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Modular Fiber Optic Cable Product Architecture for Application in Product Lifecycle Management

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Abstract: Product Lifecycle Management (PLM) is an important management concept and method in manufacturing industries and product architecture management is the core of a PLM system, which can be applied from the modularizing of product architecture through each stage of the product life cycle. It can utilize product information to achieve the strategic goal of shortening the product development and delivery schedules. This study presents 3 stages, namely, process analysis, product building architecture rules and the application of product architecture to the PLM processes. In the process analysis stage, Value Stream Mapping (VSM) and IDEF0 methods are adopted to verify required processes, process input and output; in the stage of product building architecture rules, a rule-based knowledge management system and a rule-based design method are adopted to modularize product structure and construct the product architecture; in the stage for the application of product architecture to the PLM processes, IDEF1X is adopted to establish attribute associations. Finally, a fiber optic cable product PLM system is constructed based on the above logic and demonstrated. The PLM system operations confirm that the proposed architecture can: (1) construct a feasible product lifecycle management system; (2) shorten the total time of constructing a product's architecture from order acceptance, product design, establish standard setting; and (3) increase the ratio of value-creating time in the process of constructing a product's architecture. The above functions can effectively improve the respond speed and competence of an enterprise upon customization requests.

Key words: Product lifecycle management, modularize product architecture, knowledge management system, fiber optic cable product, customization

INTRODUCTION

Technological industries face competitions of speed, which is a challenge that endures throughout the entire manufacturing life cycle, from product development to delivery, including Time to Market, Time to Volume, Time to Quality and Time to Cost. Therefore, it is critical for an enterprise to utilize existing knowledge and team knowledge to quickly respond to customer requests, speed product delivery and prevent repeated errors from causing unnecessary losses. Stark (2005) stated that the CIM core functions, which Cover Information Technology (IT) solutions and related managerial concepts and can be integrated into current product lifecycle management. However, Product Lifecycle Management (PLM) requires additional functions and models to enable a wider range of applications. Schuh *et al.* (2006) suggested that a healthy product structure is a necessary basis for a working PLM. However, product patterns and operational processes vary in different industries. Although the concept of a product structure model has been proposed in recent research, some issues, namely, how to integrate product structure, product-related information and application process of product lifecycle all deserve further study.

Past research on PLM and its applications shows that system implementation and models are affected by industry types, company sizes and operating processes. Fiber optic cable products are applied in the optical communication industry and its applications and

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worldwide development continually increase due to the high demands of communication bandwidth. As Fiber to the Home (FTTH) becomes more popular, fiber optic cable product technology has also advanced; however, product development has not accelerated according to the speed of market changes and thus, failed to maintain its competitiveness in the optical communications industry. Therefore, the study purposes of this study are as follows: (1) to build a product architecture module including product information (e.g., part numbers, roadmap, BOM, engineering standards and quality records) and apply this product architecture module information to application models throughout all stages of a product's life cycle, from order acceptance, product design, standard setting, production planning, supplier chain management, volume production and quality inspections, to customer complaints and feedback; (2) to build fiber optic cable product PLM system for application cases and validate actual applications of this product architecture in fiber optic cable product lifecycles and empirically summarize the achievements and experiences from the introduction of this model in PLM system implementation.

APPLICATION OF THE RELATED METHODS

Product lifecycle management: A clear understanding of the definition of product lifecycle management is conducive to PLM application and implementation. Stark (2005) argued that PLM manages every step of a product's lifecycle, from concept formulation to scrap disposition. PLM addresses product lifecycle management, product innovation development projects and related services, such as the control of products and services throughout the entire lifecycle and involves many elements of general business activities, such as product organizational structure, work methods, processes, personnel, information structures and information systems. Kovacs *et al*. (2006) to fulfil the increasing demands today the short innovation time and the high quality of production itself is not enough in production of goods, but all phases of a product (from idea to recycling) should be managed by advanced tools and means. Nowadays the competition among companies, joined to the environmental protection rules, is so compelling that they should not only be on the top of technology in the area, but also run their business according to life-long models. The emphasis on the product post-sale life is common for these models. The most popular model is Product Life-cycle Management, for manufacturing companies, or Service Engineering (SE), for service-oriented companies, and, for both, common paradigms are in maintenance, with conformance-to-use certification.

Schuh *et al*. (2008) suggested that there are seven elements in implementing a PLM in a process-oriented architecture, namely, integrated management of concepts, projects and product folders; dynamic request management; product design and integrated process specifications management, end-to-end configuration management, all lifecycle costs management; lifecycle environmental impact analysis and reuse of service and maintenance data in product development stage. Saaksvuori and Immonen (2002) indicated that a PLM system links a wide range of internal processes, extends to all suppliers, subcontractors and outsourcing vendors in a supplier chain, as well as partners and customers.

Knowledge management: Rezgui *et al*. (2010) provided a critical and evolutionary analysis of Knowledge Management (KM) in the AEC (architecture, engineering, construction) industry, which spans a large spectrum of published KM research in regard to management, information systems and IT disciplines. An interpretive (subjectivist) stance is adopted to provide a holistic understanding and interpretation of organizational KM practices, research and models. The paper suggests that value creation (third generation KM) is grounded in appropriate combinations of human networks, social capital, intellectual capital and technological assets and is facilitated by a culture of change. Lee and Park (2008) applied product architecture and extraction rules in directing solutions for customer requests and large customization services.

In the past there has been no structured approach to learning from construction projects once they are completed. Now, however, the construction industry is adapting concepts of tacit and explicit knowledge management to improve the situation. Top managers generally assume that professionals in enterprises already possess tacit knowledge and experience for specific types of projects. Such knowledge is extremely important to organisations because, once a project is completed, professionals tend to forget it and start something new. Therefore, knowledge multifold utilisation is a key factor in productively executing a construction project (Kanapeckiene *et al*., 2010). Hamade *et al*. (2010) propose to use a knowledge acquisition (KA) approach based on Nested Ripple Down Rules (NRDR) to assist in mechanical design focusing on dimensional tolerancing. A knowledge approach to incrementally model expert design processes is implemented. The knowledge is acquired in the context of its use, which substantially supports the KA process. The knowledge is captured which human designers utilize in order to specify dimensional tolerances on shafts and mating holes in order to meet desired classes of fit as set by relevant engineering standards in order to demonstrate the presented approach.

Lu and Feng (2010) proposed a novel concept of Intelligent Topic Map, which extends the conventional topic map in structure and enhances the reasoning functions. With the Intelligent Topic Map as infrastructure, a mechanism of distributed knowledge integration is designed. The structure is divided into three layers: local Intelligent Topic Map layer, similarity measure layer and global Intelligent Topic Map layer. It provides a uniform query interface to a multitude of knowledge sources and lays the foundation for high-quality knowledge services. Moreover, we propose a new similarity measure algorithm based on comprehensive information theory and merging rules for knowledge integration. The experimental results show that our method is feasible and it has the significance of reference and value of further study for the distributed knowledge integration. Chung *et al*. (2010) treated the high-tech industry as the subjects and probes into the correlation among organizational cultures, information technology involvement, degrees of knowledge management activities and performance of new product developments. The subjects of this research were Taiwan's high-tech firms in the Hsinchu Science-Based Industrial Park and Southern Taiwan Science-Based Industrial Park. The respondents were the project members or senior managers involved, currently or previously, in the development of new products. The design of the questionnaire items was based on literature review. The results reveal that the higher the degrees of information technology involvement and organizational cultures, the more significant the influence on the implementation of knowledge management activities and performances of new product developments. The better the implementation of knowledge management activities, the stronger the positive influence on the performance of new product developments. Different organization cultural types do not report any significantly different levels of influence on the implementation of knowledge management activities or performance of new product developments.

IDEF methodology: IDEF is a Federal Information Process Standard publication (FIPS PUBS), established by the National Institute of Standard and Technology, US. The purpose of IDEF0 is to execute and manage request analysis, benefits analysis, definitions of requests, functions analysis, system design, maintenance and a continuously improved baseline. IDEF1X is an integrated definition of Information Modeling, with its own data model language set, which is used to develop a systematic data model. IDEF1X is used to generate a figurative information model, which represents the structured and systemized information contained in an environment or system that supports management data resources, integrates information systems and constructs a computer database. The advantage of using figures to express an information architecture is the ease of upgrading the information into common assets shared within an enterprise. In addition, IDEF1X also bridges communication gaps between information professionals and nonprofessionals, thus, the members of a workgroup can establish a consensus, which further constructs solid basic data (Lin, 2000).

This study adopts the VSM and IDEF0 methods to analyze processes that combine the advantages of both methods. VSM is used to remove unnecessary processes and benefits analysis time, while IDEF0 resolves input and output process issues layer by layer and determines the critical processes and output goals of constructing a product's architecture module.

CONSTRUCTION AND APPLICATION OF FIBER OPTIC CABLE PRODUCT ARCHITECTURE

This study aims to build a core product information database for fiber optic cable architecture modules, which is applied to fiber optic cable lifecycles in combination with business processes, including all stages, from order acceptance, product design, standard settings, production planning, supplier chain management, volume production and quality inspection, to customer complaints and feedback. The following section introduces the processes of constructing a fiber optic cable product architecture and includes all stages of a product's lifecycle aimed at acquiring product information in a timely manner, while recording all application results.

Composition of fiber optic cable product: The basic architecture of a fiber optic cable product is similar to a common computer network line and is composed of Fiber Cable with Fiber Optical Connectors at both ends. Two popular and common patterns of indoor fiber optic cable products are Simplex and Duplex. Simplex consists of one fiber cable, with fiber optical connectors at both ends; while the Duplex pattern consists of two fiber cables, with four fiber optical connectors at the ends. Regarding the product, a Fiber cable outer diameter is 125 μm and fiber mode is classified according to the wavelength of the transmitted fiber optic signal, including Single Mode and Multi Mode. Fiber is made of glass, which is very fragile and vulnerable to ambient humidity, hence, if used as a fiber optic cable, a coating of an OD 900 μm plastic Buffer is applied over the fiber, meanwhile, depending upon user request, the outer diameter of most interior fiber cables is 2 or 3 mm. In addition to the requested fiber cable specifications, the greatest number of changes according to customer specifications is in regard to length. Apart from fiber, the main constituents of a fiber optic cable product are the connectors at both ends. The connector is comprised of several parts, such as outer casing, inner casing, rear casing and a ceramic core, though each customer may vary in the details of the parts in order to differentiate between products.

IDEF0 analysis: In IDEF0 analysis, seen in Fig. 1 A-0, the input processes for modularizing product architecture data includes, customer orders, technical industrial standards and international specifications; control conditions set within the customer order request, which includes confirmation of delivery time, product specifications and capacity; available resources include a business team, a design team, a quality control team and a production control team; upon confirmation of the customer request, output results, such as product architecture information and production planning, are obtained. However, requests by customers for order confirmation can be further divided into four steps, namely, confirming product specifications, designing product structure, setting product standards and production plan and re-analysis of the customer order request confirmation process, as is shown in Fig. 1 A-0.

In the product architecture module, the core hierarchy is the product structure, as seen in Fig. 1 A0, Step A-2, where product structure design is the critical process of defining a product's structure, thus, A-2 is further analyzed, as shown in Fig. 1 A2, which includes confirming the customer's technical specifications, plotting a structure design roadmap, compiling a list of part numbers, BOM and setting technical standards. Therefore, the IDEF analysis of confirmation of a product's architecture data must acquire substantial output, such as a product roadmap, product parts list and product technical standards. Based on the above, the core process of modularizing a product's architecture is to conduct a structural design on the product, which is in line with the customer's technical specifications and industrial technical standards and then, to output product information, such as a roadmap, part numbers and parts list (BOM). IDEF0 analysis of a product's architectural data construction process is as shown in Fig. 1.

Setting fiber optic cable product architecture rules: The PLM-oriented collaborative knowledge management

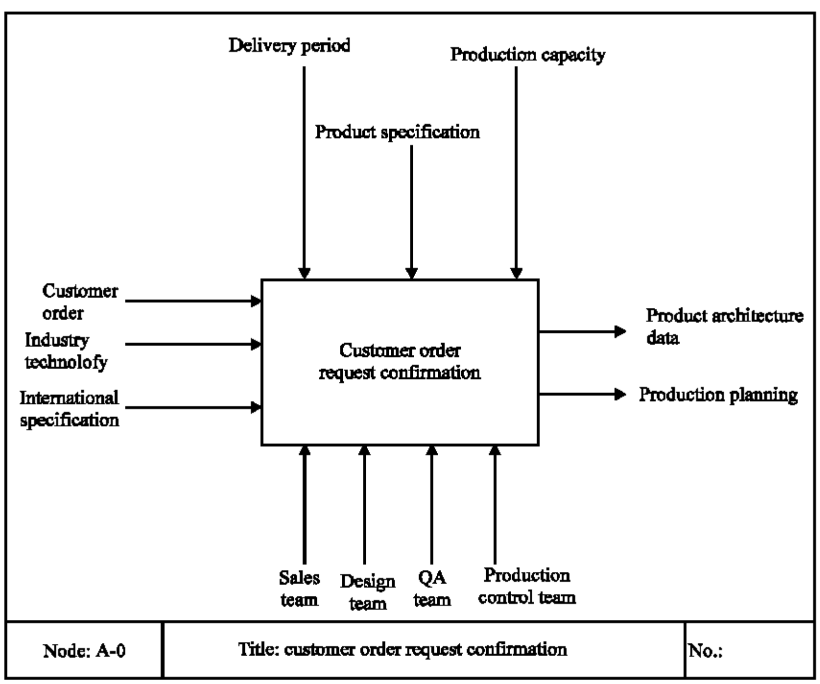

Fig. 1A-0: IDEF0 analysis of product architecture data construction process (continuous)

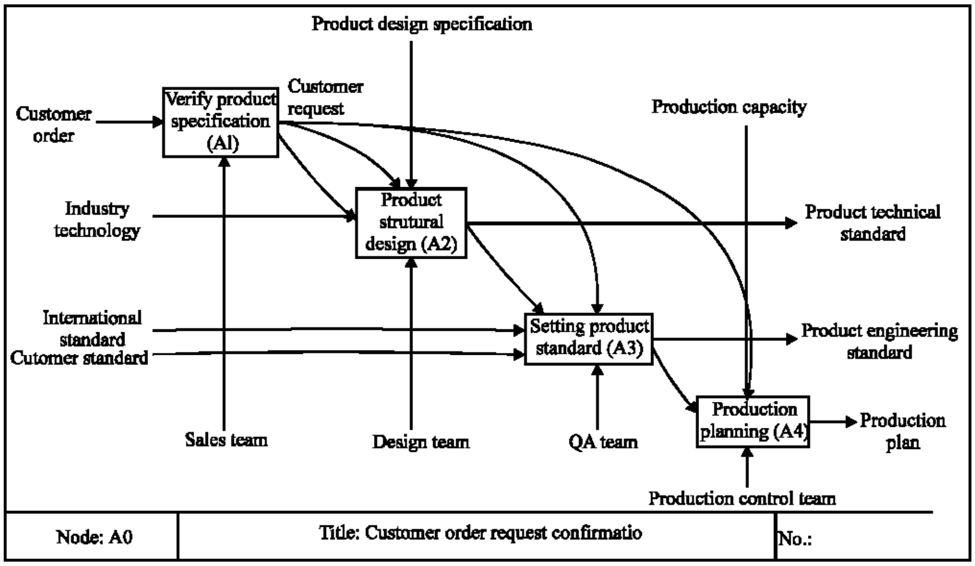

Fig. 1A0: IDEF0 analysis of product architecture data construction process (continuous)

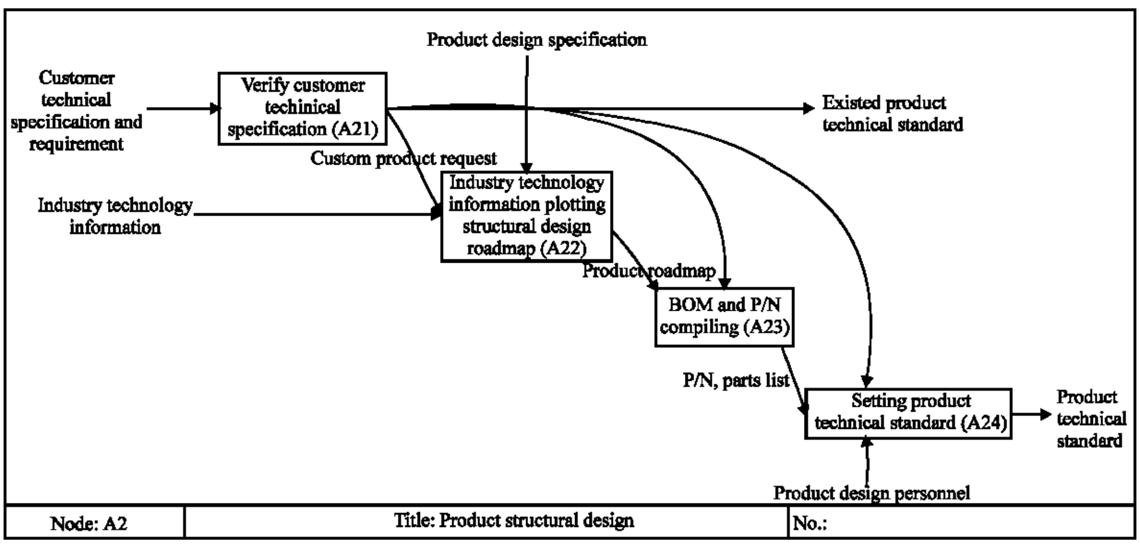

Fig. 1A2: IDEF0 analysis of product architecture data construction process

architecture also proposes to standardize processes, systematically control knowledge, which it synchronously shares with appropriate departments or through a personnel knowledge base in order to store the knowledge required for specific knowledge representations. The construction of a product's structural information is integrated with knowledge management tools" and is the core project of the entire PLM system. Therefore, this paper first establishes product structure rules and modularizes the construct in order to structure product information. Then the product structure module is combined with product structure-related information, such as part numbers, a roadmap, a BOM form, engineering standards and quality records in order to form a product architecture module.

Rule Based knowledge systems are widely applied in knowledge representation. The main application of a rule-based knowledge system constructs a knowledge base that stores knowledge of specific knowledge representation; all conclusions are generalized according to the content stored in the knowledge base. In the assembly of a fiber optic cable product, a rule-based knowledge system is used to construct the knowledge based system architecture of the fiber optic cable product; and the structural rules of the example of Customer X are as shown in Fig. 2.

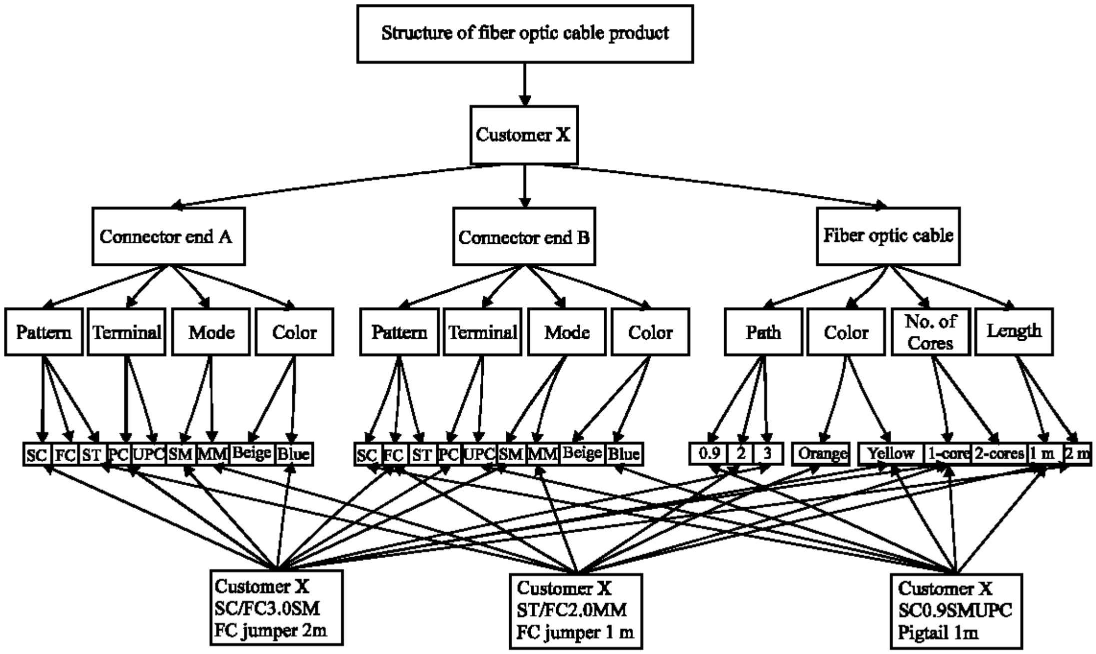

Fig. 2: Structuring rules of a fiber optic cable product

Figures derived from rule-based design: Another application of rule-based knowledge is in Rule Based Designs, supposing a group of well-defined rules, computing procedures are used to determine the best phrase formations, which are selected from all phrase combination methods. Similar figures are derived according to a few rules. Once rules are defined, patterns can be classified and figures that are different in pattern, yet similar in style, are generated through morphological grammar by a computer program.

This study aims to connect a product's structure with its roadmap; moreover, the product structure may automatically generate the roadmap. First, fiber optical connector figurative patterns and rules are defined according to the theory of rule-based design, as shown in Fig. 3. When setting this rule, product structural rules, which are related to figures and not related to the roadmap, are distinguished. Then, the related rule for making the diagram and the expected figure are defined. When the product structure required by the client is defined, the corresponding connector and fiber cable diagrams can be generated through the relational definitions of the rule-based design and then, are further combined into a fiber optic cable product diagram, as shown in Fig. 4.

Construct attribute association: IDEF1X consists of three basic elements, namely, entity, attributes and relations, which links the data content used in each process, in order to verify the data generated for use in each process of the product lifecycle. Relational analysis of the data of each process in a product lifecycle helps clarify the product's data and processes and verifies product the information required for responsible organization. Hence, requests for data are generated and utilized from clearly classify data of a product's lifecycle, with set datasheet attributes and datasheet correlation.

By building a datasheet, the data required for each process is easily identified for classifying data, which is stored in multiple datasheets. Meanwhile, the construction of attribute associations reduces repeated data input, data errors and further improves efficiency. Data queries are performed through data correlation; therefore, datasheet planning and construction is very important preliminary work prior to database correlation. Product architecture information, as constructed in this paper, can be applied to every stage of a product's lifecycle, hence, data generating and application processes are classified and planned in 5 parts, namely, (1) customer information; (2) product structure information; (3) product information; (4) manufacturing information and (5) quality information. Such classification helps establish the attribute associations of each datasheet, through IDEF1X, as shown in Fig. 5.

Process and delivery requirements of fiber optical connector product: The manufacturing processes of fiber optical connector products include procedures for

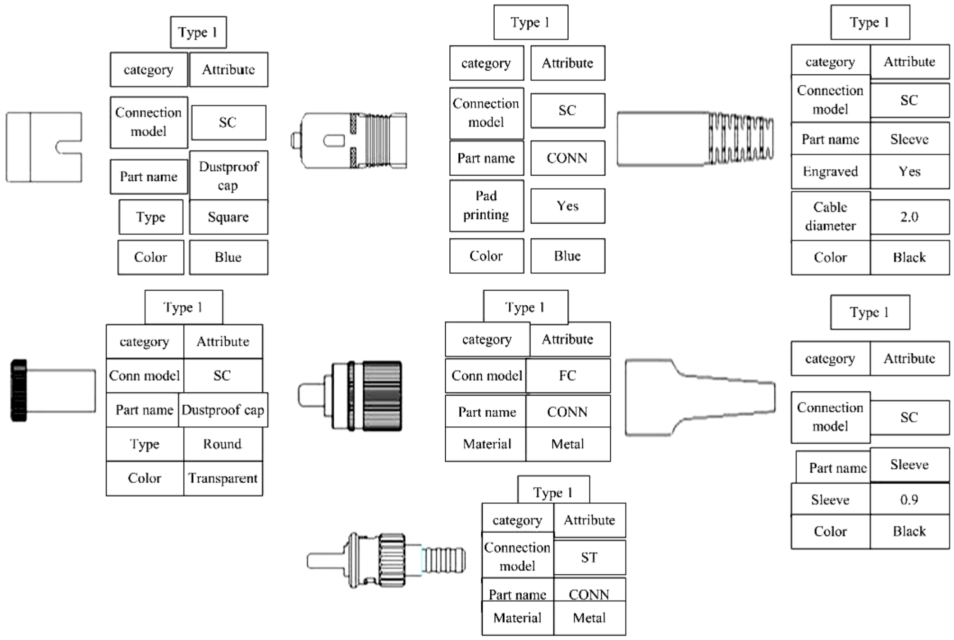

Fig. 3: Design rule of fiber optical connector diagram

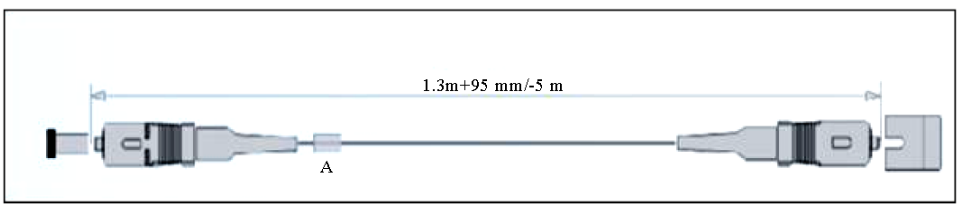

Fig. 4: Fiber cable product diagram derived from rule-based design

material preparation, product assembly and packaging. The delivery period is generally seven to ten days; however, rush orders may require delivery within three days. Material preparation means to prepare all materials and, apart from the preparation of various customized materials for the order, to sub-package materials according to the order quantity. The length of the fiber optic cable must be cut in accordance with the requirements of customers, which is then sent to the assembly production line. The assembly of the fiber optical connector has three main procedures, including the assembly of the connector, polishing of the end face and product inspection. The optimum process is set up on the basis of customers' demands. The last procedure is product packaging. Every customer has different packaging requirements; hence, the package must be designed in conformity with customers' needs and according to the requirements of packaging specifications.

Customers may order existing products, products that have never been produced, popular products, or customized products according to needs; however, they may not know whether the product should be redesigned, or whether the designated dimensions are specific. Redesigned or specific dimensions do not alter the delivery mode desired by customers, thus, the work is not required to be finished within the delivery period. Manufacturers are unsure whether products ordered by customers are existing products, or products requiring redesign or adjustment upon receiving the order. For new products, the redesign, preparation of Bill of Materials (BOM), drawing of blueprints, determination of material numbers, formulation of Standard Operation Procedure (SOP) and Standard Inspection Procedure (SIP) must all be completed. This new product information is then sent to suppliers for materials purchase, which are then delivered to the manufacturer. All operations and

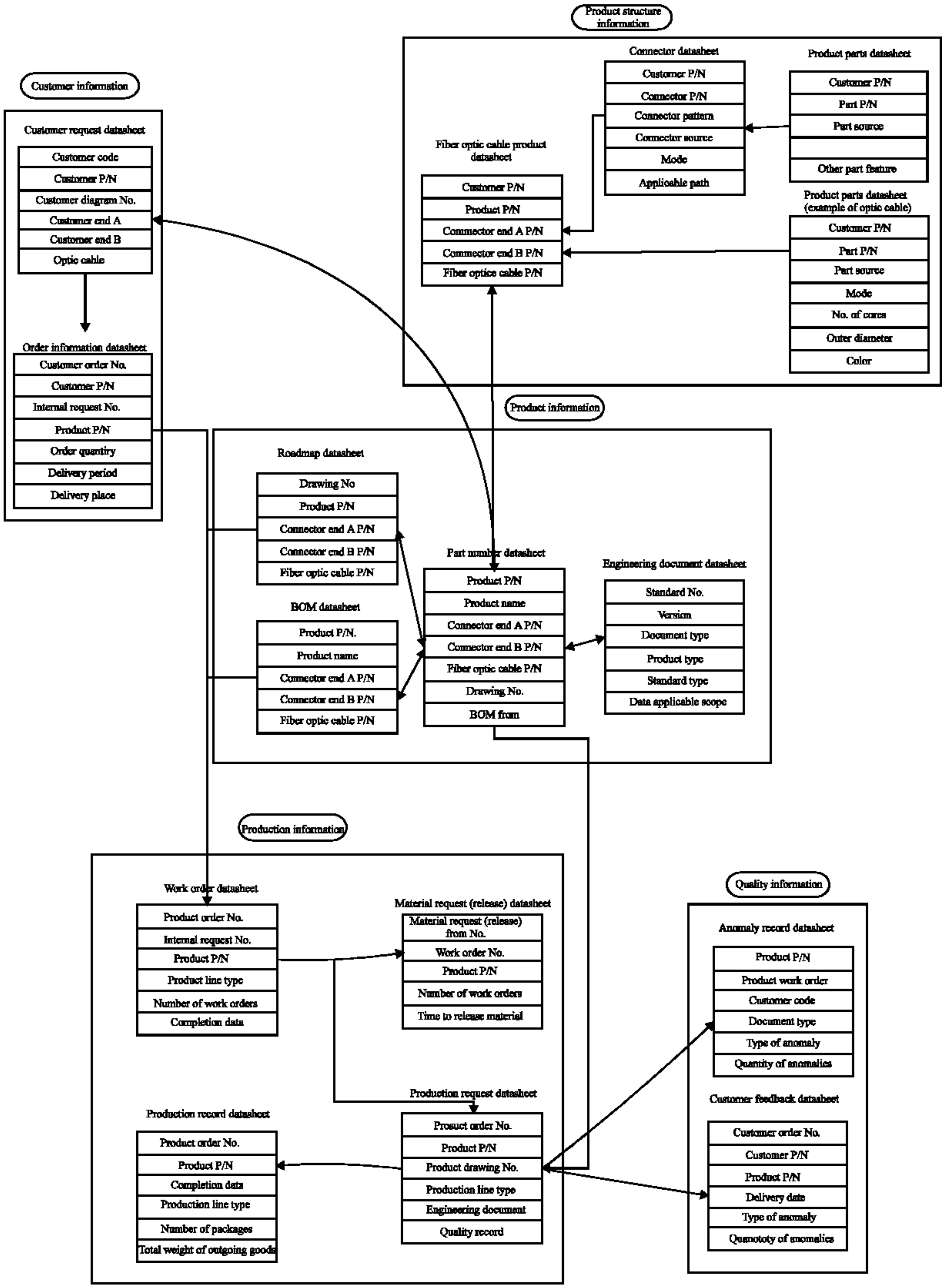

Fig. 5: Attribute association diagram of a product architecture module applied in the management of product's lifecycle

production processes must be completed before the delivery date required by customers; therefore, a very important managerial goal is to arrange all preparations within the shortest time before the production process.

Business mode and business process of fiber optical connector products: Fiber optical connector products are highly customized, thus, the production can only begin upon receipt of orders from customers; however, it differs from the Make to Order mode because the delivery period required by customers is usually short, meaning that product operations, such as purchasing and materials preparation, cannot wait for the completion of product development. In addition, it differs slightly from the order-adjustment production mode, as the degree of customization is high and sub-modules or semi-finished products are not stocked in order to avoid overstocking. As a result, this study conducts an analysis of the business mode for fiber optical connector products. First, manufacturers must analyze the customers' needs and classify product dimensions and then, the design team modularizes according to these needs. Regarding materials preparation, needs forecasting of materials are created for purchase and storage and when customers place an order, the design team accordingly selects or adjusts product modules and the products are assembled and delivered.

After the business mode is determined, it is integrated with the organizational functions of the manufacturers of the fiber optical connector in order to analyze the business processes. First, the sales department receives the orders and confirms the customers' needs and since order acceptance is conducted daily, it must include demands analysis. Then, the design unit verifies the dimensions and designs the products. Since every customized order includes verified dimensions, if the design dimension is modularized, then repetitive routine design work can be reduced. The third procedure is for the quality assurance unit to formulate SOP and SIP. Different customers or products have different SOP and SIP requirements, thus, after the product design is completed by the design department, the quality assurance department will formulate or confirm corresponding operational and inspection procedures. Next is the stage of production arrangements, which comprises materials requisition, according to the material list and production schedule of the production management unit; issuance of materials from the warehouse is according to the materials requisition list and stock levels; followed by materials preparation, product assembly and packaging by the production unit. Finally, outgoing quality inspections are performed by the quality control unit and then the finished product is delivered by the supply chain. According to the business processes of the fiber optical connector, the first three procedures determine the product architecture, which are carried out each time a customer places an order and any repetitive operations are reduced by modular product architecture, while established product architectures and relevant product information are applied to all parts of the business process.

SYSTEM IMPLEMENTATION AND RESULTS VALIDATION

With the datasheet and attribute association analysis, as established above, a relational database is constructed, which considers, (1) different formats of storage, conversion and navigation between customer and individual-use roadmaps; (2) linking and storage management among the product structure, BOM form and product-related documents; (3) additions, revisions and deletion management of product information and documents; (4) product project management and (5) information system functions, such as e-review and user privilege management; many commercial PLM systems have complete functional modules, thus, this paper uses the PTC Windchill system to build the required system window and functions. However, commercial PLM systems fail to automatically analyze the structure of products, or clarify the product information required by the enterprise, therefore, a product architecture module is proposed in this paper, which is constructed and analyzed by the system user.

Applications in the order acceptance stage: In the order acceptance stage, the sales department is responsible for collecting customer information, which includes customer product requests and order information, the window and system status of the order acceptance stage in this system are introduced as follows. Through internal processes of a company, the sales staff enters input contents into a customer request datasheet, which is the basis of assigning a product to a design department. As the product customization level is high, the sales department input consists of only the basic data of the product, then, the design department gathers additional input and compares the details of the product's specifications, in order to verify the customer request for a new product.

Applications in the product design stage: Fiber cable parts contain various custom structural attributes, while other parts, such as the fiber optical connectors at both ends of the fiber optic cable product share similar custom structural attributes. Therefore, based on a rule-based knowledge system and structural rules for models of custom parts, the custom attributes of each part are input into the database and then, compared within the system in order to generate the new part or new part number.

The second datasheet of a product's structural information is a datasheet for the connector level. A connector product is comprised of connector parts, thus, connector product information includes connector part information, which is input at the connector level in order to be directly associated via the parts-level database. In addition, as known from the product structure information datasheet, connector product information content at the connector level includes connector part numbers, connector patterns, connector modes and applicable paths and if linked to custom parts information, a basic connector-level database is formed.

The basic architecture of a fiber optic cable product consists of a fiber cable, with connectors at both ends. The basic database of a fiber cable product is comprised of the important attributes of connectors A and B for the ends, fiber cable information and the part numbers for the connectors and the fiber cable. After a product's structural information is constructed, the product design supervisor will compare and verify the customer's custom requests; thereafter, the system will conduct verifications of custom requests according to current part numbers input into the structural information and automatically generates the part numbers for existing or new products. Upon establishing and confirming the basic data at the product level, this system generates part numbers for product structures, a roadmap and a BOM form, which completes the product architecture information required by the product design stage. To verify if the system generated information is correct, the part number query function is used to check the correctness of the product's architectural information in the design stage. To further verify roadmap correctness, click "check roadmap" in order to generate a roadmap window, as shown in Fig. 6. As requested custom roadmaps may have poorly defined expression, the roadmap feature is designed with a remarks column that outlines important product assembly requirements, operations and inspection standards in production, or other important custom information, which aids the operator in reading the roadmap.

To further verify the correctness of the BOM form, click "check BOM form" in order to generate a BOM Form window, as shown in Figure 7. The product's roadmap and BOM information are further associated with the production order datasheet, which includes output material request (release) and production request data; therefore, BOM correctness is vital to this system.

Applications for supplier chain management and production planning stage: When a manufacturer of fiber optic cable products has two plants in different locations, which produce the same products, the product architectural information of these two plants must be identical, namely, using the same part numbers, BOM and roadmap. However, both plants have their respective warehouses and production lines, hence, use separate and independent production management systems. This

Blueprint

REV	ECN. NO.	APPO.
A	SZ-B-0801-0027	Y. 0. U08. 01. 2

Assembly			Inspection standard			Package
A. Length tolerance:	Length	Tolerance	1. End surface standard			
	<1M 5M>L>=1M>=5M	+5/-0CM +15/-0CM +30/-0CM	2. 3D standard			
			LC	Curvature	7-25mm	
B. Winding diameter			Axis deviation		<50μm	1. Basis of package: WB-P004
Inner diameter of winding under 10M			Fiber bumps (wavelength)		-125~+50nm	
			3. Wear standard: (wavelength 310nm&1550nm)			
C. Color			LC	IL<0. 2dB	RL>55dB	Scope of drawing
Color of the connector Model			4. Appearance standard			
Housing (blue)	Sleeve (white)	Dust cap (white)	5. Exposure requirement (see UPF0021)			

Fig. 6: Automatic system- generated roadmap window

Product BOM					
Order No.: LHSW090401001					
Product name: SC/PC-LC/PC/PC-MM-dumplex-2.0-0.32			Prosuct material No.: 41-2s12-00c 0004		
Level	Material No.	Prosuct name	Unit	Unit usage	Diagram No.
1	41-2SL2-00C-0004	SC/PC-LC/PC-MM-dumplex-2.0-0.32	PCS	1	
2	40-1711-0086		M	0.33499998	
2	41-3S121-0015	SC/PC-MM-2.0	PCS	1	
3	40-1180-0001	SC/PC Spring SUS304-WPB d0.5*ϕ3.0*L5.6	PCS	1	
3	40-1150-0001	SC MM 90-degree Black3.0 boot	PCS	1	
3	40-1110-0002	SC SMS blue housing (PBT (GF30%) Blue)	PCS	1	
3	40-1140-0004	SC/FC PC one-piece Flange (SU$303)	PCS	2	
3	40-1110-0004	SC MM BEIGE HOUSINGPBT (GF30%) cream color	PCS	1	
3	40-1160-0004	FC/SC/ST clear capldpe transparent inner hole ϕ 2.49 mm	PCS	1	
3	40-1120-0004	Inner casing SC material: PBT (GF30%)	PCS	1	
3	40-1130-0004	SC 0.9 STOPPER/ϕ 6.0*16.4	PCS	1	
3	40-1100-0006	Split ring 2.0 FC/SC A6061-T6 Inner diameter ϕ 3.4*L3.0	PCS	1	
3	40-1150-0014	SC 3.0 RED Boot	PCS	1	
3	40-1190-0054	SC/FC 2.0 CRIMP EYELET (New standard)	PCS	1	
3		FERRULE	PCS	2	
2	4L3L121.0014	LC/PC-MM-2.0	PCS	1	

Fig. 7: Automatic system-generated BOM from window

study transfers BOM information from the fiber optic cable product PLM system to the ERP and production management system of the enterprise, which is integrated with the corporate information system and provides product architectural module information for application in the supplier chain management and production planning stages. This study show the window that transfers the PLM system data to the production management system and as product architectural information is used in the ERP system, as well as the production management system, it will be generated and transferred by the PLM system in order to share product information and ensure the correctness and consistency of corporate product information.

The PLM system of a case company manages product architectural information and generates a BOM form; while the production management and ERP systems govern supplier chain information, material quantity and cost information; hence, a product's BOM form is derived from its PLM system and is applied to the various related information systems within the enterprise that require a product's BOM form. Material quantity information is based on the quantity input into the ERP system, thus, all warehouse information, such as raw material quantity, are maintained by the ERP system and the various related systems requiring raw material quantity information can extract it from the ERP system. This study show the information system integration window to transfer a BOM form from a fiber optic cable product's PLM system, which data is acquired from stock information of the ERP system, entered according to part numbers, thus implementing a materials control plan in a production management system.

Results: validation of system operations: To facilitate the data collection of operational process times of operating a fiber optic cable product PLM system, this study designs an operational process time log, which includes the person responsible and the records format; then this study conducted 100 runs of the actual processes for a fiber optic cable product PLM system and process time is recorded for statistics. As analyzed from the time log data, (1) the average process run time is 265.5 min, which is a little longer than the expected system target of 230 min, for an achievement rate versus target time of (3180-265.5)/(3180-230)x100%=98.8%; (2) compared with the process time prior to running this system of 3180 min, the process time upon the introduction of this system is a mere 8.3% of the previous time, which is 91.7% less; (3) the process time distribution graph of the modularized product architecture is shown in Fig, 8. Regarding time, the number of runs with a process time above 500 min is 7%, while all runs above 400 min account for 20%. In order to continuously improve this system, the root causes of

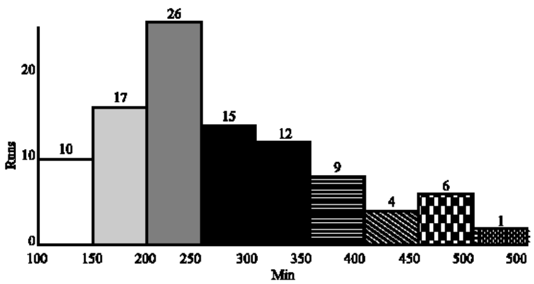

Fig. 8: Time distribution graph of a product's architectural modularized process

the longer process time runs require study and revamping in order to shorten the entire operational process time. Regarding the data log, this study found that (1) the average run time of a product's architectural modularized process is 265.5 min; (2) the longest run time of a product's architectural modularized process is 516 min, while the shortest time is 100 min.

DISCUSSION

In this study, product architectural rules and an attribute associations method were established through process analysis. A fiber optic cable product architecture was modularized and a PLM system was successfully built, where product architectural information was applied to a product's lifecycle. The research contributions are as follows: (1) total time of building the product architecture and the ratio of valuable time saved by the process is greatly improved, which effectively improves the speed of custom products from order acceptance to delivery; (2) using a product architecture database, rather than human memory to manage custom product information, greatly improved product information correctness and suggests great potential to improve personalized services of custom products and product quality; (3) part numbers are automatically generated according to product structure information, rather than manual methods, which reduces errors regarding part numbers. Linking product part numbers to product information has the potential to greatly improve the correct use of product data; (4) the established system allows each process of a product lifecycle to generate or acquire product information, as required and facilitates the reutilization of enterprise knowledge, with great potential to improve the development speed of similar new products, the training of staff, quality improvement and customer service efficiency and (5) is the construction of a rule-based product structure, which standardizes a product's composition of variations model. Regarding sales departments, customer requests can be more clearly defined; regarding R and D departments, product patterns and part detail specifications are more clearly defined for easy recognition; and regarding production departments, the differences between the different part numbers are more clearly defined and understood. Other studies apply PLM to solve the practical problems. For example, Stark (2005) argued that PLM manages every step of a product's lifecycle, from concept formulation to scrap disposition. Saaksvuori and Immonen (2002) indicated that a PLM system links a wide range of internal processes, extends to all suppliers, subcontractors and outsourcing vendors in a supplier chain, as well as partners and customers. Knowledge management is also employed to solve practical problems. For example, Rezgui *et al*. (2010) provided a critical and evolutionary analysis of Knowledge Management (KM) in the AEC (architecture, engineering, construction) industry, which spans a large spectrum of published KM research in regard to management, information systems and IT disciplines. Lee and Park (2008) applied product architecture and extraction rules in directing solutions for customer requests and large customization services. Hamade *et al*. (2010) propose to use a Knowledge Acquisition (KA) approach based on Nested Ripple Down Rules (NRDR) to assist in mechanical design focusing on dimensional tolerancing..

CONCLUSIONS

Different from other studies (Kovacs *et al*., 2006; Schuh *et al*., 2008), Kovacs *et al*. (2006) fulfilled the increasing demands, while the short Innovation time and the high quality of production itself is not enough in production of goods, but all phases of a product (from idea to recycling) should be managed by advanced tools and means. Schuh *et al*. (2008) suggested that there are seven elements in implementing a PLM in a process-oriented architecture, namely, integrated management of concepts, projects and product folders. All the above benefits of this study enable greater efficiency in communications between sales departments and customers and among departments within an enterprise, in addition to gaining latent benefits in operational quality.

In future studies, various uncertain conditions, such as uncertainties regarding customer requests or manufacturing, can be integrated throughout the entire system of information, rendering system information more realistic.

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