent Gate Process", and "NASA Technical Design Review" (Chao and Ishii 2005). The Spiral Development Model enhances the ability of the Gate Model and eliminates risks from the product design processes more effectively by applying the control cycle of "Determine objective, Alternatives, constraints", "Evaluate alternatives", "Identify / resolve risks", "Develop / verify next level of product", "Plan next phases" (Boehm and Hansen 2000). All Gate Models specify the deadlines of the activities and the criteria for passing through the gates.

Uncertainty is one of the key characteristics of the product design that causes undesirable product design outcomes. The standardized framework approaches are used to eliminate the uncertainties from product design activities effectively and efficiently.

Table 1 shows the features of these existing product design modeling methodologies. According to our observations of several Japanese manufacturing companies, the Gantt chart and the Gate Model have been widely used in for schedule management and quality management. However, other methodologies have not been utilized by the companies, although the methodologies have the capability to moderate many process-related issues. Usually, the product design processes of the companies are typical iterative processes that contain hundreds of activities for each component. We believe that the Gantt chart and the Gate Model are used because these two methodologies suit the conditions of the companies.

We assumed that a product design process modeling methodology that has the same level of simplicity and easy of use as the Gantt chart and the Gate Model, but captures more parameters and visualizes more aspects of the process, may offer better support to the companies in solving their issues. This is our motivation for developing a new modeling methodology.

Table 1: Features of the existing modeling methodologies

Methods	What the method captures	What the method visualizes
GANTT CHART	Design activities Duration and timing of design activities Dependencies between activities (roughly)	Timing of work Work order (roughly)
PERT	Design activities Duration of activities Dependencies between activities	Work order Lead time between two selected activities Critical path
DSM	Design activities Dependency between activities	Iteration (probability of rework) Coupled activities Optimal work order
IDEF0	Design activities Flows of information and resources through the process (input, output, control, mechanism)	System structure Engineering risks
IDEF3	Design activities (UOBs) Process flow (links and junctions)	Work sequence (scenario)
GATE MODEL	Design activities Design phases	Deadline of activities Criteria for passing through the gates

3. DESIGN PROCESSES MODELING BY THE RDC MODEL

Product design processes include tacit and ambiguous activities that often exist only in the engineer's brain. In order to capture appropriate parameters within acceptable resource consumptions (time, human hours, etc.) and identify necessary aspects of such processes, this paper proposes the *Requirement-Definition-Confirmation Model (RDC Model).*

The RDC Model analyzes activities in the product design process, focusing on sources of respective design intentions, which are referred to as *"Objects to adapt" (OTA).* The analyzed activities are classified into one of three fundamental design elements, which are referred to as *"Requirement", "Definition" and "Confirmation"*. After the analysis, the analyzed design elements are synthesized using their interrelations. Nakazawa (2003) gave the steps of the analyses and the syntheses (explained graphically in Figure 3):

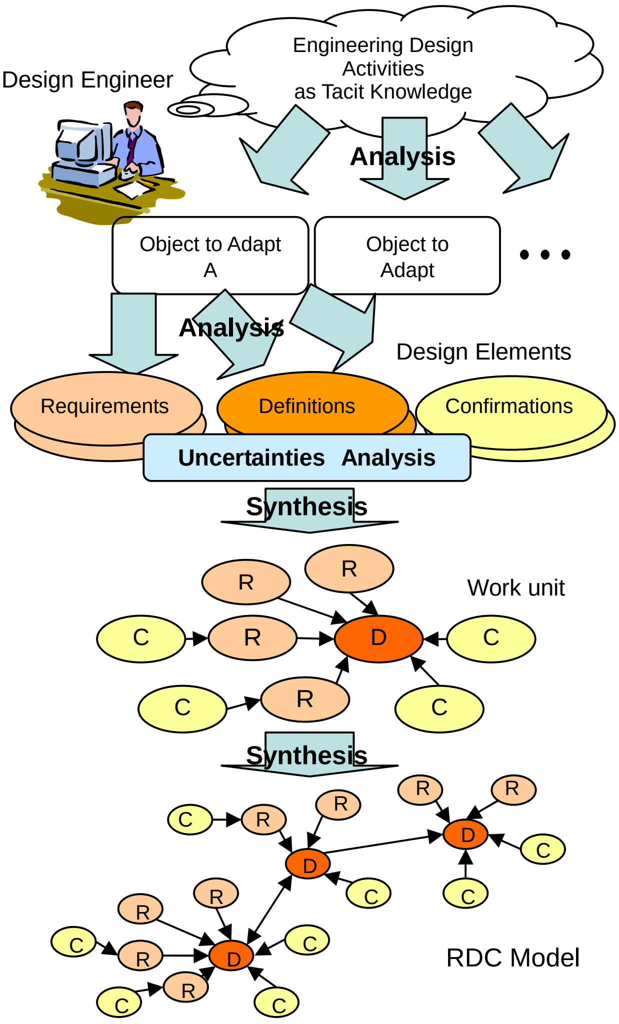

Figure 3: RDC Modeling Procedure

(Analyses)

Step 1: Find objects that the product shall adapt (Object to adapt=OTA)

Step 2: Describe design elements (requirements, definitions and confirmations) for each OTA

(Syntheses)

Step 3: Find interrelations, OTA by OTA between the design elements

1) Requirements and definitions
2) Confirmation and requirements
3) Confirmation and definitions

Step 4: Find interrelations (dependencies) between definition elements

As a result of the analyses and the syntheses, the RDC Model captures parameters and visualizes aspects of the product design processes as shown in Table 2.

Table 2: Features of the RDC Model

Method	What the method captures	What the method visualizes
RDC MODEL	OTAs (sources of requirements) Design elements (requirements, definitions, confirmations) Interrelations among design elements	Uncertainty in requirement and definitions Risks in the design process Minimal unit of work Iteration in definitions (using DSM) Coupled definitions (using DSM) Ideal work order of definitions (using DSM) Probability of conflict

This paper also presents a case study of the product design process for an automobile head-light, which is analyzed and synthesized by the RDC Model.

3.1. OBJECTS TO ADAPT (OTAs)

During product development, the design engineers have to consider a number of targets and conditions. When they consider these, they image objects that generate the targets and conditions, such as the user, the market place, regulations, standard parts lists, styling, the manufacturing process, etc. We refer to the object as an “Object to Adapt” (OTA). The concept of OTAs helps us to consider that the product design process consist sets of design activities such that the designed product adapts appropriate OTAs.

Finding the OTAs for a product design process is the first step in creating an RDC Model. As shown in Table 3, some OTAs (Level 1) can be decomposed into detailed OTAs (Levels 2,3…). Process analysts (usually design engineers themselves) may decompose OTAs until they can easily find “*design elements*” which are defined in the next section.

An OTA assumes two important roles in analyzing and synthesizing product design processes. First, when a tacit product design process is analyzed and activities are abstracted by process analysts, the OTA helps analysts to focus on a single objective of the product design, and encourages them to reach simple and unambiguous descriptions of activities without any confusion. If an analyst tries to describe activities in a product design process without an OTA, the analysis may omit aspects of the activities. Second, the OTA may help to visualize conflict in product design processes. The OTA is a representation of the sources of multiple objectives of the product design. As such, it helps analysts to clarify the causes of conflicts, which usually occur between two different objectives that can be represented as OTAs refer to section 3.8 for a more precise explanation. Because of these two capabilities, the OTA plays an essential role in the RDC Model.

Table 3: Examples of OTAs

Level 1	Level 2
User	User safety User convenience Preference
Styling	
Product target	Functional target
Regulation	US regulation European regulation Japanese regulation
Manufacturing process	Molding process Stamping process Assembly process
Die and tooling	
Quality standard	
Development process	Design standard Checklist Design review Design review Validation plan Specification
Part and material	Standard part Standard material
Layout	Other components
Product structure	
Supplier	Supplier's standard Supplier's manufacturing process
Cost	
Weight	
Society	Recycling policy Energy consumption policy
Region	Environment Custom Religion

3.2. DESIGN ELEMENTS - REQUIREMENT, DEFINITION AND CONFIRMATION

The RDC Model rests on the premise that activities in product design processes can be classified into three categories referred to as *design elements*. The design elements consist of the requirement element, definition element and confirmation element, and their precise descriptions are given in Table 4.

Usually, an OTA can be a trigger for finding the design elements, especially the requirements. For example, the OTA: “Assembly process” (Table 3) may be the trigger for finding the qualitative requirement “Easy assembly operation” or for finding the quantitative requirement “The product width shall be less than 500mm in order to adapt the maximum assembly jig size”. The OTA “Environment” may be the trigger for finding the qualitative requirement ‘Acid rain” and the quantitative requirement “Environmental temperature does not exceed 50 °C”. These requirements are the external “inputs to the product” (1). In addition to these external inputs, there are two more types of requirements. One is “the qualitative properties and characteristics of the product and the components of the product” (2). For example, the OTA “Standard material” may generate the qualitative requirement “Material strength is affected by temperature”. Considering this requirement, the design engineer may set his/her expectation as “Material works properly in an environmental temperature up to 60 °C”. This is the “quantitative expectation for the behaviors of the product and the components” (3).

Table 4: Design elements

	Descriptions	Examples
Requirement	1. Qualitative and quantitative inputs to the product and the components	Customer requirement, usage conditions, manufacturing conditions, regulations, design standards, test conditions, styling lines and surfaces
	2. Qualitative properties and characteristics of the product and the components	Design constrains, layout conditions, material properties, structural limitation
	3. Quantitative expectation for the behaviors of the product and the components	Functional target, product duration, chemical resistance, heat resistance
Definition	Determination and selection of the parameters of the product and the components	Dimension, structure, shape, mechanism, position, location, direction, material
Confirmation	1. Validations of assumed requirements	Market research, user survey
	2. Validations that assumed definitions fulfill quantitative requirements	Vibration test, endurance test, water proof test, rust test, heat resistance test, chemical resistance test, quality inspection
	3. Validations that definitions fulfill non-quantitative requirements	Field test, exposure test, user monitoring

The design engineer has to take into account the requirements and determine the definitions of the product, such as size, shape, components or materials. Each definition that is generated from an OTA is constrained by one or more requirements generated from the same OTA. In the above example, the definition "Size of the product" may be constrained by both the "Easy assembly operation" requirement and "The product width shall be less than 500 mm in order to adapt the maximum assembly jig size" requirement.

In the product design process, the confirmation element is important as well as the requirement and the definition elements. Confirmations can also be generated in association with OTAs. The RDC Model identifies three types of confirmations: "the confirmation of the assumed requirements" (1), "the confirmation of the assumed definitions" (2), "the confirmation that the definitions fulfill the non-quantitative requirements" (3). Because, requirements are not always measurable, we have observed that many definitions are created without knowing the exact magnitude of the requirement. Therefore, the last confirmation is for a "yes" or "no" judgment of whether the characteristic, as a result of the definition, exceeds the requirement.

3.3. IDENTIFYING RISKS IN THE PRODUCT DESIGN PROCESS

In order to identify risks in a product design process, several techniques have been studied. Design Process FMEA (Chao and Ishii 2003) analyzes error risks by classifying the process into six categories ("Knowledge", "Analysis", "Communication", " Execution", "Change", and "Organization") in the FMEA table. The Signposting Model (O'Donovan et al 2003, 2004, Wynn et al 2005) identifies risks as the confidence level of the signposting parameters contained by tasks in the product design process.

In the RDC Model, risks in the product design process are identified as the uncertainties of the requirements and definitions. In this study, we assumed that the weights of the uncertainties are determined by which phases of the confirmations are scheduled to resolve the uncertainties, in the project time frame.

3.4. UNCERTAINTY OF THE REQUIREMENTS

As Quality Functional Deployment (QFD) (Akao 1990) converts the quality requirements from ambiguous needs (voice of customer, VOC) to part characteristics, which directly link to the product definitions and parameters, there are levels of uncertainty on the requirements as in Figure 4.

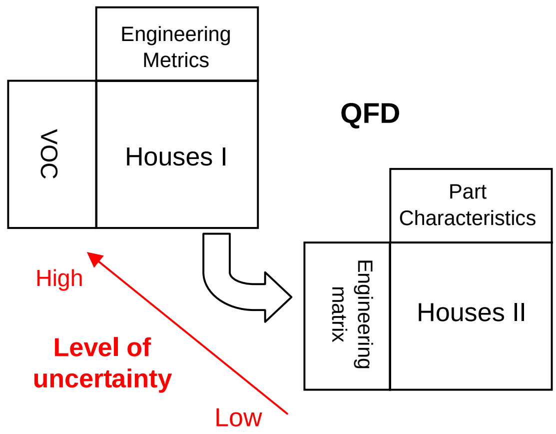

Figure 4: Uncertainty levels of the requirement

The requirement "Easy assembly operation" discussed in section 3.2 is an example of an uncertain requirement. In order to determine a product definition such as "Size of the product", the requirement "Easy assembly operation" has to be translated into a more accurate representation. On the other hand, the requirement "The product width shall be less than 500 mm in order to adapt the maximum assembly jig size" is a certain requirement because it allows an engineer to determine the dimension of the product directly from this requirement with a simple arithmetic calculation.

Qualitative requirements such as "Easy assembly operation" and "Acid rain" can be considered as uncertain requirements. Such requirements are risk factors in product design processes. When facing uncertain requirements in actual product design processes, the engineers usually make some assumptions by complementing the uncertainties of the requirements using their knowledge and experience, and proceed with the product design process. However this often has a disastrous impact on the project when these assumptions are denied after the completion of the product design. This impact may necessitate the modification of the design concept, the basic structure, and the layout of the product, or the compromise or withdrawal of the requirements.

3.5. UNCERTAINTY OF THE DEFINITIONS

In existing studies that focus on the uncertainties in the product design process (O'Donovan et al 2003, Yang et al 2005, Zang et al 2002), the uncertainty has normally been treated as that associated with product definitions.

While certain definitions, such as the standardized definitions, are experimentally or logically proved to satisfy the requirements, an uncertain definition means "you never know till you have tried". Some examples are unprecedented shapes or structures or new materials. "Environmental temperature does not exceed 50 °C" can be considered as a certain requirement. However, definitions such as "Material" and "Thickness of the body", which are influenced by this requirement, can not be determined without the proof of a precedent or confirmed theory. If no such precedent or theory exists, the design engineer is obliged to determine the definitions with uncertainties. On the other hand, for the requirement "The product width shall be less than 500 mm in order to adapt the maximum assembly jig size", the design engineer can define numerically the adaptable product size (450 mm, for instance) without any uncertainty.

Uncertainties of definitions generate different types of risks depending on the phases of the product development lifecycles in which they occur. For instance, in the design phase, the design engineer is able to eliminate the risk by simply modifying the design data (drawing and CAD data). However, in the manufacturing process planning phase, a modification of tooling and facilities may be required to eliminate risks and, in the product shipping phase, critical risks such as market claims or recalls must be considered.

3.6. RESOLVING THE UNCERTAINTIES BY THE CONFIRMATIONS

The role of the confirmation in the product design process is to moderate or to resolve the uncertainties of the requirements and definitions, as shown in Figure 5.

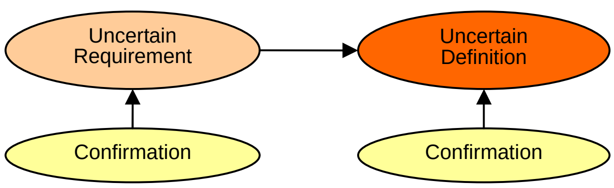

Figure 5: Role of the confirmations

For example, the uncertainty of the requirement "Easy assembly operation" and the uncertainty of the definitions "Material" or "Thickness of the body", described in the previous sections, can be resolved by confirmations such as "Trial assembly" and "Strength test".

The uncertainty of the requirement and the uncertainty of the definition fundamentally need to be resolved by appropriate confirmations. However, in many actual product development processes, appropriate confirmations often do not exist, or they exist only in the very late phase of the project. Both cases increase the risks in the product design process. As shown in

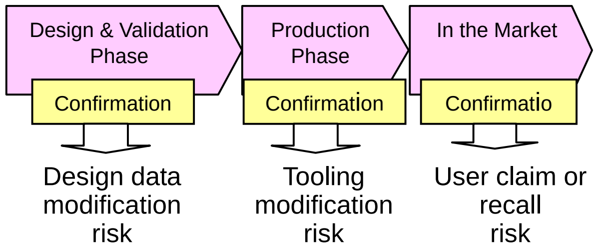

Figure 6: Engineering process risks

Figure 6, the impacts of uncertainties depend on the phases in which confirmations to resolve the uncertainties are scheduled.

3.7. WORK UNITS

Figure 7 shows that a definition AD1 generated by an OTA A is constrained by the requirements AR1~AR4 generated from the same OTA. The uncertainties of the requirements AR3 and AR4 are resolved by the confirmation AR3C1 and AR4C1, and the uncertainty of definition AD1 is resolved by the confirmations AD1C1 and AD1C2 from the OTA A. These interrelations configure a group of design elements in the OTA. We refer to this group of design elements as a "*work unit*" and

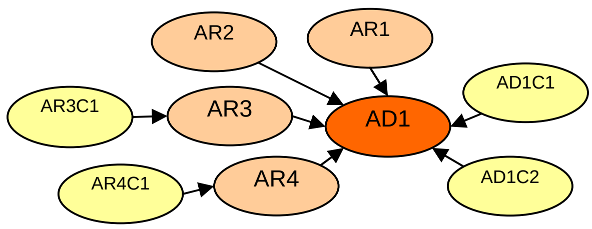

Figure 7 : Work unit

consider it as the minimal unit for decision making in the product design process.

3.8. INTERRELATIONS BETWEEN DEFINITIONS

DSM (Steward 1981, Eppinger et al 1989) focuses on the dependencies between activities in product design processes. DSM represents the dependencies between each pair of activities in one matrix, without distinction as to the types of activities.

In the RDC Model, analysts need to distinguish interrelations within one work unit, as described in section 3.7, and interrelations across multiple work units. As one work unit contains only one definition element, interrelations between definitions have to be identified across work units, as in Figure 8.

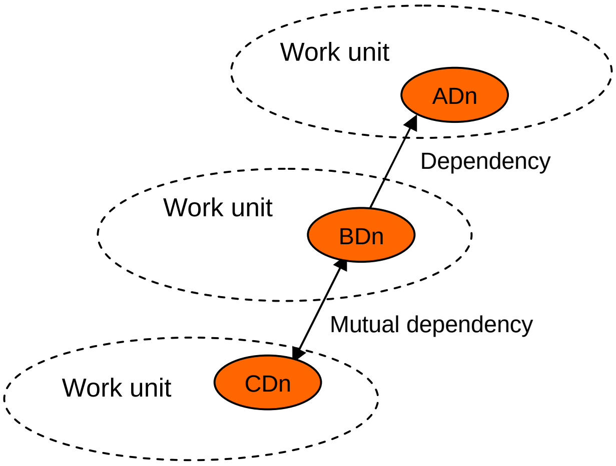

Figure 8: dependency network between definitions

Therefore, we need ways to identify the interrelations between definitions, which may be a very complex dependency network. The DSM for definitions (Figure 9) will satisfy this need. In addition, by its inherent geometrical characteristic, the DSM can visualize the iteration including the mutual dependencies between the definitions.

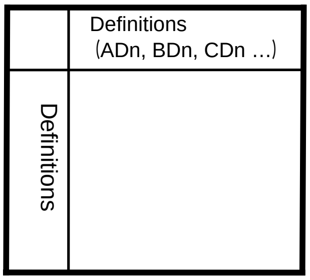

Figure 9: DSM for definitions

In product designs, product definitions are usually constrained by multiple requirements and conditions. As a result of the analysis by OTA, each definition described in the RDC Model is simplified to have a single objective. Consequently, the mutual interrelations between definitions often cause conflict between them when the definitions have no common space (solution) due to their antithetical objectives (Figure 10). For instance, the definitions may be incompatible with each other in their shapes, positions or materials in order to adapt to their respective OTAs. Descriptions of the mutual dependencies between definitions in DSM can visualize

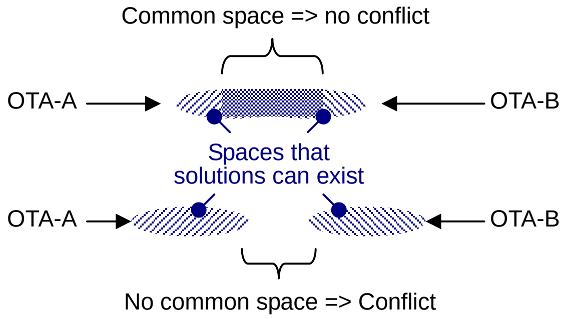

Figure 10: Conflict between definitions

probabilities of such conflicts in product design processes.

In addition, iterations are used to rearrange the work sequence of the definitions, and this consequently prioritizes the OTAs. This prioritization of OTAs leads to a product design process that is similar to the standard work sequence proposed by Pahl and Beitz. (Nakazawa and Shimizu 2004).

3.9. STRUCTURE OF RDC MODEL

As a result of the analysis and synthesis of a product design process using the RDC modeling methodology, the process is structured as in the network diagram shown in Figure 11.

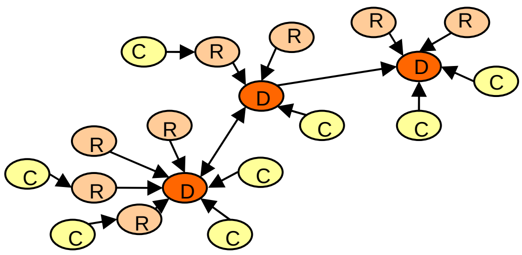

Figure 11: Network diagram representing the RDC Model

4. CASE STUDY

A product design process for a head-light of an automobile was analyzed and synthesized, using the RDC modeling methodology by the design engineer of the product himself.

The first step of the analysis is to find the OTAs. This can be done without difficulty from day-to-day design engineering experience. 18 OTAs found by the analysis are: aiming process, service process, styling design, appearance quality, housing tooling, reflector tooling, lens tooling, client testing, client assembly process, client quality standard, inspection process, validation standard, assembly process, vehicle layout, luminous specification, housing finishing process, reflector finishing process, and structure of the light unit.

For each OTA, the design elements were analyzed. In total, 90 requirements, 74 definitions, 38 confirmations were found. Table 5 shows the design elements found in the OTA “Service process” as an example.

Table 5: Design elements of the head light (OTA = service process)

Requirements	Definitions	Confirmations
Battery position	Housing shape	Light detach-ability
Body panel position	Fixing position	Bulb maintenance
Wire harness	Rubber cap	Rubber positioning
Radiator position	Bulb spring	
Tooling	Bulb position	
	Screw	

When all of the design elements of the OTAs were analyzed, the uncertainties were investigated for each requirement and definition. This showed that 14 out of 90 requirements and 34 out of 74 definitions had uncertainties at the phase of the engineering design data release (Table 6 and 7). This result suggests that some tentative assumptions are made by the design engineer in order to release the design data on time.

Table 6 and Table 7 also include the actual confirmations for the uncertain requirements and definitions in this process. The rightmost columns show the risks for changing according to the uncertainties and the timing of the confirmations. Among the uncertainties of the requirements, several critical risks were found. These have the probabilities of withdrawing either the requirements themselves or the product concepts. Detected risk types are as follows.

(1) Possibility of modifying the predefined layout of the product
(2) Impossibility of adapting the client assembly process
(3) Possibility of changing the manufacturing process or tooling or robot
(4) Possibility of changing the parameters in the manufacturing processes, like the hot melt (adhesive) material or the hot melt applicator conditions
(5) Impossibility of adapting specifications or product concept or target

Also, among the uncertainties of definitions, detected risks are:

(1) Possibility of modifying the design data
(2) Possibility of modify the tooling
(3) Possibility of denying the product concept

In the early phase of the product design process, the design changes impact only on the drawing or the design data. In the later phase of the process, the design changes have more physical impacts on the tooling and facilities or on the product itself. The results indicate the importance of the frontloading of confirmation activities.

5. CONCLUSIONS AND REMARKS

In this paper, we propose a new approach to the analysis and synthesis of the product design process using the RDC Model. In the described process model, three characteristics of the process can be visualized as “iteration”, “conflict”, and “uncertainty”. Confirmation is the key to reducing uncertainties.

The presence of risk within product design processes has been recognized for many years, but the amount of risk in the entire process is still unmeasurable. No companies have infinite resources (time, human hours and money) to eliminate all of the risks from the process. This consequently requires companies to prioritize the risks to be resolved. The RDC Model is useful for capturing tacit activities and assessing the entire risks in the product design process in terms of the uncertainties of the requirements and the definitions.

The result of the case study showed that 16% of the requirements and 46% of the definitions had uncertainties at the phase of the engineering design data release in this process. In the current product design process, the confirmation activity has been conducted without a distinct awareness of the identified uncertainties. Describing the confirmations allocated to each uncertainty may yield an opportunity to reevaluate the ways and means of these confirmation activities. In this manner, companies may control the uncertainty in their product design processes.

Since our study was started, the RDC modeling methodology has been tried for a number of product design processes of automotive components, a tooling of an automotive component, a manufacturing facility, an office machine, and a laptop computer. In these studies, we have focused on visualizing the “iteration” and “conflict” characteristics of the processes. We have recently initiated a study for measuring the process risk in the product design process using “uncertainty”. This paper is the first step of the study.

Here, we have just counted the number of design elements that contain uncertainties. However, our goal is to enhance the methodology and quantify the risk in product design processes. We believe that if the risk can be specified by a simple number, it will guide a company to make appropriate investments towards appropriate solutions in order to moderate the risks in their processes

Table 6: Requirements of the head light

Objects to adapt	Requirements with uncertainty	Confirmation	Risk for changing
Service process	Accessibility for service	Bulb service-ability, Light service-ability	Layout
	No risk of injury		Layout
Client assembly process	Aiming workability	Aiming adjust-ability	Client assembly process
	Assembly space	Assembly-ability	Layout
	Assembly workability		Client assembly process
Client quality standard	Aspect quality	Quality sample inspection	Manufacturing process or Tooling
	Process capability	Quality report submission	Manufacturing process or Tooling
Inspection process	Automatic aimer	Aimer trial	Automatic aiming process
Assembly process	Hot melt applicator robot	Hot melt cross section inspection	Hot melt material or Robot or applicator conditions or Housing tooling
	Lens compress force	In line air leak test	Hot melt material or Robot or applicator conditions or Housing tooling
Structure of the light unit	Bumper stroke	Collision test	Layout
	Hood travel distance	Hood over stroke check	Layout
Luminous specification	Client line tester	Cut off position check, Hot spot position	Specifications or product concept
	Client luminous target	Screen test, Road test	Target or product concept

Table 7: Definitions of the head light

Objects to adapt	Definitions with uncertainty	Confirmation	Risk for changing
Appearance quality	Reflector flange	Aspect check	Tooling
Housing tooling	Slide thickness	Tooling realization	Design data
	Slide depth		Design data
Reflector tooling	Gate locations	Tooling realization, Mold trial	Design data
	Eject pin locations		Design data
Lens tooling	Gate locations	Tooling realization, Mold trial	Design data
	Slide thickness		Design data
	Slide depth		Design data
	Lens flange		Design data
	Eject pin locations		Design data
Client testing	Housing reinforcement ribs	Strength test, Impact test, Vibration test	Tooling
	Reflector fixing layout		Tooling
	Lens varnishing	Weather resistance test, Chemical resistance	Product concept
	Ventilation hole location	Water proof test	Tooling
	Water proof ribs		Tooling
Client assembly process	Aiming screw layout	Aiming adjust-ability	Tooling
	Aiming screw		Tooling
	Temporally fixing	Assembly-ability	Tooling
	Light fixing legs		Tooling
	Fixing positions		Tooling
Client quality standard	Housing thickness	Quality sample inspection, Quality report submission	Tooling
	Housing reinforcement ribs		Tooling
Inspection process	Adjust screw	Aimer trial	Tooling
	Aiming guide		Tooling
	Reflector surface		Tooling
	Lens fixing hook form	Leak checker trial	Tooling
Validation standard	Housing material	Heat duration test	Tooling
	Reflector fixation	Heat impact test, Heat vibration test	Tooling
Assembly process	Sealing channel cross section	Hot melt cross section inspection	Tooling
	Housing positioning pins	Jig design	Tooling
	Lens assembly direction	In line air leak test	Tooling
	Lens fixing hook layout		Tooling
	Lens fixing hook form		Tooling
Luminous specification	Reflector surface	Cut off position check, Screen test, Hot spot position, Upper beam intensity, Visibility test, Road test	Product concept

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