QUOTATION PROCESS MANAGEMENT OF ONE-OF-A-KIND PRODUCTION USING PSLX INFORMATION MODEL

Yasuyuki Nishioka
Engineering and Design Department, Hosei University, 2-17-1 Fujimi Chiyoda-ku, Tokyo, Japan

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Abstract: One advantage of SMEs is flexibility for supporting one-of-a-kind production. In order to do this, quotation process need to be managed appropriately by using ICT. This paper deals with production management for quotation and collaboration processes of SMEs, which have huge variation and difficulty of information integration. This paper shows two industrial case studies, and a typical model of quotation process. Then PSLX information model, which is a result of standardization activities, is applied for supporting the management. Finally capability of human-involved ICT is discussed as concluding remarks.

1 INTRODUCTION

Manufacturing industries nowadays have to deal with the global emerging market by means of global supply network spreading especially to the Asia Pacific regions. Whereas mass production reduces the production cost per unit in the new developing countries, one-of-a-kind production is still necessary in order to catch up the uncertain and unpredictable market in the developing countries.

Production system for small lot size and large variety is well researched and developed since 1980s as the conventional FA (Factory/Flexible Automation) and CIM (Computer Integrated Manufacturing) technologies (McKay, 2004; Proud, 2007). Nevertheless, those processes are based on the predefined variation. The new situation we are facing today is that the manufactures cannot make an appropriate plan of resources and capacities before the order is received. This is caused by huge uncertainty and luck of forecast capability.

Unexpected demands such as parts and equipment for research-and-engineering, emerging goods in early stage of product life cycle, supply parts of discontinued products, and unusual equipment for long life facilities are increasing more and more in the current industries. Manufacturers who take care of these diverse problems are not large companies, but small manufacturing enterprises (SMEs) who have their own network of supporting industries.

It needs to be concerned that, flexibility and quick response, which is the advantages of SME, is based on the geographically close relationships. The face-to-face negotiation of engineering specification and quotation will be impossible in near future because of the shift to the global production environment. Information and communication technologies (ICT) have to support such inter-enterprise networking and negotiation processes.

To survive in this situation, SMEs should be aware of ICT's potential capability and use it in their own ways. In other words, there is no standard package for each SME, and no single method to be applied. One-of-a-kind production or Engineer-To-Order management is investigated in literatures (Xie, 2005; Angelo, 2010). In this problem, huge variation of cases and difficulty of information integration refuse easy implementation of ICT. Some theoretical models can be applied for particular domain (Chen, 2003; Bidanda, 1998). However, models required by actual ICT systems have enterprise-wide variation.

The practical approach we propose in this paper is as follows. Instead of applying software packages, SMEs should try to make their quoting system by themselves using common data models and Ontology. Then the proposed activity model of quotation can guide their data processing implementation.

This paper deals with production management for quotation and collaboration processes of SMEs.

Nishioka Y..
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After clarifying the target management systems in Section 2, Section 3 shows preliminary studies of industrial cases, and a proposed model of the quotation process is described in Section 4. Using the model defined in Section 4, Section 5 illustrates result of the industrial case studies with typical numerical data. In order to manage the process of quotation, the paper proposes usage of PSLX information model. The section 6 briefly introduces the standard model, and then explains how to apply the PSLX onto the quotation. Finally in Section 7, the concluding remarks are described for future discussions.

2 TARGET MANAGEMENT PROCESSES

Manufacturing operations management can be modelled with the viewpoint of customer order fulfilment strategies. With respect to occasion of start production, make-to-order (MTO) and make-to-stock (MTS) strategies are defined. Considering that whole manufacturing processes begin with design and engineering, procurement, production, and shipping and delivery, make-to-order (MTO) strategies are divided into finish-to-order (FTO), build-to-order (BTO) and engineering to order (ETO). One-of-a-kind production can be categorized in ETO strategies.

The scope of this paper is mainly on management processes on ETO strategy. But it is not limited to, because when a particular one-of-a-kind production order will be repeated several times, then the situation changes to BTO. It is assumed that the target management process has a quotation process before receiving a firm order from the customer. During such quotation process, a customer and the manufacturer have to exchange engineering specification necessary for estimation of cost and delivery date.

Information exchanged in this process contains engineering drafts, 2D or 3D CAD data, bills of materials/resources (BOM/BOR), instruction sheet of fabrication, quality assurance test specification and so on. Initial offers are provided by customers, but sometimes, the first offer may be revised by the manufacturer to optimize the specifications and increase effectiveness. The manufacture, at this time, uses domain specific knowledge and huge technical experiences.

Some manufacturers receiving a quotation request cannot make a final estimation without initiating another quotation process to their second tire suppliers. Usually those second tire suppliers are also SMEs, and take an important role of partial manufacturing processes or providing key supply parts. They have to deal with information chain in quotation process among the SMEs network.

3 PRELIMINARY CASE STUDIES

Preliminary research was done with industrial case studies of two SMEs in Japan. Yuki Precision Co. Ltd., Kanagawa prefecture, is a precise manufacturing company of approximately 20 employees. Yuki provides precise parts in small lot-size for aero and space industries as well as medical and welfare equipment industries. In terms of quotation, the company receives a quotation request with engineering data and quality insurance information. Most of those requests need to have a face-to-face meeting with engineers in the first place.

After clarifying the specification, Yuki start quotation process by deciding material treatments, selection of fabrication process and equipment, design of tools and operations. Then, Yuki tries to plan whole manufacturing processes including outsourcing. Cost and lead time estimation is done after those resource allocation and optimization. In order to reduce the effort for this quotation process, Yuki tries to acquire the knowledge of quotation by storing the fact of those decisions. Most of manufacturing steps are standardized and defied in database schema.

The second company, Konno Corporation Ltd. of approximately 30 employees in Tokyo, is providing products and equipment parts made of stainless steel panels. Main fields of Konno's customers are laboratories and research and development division of makers or institute, especially chemical, foods, and life sciences. In this case, quotation processes start with rough sketch written by hand. Konno's customers send e-mail of quotation request with pdf-file attachments.

The information that Konno receives from customers has functional requirements of the final product. Since the information received doesn't have detailed specifications for manufacturing, additional engineering information must be produced by Konno, such as material component, size and mechanism of parts, estimated strength, surface preparation, and so on. All of these engineering processes are included in the quotation process and need to be done in average of 5 to 10 days.

4 COMMON QUOTATION PROCESS OF OKP

The outcomes of the preliminary research can be summarized as a common quotation process of one-of-a-kind production. Regarding PSLX technical specification (Nishioka, 2008) and definition of Advanced planning and scheduling (APS) (IEC 2007), we define three major steps of the quotation process.

Step 1: Master Production Engineering

After the first inquiry from customer, retrieving the past knowledge and investigating the relevant engineering information are made in as a first step. Then, master production information including bills of materials (BOM) and bills of resources/routings (BOR) are generated. In contrast to the typical production management in which BOM and BOR are master data that is not revised often, this step needs to define such engineering information with respect to the structure of the product and the process of appropriate production.

Step 2: Advanced Planning and Scheduling

The second step is to decide resource allocation and materials requirement for the desired production. In this step, net requirement of materials need to be calculated in the planning time horizon. At the same time, the resource capacity constraints need to be considered. The planner does not decide a single plan, but couple of alternatives so as to achieve the final result can be more optimal. In other words, the allocation is allowed to have alternatives, such as in house production versus outsourcing.

Step 3: Cost and Lead Time Estimation

Finally but sometimes repeatedly, total cost and lead time are calculated depending on two aspects. First, the production process and resource allocations from a process view. Then, from a object view or material view, the purchasing materials and equipment tools are took into account. When the plan need to have outsourcing or special purchasing that need a second tire quotation, the final result can be made after the planner receives the answer from their partners. If the calculation result is not satisfactory, then move to the first or second step and repeat the process.

The model of quotation process above can be described with respect to our two research perspectives: one is the variety of decision parameters spreading to design and manufacturing. Product definition information and manufacturing process information are necessary to be managed in simultaneous way. The second feature is that decentralized and networking decision making need to be concerned. Both those two features cause difficult problems in terms of technical knowledge management. Any ICT method cannot be simply applied to the problem without standardization efforts and human-involved approaches.

5 APPLICATION OF INDUSTRIAL CASE

This section shows a practical industrial case of quotation process and verifies that the standard model can be suitable. The application case described here is also used for discussions that PSLX standard models introduced the next section is applicable.

The data in Table 1 is arranged a little bit because of confidentiality but the variation is within the level that does not affect any essential change of quotation process. The following numerical data listed in Table 1 is calculated and used for making the final quotation. As a result, this case estimates that cost estimation is 172,600 JPY. The table shows several components of the final cost amount for the particular order received by Konno’s case study.

Using the final data of this quotation listed in Table 1, the decision making procedure of the quotation process is traced for verification of the model. First, in Step 1, master production engineering tries to get BOM and BOR for the customer requirement. Figure 1 illustrates the chart diagram that is obtained by combining of BOM and BOR.

In Figure 1, sharp rectangle denotes an object which represents products, materials and resources. On the other hand, round rectangle denotes a process which represents manufacturing activities as well as purchasing and design activities. All those rectangles in the figure will be certain cost pools when the objects and the processes are defined with connection to materials and resources that consume certain cost in the actual world.

The chart diagram that represents engineering ideas of whole manufacturing process cannot be defined completely, because the result may have alternative routings that affect the structure of the diagram. For example, a process may be assigned to factory outside of the company, and then the works need to be transported by an additional process.

Thus, the chart diagram must have several variations in the beginning.

Additionally, depending on the status of inventory, several rectangles in the chart of Figure 1 might be eliminated because of the stock of the parts

Table 1: Quotation data and cost components.

Item name	Cost item	Resource	Unit cost	Quantity	Data Unit	Cost
Production	Fab 3	Site 1	100	90	Min	9,000
	Fab 4	Site 2	100	130	Min	13,000
	Assy 1	Site 3	80	40	Min	3,200
	Inspect 1	Site 4	100	60	Min	6,000
Outsourcing	Fab 1	Partner 1	1,600	20	QTY	32,000
	Fab 2	Partner 2	800	40	QTY	32,000
	Surface 1	Partner 3	1,100	20	QTY	22,000
Material Cost	Material 1	Supplier 1	3,300	2	Kg	6,600
	Material 2	Supplier 2	6,400	3	M	19,200
Parts Cost	Parts 1	Supplier 3	580	20	QTY	11,600
	Parts 2	Supplier 4	20	60	QTY	1,200
Design	Design 1	Planner 1	5,000	3	Hour	15,000
Transport	Delivery 1	Carrier 1	1,800	1	Set	1,800

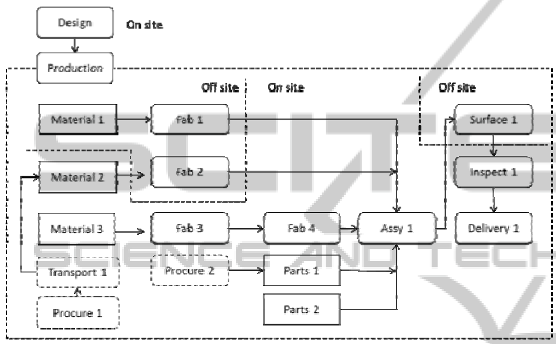

Figure 1: Chart diagram of production.

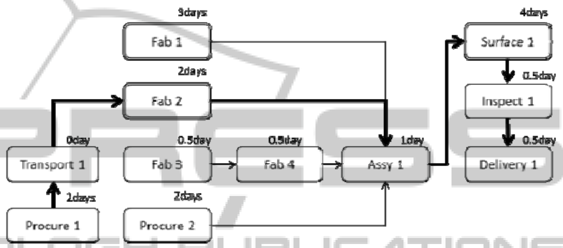

Figure 2: Critical path for production lead time.

and materials. This consideration is made in the second step of advanced planning and scheduling in the quotation process.

The term advanced planning and scheduling (APS) in this study, means that material requirements and resource capacity allocations are simultaneously planned in a short term planning period (couple of weeks). In this case, the time bucket of the planning is day.

APS needs to know standard lead time for each combination of manufacturing resource and desired process. In some cases, the data is stored in database. In others, the planner needs to approximate the value. If the resource is off-site and controlled by other enterprises, the planner needs to make another quotation to the partners.

In Figure 2, the chart diagram provided by step 1 is translated from the viewpoint of resource scheduling. All the processes that compose the whole manufacturing process remain in Figure 2. When those processes are assigned to particular resources, each component can have the lead time estimation by calculating with standard lead time and quantity of the order. Double line processes in Figure 2 denotes that the lead time is obtained by inter-enterprise communication.

The third step, that is, cost and lead time estimation can be executed after above preparation steps. With respect to the total lead time of the production, planner can calculate the critical path of the process network illustrated in Figure 2. Where the count of the date excludes holiday, the planned delivery date of the final products should be arranged regarding the work calendar.

Finally, the cost amount is calculated using all the information obtained so far. As the Table 1 shows, cost components can be listed by deploying the rectangles illustrated in Figure 1. This means that all the processes and leaf objects are cost consuming entities.

Each cost item of row is calculated simply by means of multiplying a standard cost and quantity. This calculation can be arranged depending on the knowledge of production engineering. It may be better to choose an experience of past cases than the calculation using such logical expressions. Therefore, the calculation logic of each row, as well as result of the cost data should be reusable.

As the final step of quotation process, total cost and lead time are calculated and compared to the customer request. In some cases, all the alternatives of the calculation result are not satisfactory to the request. In such cases, planner tries to choose a constraint or boundary that affects the cost and lead time, and relax it or remove it before going back to the first step of the quotation process.

6 PSLX ONTOLOGY AND INFORMATION MODEL

It is very important to have a standard model and modelling guidelines for representing quotation information of each industrial case. PSLX ontology and information model (Nishioka, 2008, 2010, 2011) actually have been very helpful for the two case studies of this paper. Moreover, this is a key to success when such information should be exchanged between enterprises because the data content sent by requester cannot correctly understand by the receiver.

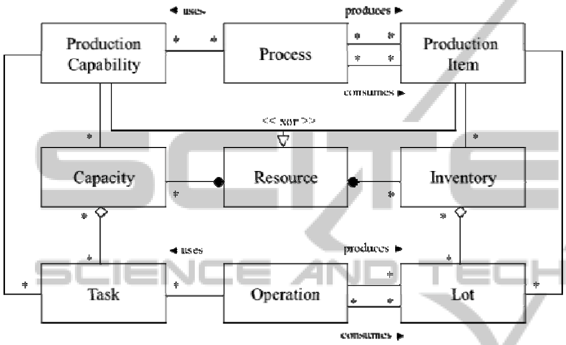

Figure 3: PSLX object model.

Of course, all the objects and processes don't need to be exchanged in detail. However, in cases of quotation process and engineering negotiation, master data such as BOM and BOR need to be shared. This section verifies that PSLX ontology and information model have capability to support for such representations.

In order to establish information exchange among manufacturing operations management, B2MML specification provides a XML schema depending ISA-95/IEC62264 object model (B2MML, 2011). On the other hand, OASIS Production Planning and Scheduling Technical committee publishes another messaging model based on PSLX ontology (OASIS, 2011).

Figure 3 is an essential portion of PSLX object models, some of which objects correspond to PSLX ontology components. According to the model, the term used in the previous sections can be simplified. In Figure 1, Fab x, Procure x, Transport x, Assy x, Surface x, Inspect x, and Delivery x are Process, while Material x and Part x are Production Item.

For the advanced planning and scheduling step, Resource in Figure 3 has two different roles: one is a role of production resources which have capability to produce, and the other is that the production produces or consumes. The former includes Site x, Partner x and Supplier x. The latter includes Parts x and Material x.

All the source of cost accounted come from the Resource in Figure 3. And the aspect of process cost can be considered by capacity usage, while the aspect of object (shaped rectangle in Figure 1) is Inventory in Figure 3. On the other hand, with respect to lead time, only the Process in Figure 1 should be focused.

PSLX information model has activity model on the other side (Nishioka, 2006). The PSLX technical specification prescribes that activity composes a management function brock (MFB). Typical examples of MFB defined so far include S&OP, Master planning, Advanced planning and scheduling, Detailed scheduling, and so on.

It has not been defined in the latest version that which existing MFB corresponds to the quotation process. At least, it can be said that many essential functions of the existing MFBs are useful for quotation management. For example, procedures such as MRP logic and PERT/CPM algorism can be applied. As those procedures can be defined as activities, it is easy to create a new SMB for quotation. Otherwise, it is also possible to remain free formation of quotation process while standard can only guide to use or select the predefined activities.

7 CONCLUDING REMARKS

In the case studies of this paper, both two companies don't use the package software or IT systems designed for quotation. The practitioners mention that typical spread sheet tools provide them the best support. This is because the process of quotation is neither well defined nor well structured, but ill-defined.

The question arises here that, what is the best solution for them by using ICT. It is clear that spread sheets are not enough for such business activities that need to share the information. Concrete and precise quotation system performs well, but less flexibility for unsuspected situation and change of business strategies. The insight obtained by the case studies is seeking the answer where the semi-standard model, which can be evolved according to the system circumstances, should be maintained by human beings, and continually add/replace information to a simple database.

PSLX information model consists of object model, activity model, where PSLX ontology and data pool are performed to connect with the actual world. The experimental result shows that quotation process is emerging target of ICT application, and that standardized activities such as PSLX can be applied as a tool for human-involved information and communication technologies. We believe that loose coupling between computers and human beings can be provided by standardization of semantics and software components that supports communications with evolutional vocabularies. The future studies of information exchange methods between different enterprises are also challenging.

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