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An Ontology-based Product Development Framework Considering Eco-design

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Abstract—**The environmental protection issues have been received serious attention worldwide. This trend results in the balance between the economic benefits and the environmental protection needs should be carefully considered when companies launch new products. The purpose of this study is to provide an ontology-based process-oriented framework to support the product development with the eco-design concept. In the proposed framework, the life cycle assessment (LCA) is applied to analyze the environment impact of product development process. The Design Chain Operations Reference model (DCOR) and the design structure matrix (DSM) are used to describe and classify the process with the eco-design dimension. Then, a Protégé platform using a language called the Java expert system shell (Jess) is established as an ontology-based knowledge management system of product development process. Finally, an all-in-one (AIO) computer designed by an OEM/ODM company in Taiwan is chosen to demonstrate the usefulness of the proposed framework.**

Keywords—**Eco-design, ontology, LCA, DCOR, DSM.**

I. Introduction

The international community has gradually come to consider environmental protection a major subject. The economic benefits and sustainable ecological development needs in the whole product life cycle should be considered simultaneously when enterprisers decide to launch new products. The new product development (NPD) is one important stage in a product's life cycle. It can promote the environmental protection efficiently and obviously if consideration is given to economic benefits and Eco-design [1, 2].

The trend of the latest new products development results in provision of many methods which analyze the impact of environmental factors on the product life cycle. Nevertheless, these methods are integrated to the process of product design, but there is a lack of actual case applications. This leads to inappropriate use. Among various methods, the life cycle assessment (LCA) has been widely applied in products environmental impact evaluation [3]. LCA is based on the rigid standards of ISO series (14040~14044). It defines materials processing and environmental consequences in product life cycle, evaluates environmental impacts, and finally interprets the significant results in terms of ISO/TR 140402006. In other words, through the use of auditing impact assessment from raw material extraction, manufacturing, use, recycling, and disposal in the whole product life cycle, the environmental influence can be quantified[4].

Four key problems should be considered for LCA [5]: (1) traditional LCA requires the collection of a massive amount of data, (2) collecting process costs much time and resource, (3) the new product development activity is an iterative process and various changes will be occurred, and (4) LCA requires a high degree of professional talent. In most enterprises, although design engineers have strong product knowledge and experience on the product development, but few of them understand the critical life cycle assessment about the application of design for the environment (DFE) [6]. Hence, developing an appropriate framework or method is needed.

The life cycle assessment information is increased along with accumulated information and knowledge in releasing product. With related knowledge of products distributed to each department of a firm, a knowledge management system about the whole product life cycle is needed to give a balanced consideration of Eco-design and economic benefits. Ontology can be used as a basis of the knowledge representation. It enables one avoid the overlap of analyzing domain knowledge and meet the purpose of sharing knowledge relating to defined terms and concepts[7].

With the reuse of knowledge and sharing, promotion of the quality of life cycle assessment and knowledge management system, reduction of relevant costs, and reduction of environmental influence can be achieved. It is necessary that integrated knowledge structure should be constructed for sharing information about organizations, suppliers and customers.

The reference model for those enterprises whose business partners are different in the stages of life cycles assessment, the procedure of assigning information and knowledge to those stages and developing mutual co-operation model, it is promoting to accelerate mutual agreements among business partners, and implementing the comprehensive information model [8]. Poudelet et al. [2] adopted the method of Business Process Reengineering (BPR) to draw up an coordinated and efficient decision support tool, enabling them to make the decision based on different design solutions and quantitative

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indicators at the initial informatics design stage, providing the users to have decision solutions with economic benefits and environmental protection, nevertheless, this concept is short on a set of standard reference flow for the enterprises in order to provide the usage instructions.

The Design Chain Operations Reference-model (DCOR) developed by the Supply Chain Council (SCC) (Supply-Chain Council, 2006) can be used as a process-oriented design method of the product development. The scope of the DCOR includes those collaborative operation partners including enterprise itself called your company, suppliers, and customers. In the DCOR, the process-oriented perspective, performance evaluation, and the best practice are used to form a design chain tool. It is a useful operation reference model when the members of a design chain collaboratively develop new products. It also assists the analysis of the design chain operation process. a tool with the feature of integration and improvement, it constructs the reference model of life cycle assessment process between the internal enterprises and business partners[9].

The purpose of this study is to provide an ontology-based process-oriented framework to support new product development. The proposed framework can provide the managers of a company with a balanced consideration between the economic benefits and eco-design decision needs in the new product development activity. It can also solve the disadvantages of new product development knowledge distributed to different firm's departments and gain the advantages of sharing knowledge among different processes.

II. Methodology and the Proposed Framework

The LCA is a good tool for understanding the environmental impact of a product. That is, it can be used to analyze the environmental impact of selection of raw material, manufacturing, usage, and disposal of waste in the whole product life cycle. The Ontology is suitable for systematic representation of the information obtained from the LCA and knowledge dispersed in each organizational department so that the knowledge among processes can be shared efficiently.

The ontology is a formal specification of domain knowledge and has been used to define a set of data and their structure for experts to share information in a domain of interest. It is well suited for the representation and utilization of relations among data, and is efficient in knowledge reasoning. Ontology-based methods are a new and promising approach to manage knowledge in engineering, integrate multiple data resources, and facilitate the consideration of the complex relations among concepts and slots in decision making [10].

Natalya and Deborah [11] pointed out that ontology is a common field of information structure between people and systems. The development process includes defining the scope and purpose, building ontology, assessing ontology, and finally establishing documentation. It is a reusable framework for carefully and definitely describing the concept of a domain of interest, and provides a method of analyzing a knowledge domain to integrate existing knowledge database about the information obtained from the LCA.

The most commonly used tool within ontology is called the "protégé". Its user interface is shown in Figure 1, which is an applied tool based on ontology knowledge framework. The Protégé is adequately adopted to transform the ontology-based knowledge into the platform of information technology [12].

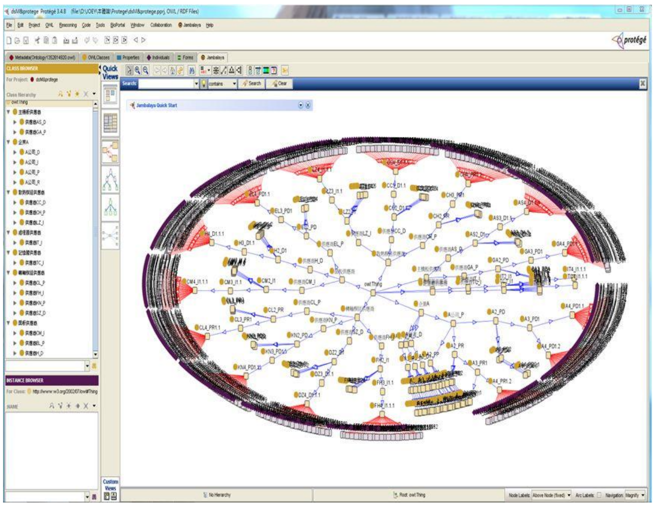

Figure 1: Protégé platform

Ontology is a concept which a set of standard flow method is needed when leading the LCA in. At the Ontology stage of identifying scope and purpose, we must delimit the enterprises introduce into the Eco-design process firstly and apply the range of LCA information, includes the participation of organization departments, process and products; secondly, at the stage of Ontology building approach under the selection, utilizes the DCOR process to give a breakdown from the first model to fourth model of enterprises' practical processes, this practical process needs a system to organize the LCA information, the inputs and outputs relationship in the organization department, process, products that is from raw materials to prototype materials, the data structure matrix, DSM possess the analysis of each process relationship, and classifies DSM to be a multi-domain element systems[13].

This study spreads the DCOR process to DSM analysis that includes product area, organization area and process area, inputs the result analysis into protégé, and expresses each functional state with a Tree flow Chart. It then represents the mutual functional states above, as shown in Figure 2. At the stage of Ontology assessment, it adopts the modified DCOR and issued by its predecessor SCC. SCOR 10.0 is the assessment indicator of performance attribution and includes the green index, which features reliability, responsiveness, flexibility, cost and asset management efficiency to become the environmental definition. When the costs associated with operating the design chain, about the definition of environmental cost is about the life cycle assessment which contains the cost of environmental compliance and cleanup as well as energy costs [14], develops Java Expert Systems Shell (Jess) [15], at the final stage of building files, enterprise organization department queries the process of LCA relative products information based on question demands.

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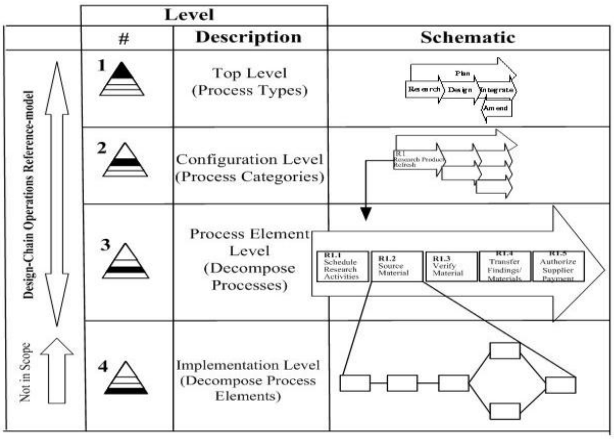

Figure 2: Four levels of DCOR

The representation of the proposed framework, including three stages: (1) concept, and (2) design, and (3) implementation, is shown in Figure 3. The six steps are described as follows:

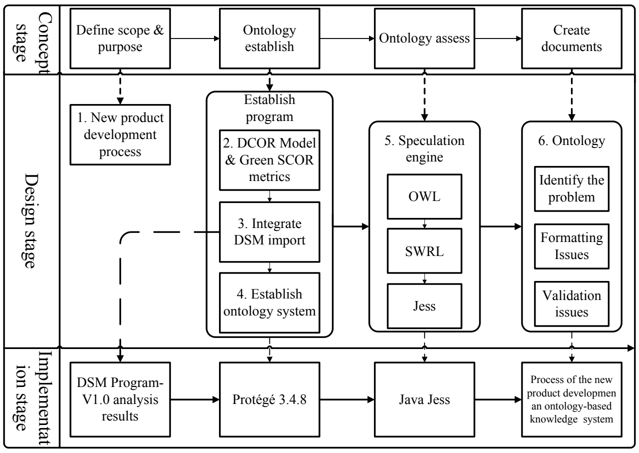

Figure 3: The proposed framework

Step 1: Define the process scope of the new product development using the LCA. It may cover customer's demand, selection of supplier's raw materials, or pilot production of new product.

Step 2: Establish the product development process using the DCOR. The process is deployed in order from D-L1-M (DCOR Level 1 Model) to D-L2-M (DCOR Level 2 Model), to D-L3-M (DCOR Level 3 Model). According to the best practice on D-L3-M, applying EPC flow chart of Architecture of Integrated Information System (ARIS), the D-L4-M (DCOR Level 4 Model) is finally deployed.

Step 3: Apply the DSM to analyze the process information obtained from the D-L4-M of the DCOR. Aim at D-L4-M for enterprises on the new products development process, according to a multi-domain element DSM distributes to organization department, process and the relationship among parts suppliers, utilizing integrated DSM and analyzing the relationship with green SCOR metrics, indices given is to represent the experts' evaluation from internal enterprises, synthesizing this information for system file.

Step 4 Construct the ontology based on the integrated archives obtained from the DSM. All archives of integrated DSM are imported to ontology content, constructing and operating by classes, properties and instances.

Step 5 Form reasoning engine and establish an ontology-based knowledge decision supporting system. After the ontology is constructed, a language called Jess is used to transform the knowledge into the linguistic information in terms of OWL and SWRL forms.

Step 6 Verify Ontology-based knowledge systems. With reference to the above results, we can open up the protégé with the programming of Java Expert Systems Shell (Jess), to verify a user's questions, process in sequence and to evaluate the results of an execution, accessing the final verification. Start using immediately after everything is matched with the user.

According to the six steps mentioned above, an ontology-based knowledge decision supporting system based on the Protégé platform using the Jess language is completed.

III. A Practical Application

This section uses an example from a famous Taiwanese manufacturing company named A Company which produces the big screen names AIO (All-in-one), which verifies the accessible frame in this report. A computer company was established in Taiwan, 1988, to satisfy the market demand on this big screen AIO PC. It hoped to utilize the information of life cycle assessment that already spread in each department at new products development stage. It considered environmental protection from the beginning, it made the decision to have parts suppliers joined with the AIO PC development earlier, in order to have the concept of eco-design on those new products. It was the company who cared about the green products with other rivals.

The most important raw materials of AIO PC include touch panel (EL, H, and CM suppliers are including), main board (AS and GA suppliers are including), hinge module (CL, FH, SZ, and KN suppliers are including), thermal module (CH, CC, and LZ suppliers are including), CPU (IT supplier) and RAM (TC supplier), those chosen parts suppliers above must comply with environmental protection requirements in the new product development (Step 1).

A company would raise the mechanism issue among those parts suppliers in order to apply the big screen of AIO PC at the initial development stage. The relative departments of this new product development pursue the purpose of green AIO PC product in the market, building D-L1-M for A company and the suppliers, is shown in Figure 4, refer to the standard practical flow of DCOR Level 3 and temperate practice in the firm, selecting the parts suppliers based on last level and making the input-output process, D-L4-M (step 2), is shown in Figure 5; refer to DCOR and extending the flow relationships between A company and suppliers, organization and products and then inputting to DSM for analyzing (step 3) and entering to the ontology software Protégé by the results of classes, properties and instances (step 4), knowledge will transfer to semantic information when the framework is finished and entry to Java Expert Systems Shell, Jess to set up the demand of A company (step 5), in the end, to verify the evaluated assessment with ontology is right or wrong (step 6) due the limitations of space, this research only offer one example of A company and Touch Panel Suppliers.

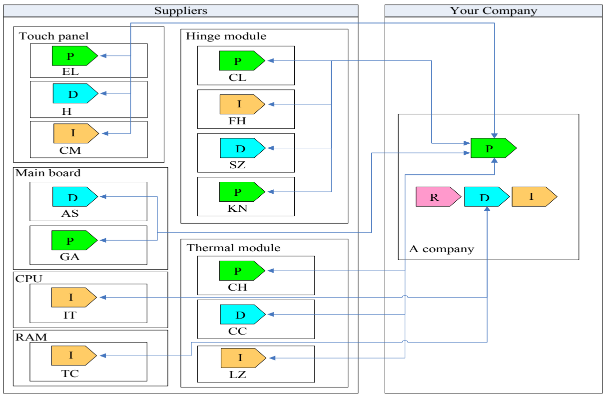

Figure 4: D-L1-M of New Product Refresh process for A Company

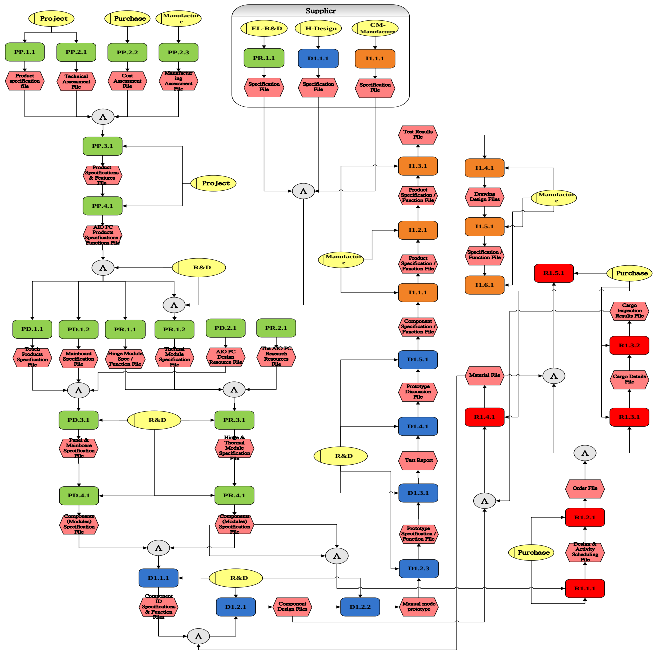

Figure 5: D-L4-M for A Company and Touch Panel Suppliers

Each D-L4-M process and input-output information between A Company and each relative parts supplier, based on process, those departments which are responsible for those parts use the software of DSM_Program-V1.0, construct DSM and dividing up the partition and find out the relationship between A Company and suppliers is shown in Figure 6.

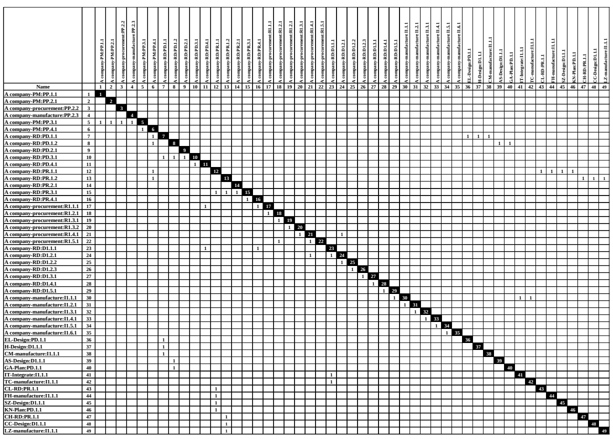

Figure 6: Partitioned DSM

Let A Company integrate information with DSM into the protégé ontology framework, according to the relationships among the departments, process and parts and entering to software with the analysis result, in Figure 1. Lastly, it utilizes the Java Expert Systems Shell, Jess to complete the evaluated work in Figure 7.

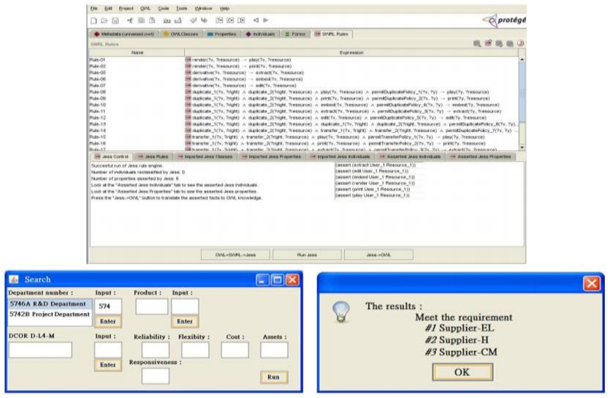

Figure 7: Jess rule engine and results

IV. CONCLUSIONS

This research mainly develops eco-design on the new product development with ontology based on DCOR model, supporting enterprises to face the critical requirement of environmental protection and sharp market competition, choosing the appropriate method for developing new products. It also shortens the timeframe for launching new green products. Along with LCA it is able to meet the needs of green products, utilizing four stages of DCOR to extend the framework. It can also be clear and explicit in expressing the procedure information between the enterprises and design chain partners, DSM can further transfer the particular practical information framework at DOCR's fourth model to the analysis of input-output information, ontology transfer all information to become a set of knowledge architecture. As such, promoting enterprises get the knowledge operation efficiently at the development stage and this knowledge architecture is a very significant operation instrument at the development stage for new products.

Applying a development framework for new products with past experience and acquisition of information is the most important contribution in this research, nevertheless, in this framework it still has in-depth debates in the future to result in an comprehensive solution, for example, the scope of entomology can extend to customers, in the part of Jess-rule engine, knowledge transfer to semantic information, enables one to provide further specific solutions, in order to provide the Ontology in subsequent applications and the LCA enquiry demand in the future, beside the application, it still needs to update the information of life cycle assessment on the new products any time.

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