An Application of Simulation Based Process Design

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Abstract. One critical issue in process management is that managers can only rely on their experience when they make decisions in designing their business processes. To provide effective decision-making support, a simulation based approach (PMT:Process Management Tool) has been developed to quantitatively predict the performance of designed processes. In this paper, two types of automotive design processes, one product based and the other function based, were examined by applying the simulation based process design. The PMT analysis revealed the fragility of product based process and the tolerance of function based process to overload. In addition, effective human resource allocations were identified.

Keywords. Process Design, Simulation Based Approach, Effective Assistant for decision-making, Tolerance to the Overload, Way of Human Resource Allocation

1 Introduction

In order to survive the global competition, manufacturers have been employing various methods [1 ~ 4] and technologies [5, 6] for improving their performance of engineering and manufacturing processes. However in the field of process management, there have been few effective solutions for managers to design an entire process or help them make proper decisions about "*How to arrange tasks and assign human resources?*". As a result, considerable numbers of process innovations and improvements have resulted in failure [7].

To develop effective technologies for process design, two critical issues shall be addressed. The first issue is related to the impact of coordination on the process performances. Especially in knowledge application processes such as engineering design, designers need to not only process the actual design work but also actively coordinate with each other through communications, reports, and waiting for decisions and/or replies from others. Few existing methods take coordination into consideration. The second issue has to do with the complex relations between

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clients and corresponding processes and with the impact of these relations on the process performance. For instance, predicting the performance of a design process of 5 car models should be more complex than that of a design process of one model. Although VDT (Virtual Design Team) [8] method explicitly addresses the coordination work, it does not consider the relation complexity between changing clients in the market and the business processes of an enterprise partly due to its focus on project management.

Considering the issues described above, a simulation based approach for enterprise business process design, implemented as PMT (Process Management Tool) [9], was developed. PMT has a graphical modelling editor for designing an enterprise business process, a discrete event driven simulation engine for predicting the process performance, and a graphical reporter to display the simulation results of various performance measures.

In this paper, after a brief introduction of our proposed approach, we describe a case study in which PMT was applied to examinate possible options of designing an automotive press-forming-dies design process.

2 Conceptual Model of PMT

The key concepts of PMT include Client, Organization, Process, and Resource. A client is modelled as a source of work for an enterprise. It has its own operations (COP: Client Operation) and sends service requests (SRI: Service Request Item) to the enterprise. A service process of an enterprise is a procedure for processing SRIs. It is composed of a set of required operation (SOP: Service Operation). An organizational position is assigned to SOP and processes SRIs. Positions form an organization through report-to relations. When a position processes a SRI, a coordination work such as communication and exception might be generated. A communication is sent to and processed by a task-related position, while an exception is sent to a supervising position for guidance or decision. This way, a position processes not only the direct work from clients but also the coordination work generated from co-workers. In this information-processing view [8, 10, 11] based conceptual model, a position is considered as an information processor and the requests (SRI) from clients, communications and exceptions from other positions, as well as decisions regarding the exceptions, are considered as the information to be processed by the positions.

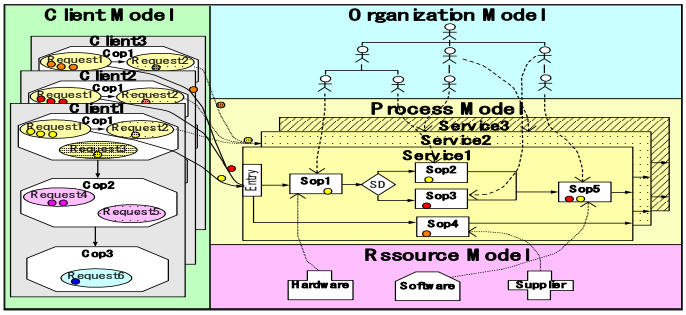
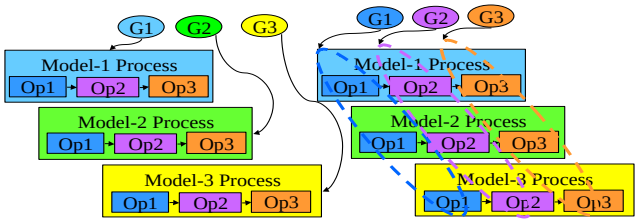


Figure 1. Conceptual Model of PMT

3 The Automotive Press-Forming-Dies Design Case

The following paragraph states the automotive press-forming-dies design case:

The current design process is a product based process (Figure 2. a)). Due to the high demand, the process was overloaded. In addition, a large number of new unskilled designers were allocated to the process and it drastically reduced the design throughput. Finally, its responsible manager started to consider reforming the current design process to the function based process by re-grouping the operations (Figure 2. b)). Most crucial requirement for their design process is to maintain the throughput when the process is overloaded.



a) Product Based Process **b)** Function Based Process

Figure 2. Product and Function Based Process

Based on the case described above, the crucial problems to be addressed prior to re-designing the process were identified (Table 1). The answers to these problems used to solely depend on the Manager's experience.

Table 1. Problems to be predicted

Problems	Predictions	
	Product Based Process	Function Based Process
Tolerance to the overload	Analysis by the simulation based approach	
Where to allocate unskilled designer		

Regarding the design process of the press-forming-dies, the necessary information required for its simulation model was collected as follows (Figure 3).

- Press-forming-dies are designed with respect to 6 model types.
- The Press-forming-dies design requires four major operations, i.e., "Protype Design", "Prtotype Try", "Product Design", and "Product Try".
- The operations are becoming more complex from "Product Try" (last operation) to "Prototype Design" (first operation).
- 50 designers, including managers, are assigned into the process.

Figure 3. Press Forming Dies Design Process

To examine the process with respect to "allocation of human resources", the skills and the skill levels of the 50 designers were defined with respect to the four operations in the design process as shown on Table 2. Persons 41 to 50 are the unskilled designer assigned to the process lately.

Table 2. Properties of Human Resources

Staff's ID	Skills and levels			
	Prototype Design	Prototype Try	Product Design	Product Try
Person1~ 10	High	High	High	High
Person11~ 15	Medium	High	High	High
Person16~ 20	Medium	Medium	High	High
Person21~ 25	Medium	Medium	Medium	High
Person26~ 30	Low	Medium	Medium	Medium
Person30~ 35	Low	Low	Medium	Medium
Person36~ 40	Low	Low	Low	Medium
Person41~ 50	Low	Low	Low	Low

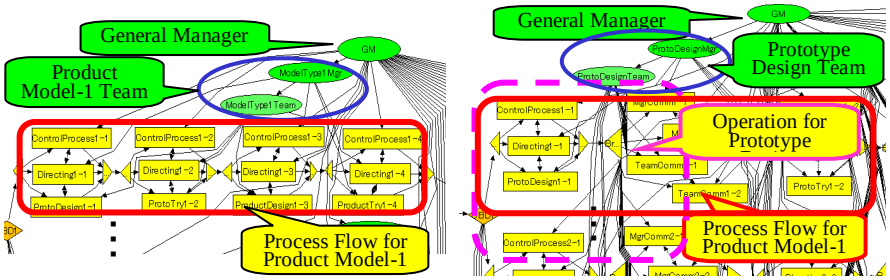
4 Modeling the Design Process

The 6 model types are the sources of work for the design process. The modeling procedures of product and function based processes are described as follows (Figure. 4).

Firstly, the operation flow for processing the requests from each model type is defined. Each operation flow comprises three types of operations, which are "designing operations", "directing Operation", and "control process operation". The designing operations are "Prototype Design", "Prototype Try", "Product Design", and "Product Try". They directly contribute to completing the designing work. Directing operation monitors the designing operations and directs the designers. Control operation integrates the all team managers from a management perspective. Both the designing and control operations are information-dependent on the directing operation.

Secondary, the responsible organizational positions are defined with respect to the operations defined above. The four designing operations are assigned to the design teams. The directing operations and the control operations are assigned to the Team Manager and the General Manager, respectively. When a position is assigned to a set of operations with respect to a specific model type, it forms a product based process (Figure 4 a)). When a position is assigned with respect to a specific function of operations, it forms a function based process (Figure 4 b)).

Finally, the report-decision relationships between the positions are defined. The network of the relationships forms a service organization.



a) Product Based Process b) Function Based Process

Figure 4. Modeling the Processes

5 Simulation and Analysis

In this examination, four scenarios were applied (Table 3.). In Scenario1 and 2, the average skill levels of all design teams were equal. Scenario1 and 2 were for the product based process and the function based process, respectively. Scenario3 was for the product based process. Its average skill levels of all design teams were different from each other. Scenario4 was for the function based process. In this scenario, the average skill levels of the two teams assigned to the first two complex operations were higher than the other two teams. In other words, it considered the complexity and skill level matching. For all scenarios, the simulations were executed by varying the load conditions from 50% to 100% by 10% steps. The following two performance measures are evaluated to assess the simulation results.

Table 3. Simulation Scenario

Scenario ID	Applied for	Human Resource Allocation
Scenario-1	Product Based	Skill Level of all teams are equal
Scenario-2	Function Based	
Scenario-3	Product Based	Skill Level of all teams are varied
Scenario-4	Function Based	Two teams has higher skill than the others

Process Throughput: The process throughput is defined by the number of completed requests from the clients (Model Types) in a specific period of time (3 months in this simulation).

$$TP = Total\_TP / Sim\_T \quad (1)$$

TP: Process Throughput (Number of requests / Month)
Total_TP: Throughput during a simulation period (#)
Sim_T: Simulation period (Month)

Communication Quality: Communication quality is defined by the ratio of the number of responded communications to the number of the initiated communications within a defined period of time. In this simulation model, a

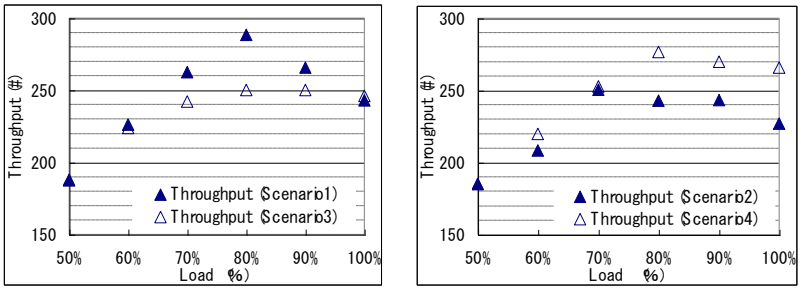
communication request evaporates after 72 hours. It means that the communication fails if the position cannot respond it within 72 hours. As the number of responded communications decreases, communication quality becomes worse (low).

Comm_Quality = Processed Comm / Requested Comm (2)
Comm_Quality: Communication Quality
Processed_Comm: The number of responded communications by a position (#)
Requested_Comm: The number of received communications by a position (#)

The simulation results have been analyzed to evaluate the organization structure impact on both the Process Throughput and Communication Quality.

Structural impact on both the Process Throughput: Figure 6a shows the changes of the throughput to the workload with respect to the product based process. As shown in Figure 6a, the peak throughput of Scenario1 is higher than that of Scenario3, indicating that the maximum throughput can be improved by human resource allocation. However, the improvement is only effective around the peak and the throughput after the peak decreases as the workload for the design process increases.

Figure 6b shows the changes of the throughput in response to the workload in case of applying a function based process. As shown in Figure 8, the throughput of Scenario4 is higher than that of Scenario2. From this result, it is recognized that the maximum throughput can be improved by the human resource allocation. In addition, the improvement is still effective after the peak and the throughput after the peak remains almost the same as its maximum.



a) Product Based Process b) Function Based Process

Figure 6. Work Processing Performance

From the above observations, the followings can be concluded regarding the throughput performance of the two types of processes.

- Function based process is more tolerant to the overload than the product based process.
- Although human resource allocation to the product based process can improve maximum throughput, it cannot improve its tolerance to overload.
- The human resource allocation to the function based process can improve the maximum throughput and the tolerance to the overload.

Structural impact on both Communication Quality: Figure 7 shows the the changes of the communication quality with respect to workload. To the product based process, the better human resource allocation regarding the processing capability, Scenario1, was applied. To the function based process, the worse allocation, Scenario2, was applied.

In the product based process, the communication qualities of operations Prototype-Design and Product-Try become worse at the same pace after a certain workload level. It is considered that the communication qualities of all operations would decrease in a similar way when the workload reaches to the maximum capability of all operations in a process.

In the function based process, the communication quality of Prototype-Design becomes worse after a certain workload level. However, the communication quality of Product-Try stays almost constant with all load levels. It is considered that the last operation Product-Try is less sensitive to the overload situations because the first operation Prototype-Design would not send to the operation the amount of work more than it can complete.

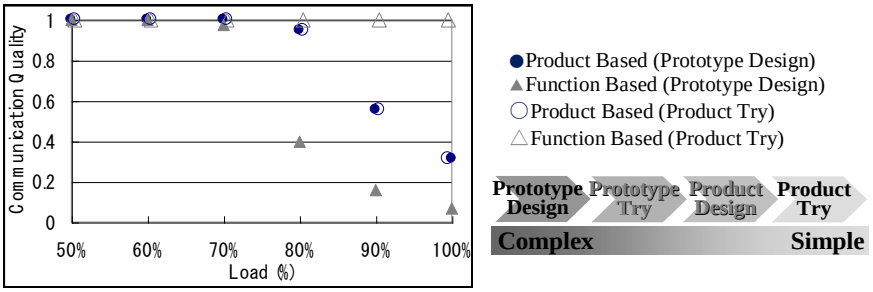


Figure 7. Communication Processing Performance

From the analysis results described above, the followings can be concluded regarding the effect of human resource allocation on the two types of processes.

- When the product based process is overloaded or highly loaded, the unskilled designers are unable to receive enough information to complete their work because they need more information than the skilled designers.
- In the function based process, the unskilled designers should be allocated at the last or later operations in order to get enough information for them.

Through the analyses described above, the problems listed on Table 1 were predicted as follows.

Table 4. Problems and Predictions

Problems	Predictions	
	Product Based Process	Function Based Process
Tolerance to the overload	Weak Cannot be improved	Improved by human resource allocation
Where to allocate the unskilled designer	Cannot be solved	Allocating to the last operation

7 Conclusion

As an application example of our proposed simulation based approach for process design, a press-forming-dies design process was examined using PMT. This examination verified the conceptual model of PMT for modeling and simulating the actual design process. In addition, it was also verified that the simulation results could deliver effective solutions for designing business processes. The findings through this examination were discussed with the managers of the enterprises that had similar design processes. Through the discussion, it was found that our approach and the PMT system would be effective for supporting actual business process design.

8 References

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