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# Simulation-Based Service Business Process Design Method for Different Types of Demand Fluctuations

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**Abstract.** In business process reengineering, engineering approaches to realize effective business processes have been studied in an interdisciplinary manner involving researchers in management, sociology, and other fields. Predicting design effectiveness, identifying effective design parameters and their settings, and selecting the optimal design are essential to realize effective business processes. Therefore, the objective of this paper is to demonstrate that the method with agent-based models and simulation can assist designers' decision-making and provide necessary knowledge through a case study of business process design for both cyclic and acyclic demand fluctuations. The case study was conducted on an IT systems department business process of a company that processes 50 demands with different demand fluctuation types. The simulation model described the demands and corresponding operations in a hierarchical manner to reduce the complexity of the design description. 16 design scenarios were prepared by combining 4 design parameters. The case study examined the problems of how the proposed method could provide knowledge regarding selection of optimal design scenarios, effective design parameters and their settings, and causal relationships of design parameter changes and effects. The case study results confirmed that our proposed method can provide useful knowledge. For example, that two specific design parameters have a synergistic effect, and that the effect of changing the design parameter of teaming is not caused by teaming itself, but the communication-work reduction that results from teaming, were provided. The results demonstrated that the proposed method could assist designers' decision-making and provide them with necessary knowledge in designing business processes.

**Keywords.** Process design, Agent-based model, Decision-making, Complex system problem, Knowledge.

## Introduction

In recent years, it is getting difficult for conventional business process design methods to respond to rapid environmental changes surrounding the business process, such as imitating other successful examples, relying on mental models that rely on the experience

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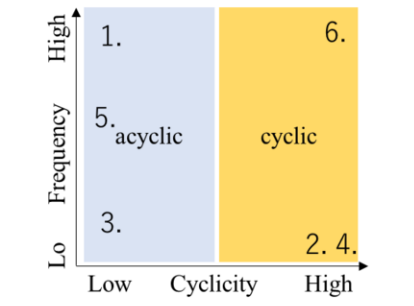
and intuition of experienced management, and repeating trial and error through implementation.

In particular, unlike the manufacturing industry, where the effects of demand fluctuations can be mitigated with inventories of finished goods or intermediate products, service businesses must design business processes based on accurate forecasts of the effects of fluctuations in the demand environment on the behavior of their business processes. Examples of such service businesses include emergency medical services and trouble-shooting in the IT business. The business processes of these service businesses are required to efficiently process requests from both cyclic demands, which are repeated on a regular or periodic basis, and acyclic demands, which require immediate responses, even though the timing of the occurrence of the demand is uncertain. Furthermore, the number of operations that compose the business process tends to increase in number and complexity because these service businesses are required to process requests from a wide variety of demands with different requirements. Discrete simulations such as queueing are commonly used to predict and solve problems in such complex systems, but the following issues should be considered in business process design.

First, there is the issue of how to build a visually understandable simulation model of a large number of demands with different demand variability characteristics, required operations, and requirements (e.g., processing time) (Figure 1). In this study, the works to be processed by the service business process were defined as external requests, and the sources of these requests were defined as demands. For example, as shown in Figure 1, "PC license management" or "user Q&A" are subjects of works to be processed by the IT system department, but the existence of these works is time-dependent. Second, there is the issue of how to allocate human resources to operations that satisfy both the constraints of skill matching (matching skills possessed by human resources with those required for operations) and the goals imposed on the business process. Furthermore, there is the issue of how to decide the appropriate size of a team, which is a set of human resources. In this study, the overhead of coordinating information (communication) among teams was also considered in the prediction and evaluation. Larger team sizes increase these overheads, while smaller team sizes are associated with lower team availability, either extreme of which could affect the processing time of a request.

Therefore, the objective of this study was to propose a simulation-based service business process design method for different types of demands and fluctuation, and to demonstrate the effectiveness of the proposed method through a case study. In the case study, skill sets and demands in the simulation models were based on the data collected from the target business process.




| No | Demands | Fluctuation types | Frequency Times/period |
|---|---|---|---|
| 1. | Users Q&A | Acyclic | 10/day |
| 2. | PC license management | Cyclic | 4/year |
| 3. | Responding virus infection | Acyclic | 4/year |
| 4. | Audit | Cyclic | 3/year |
| 5. | Responding network trouble | Acyclic | 1/week |
| 6. | Monitoring system | Cyclic | 1/day |

**Figure 1.** Classification of demands for an IT system service in the proposed model.

## 1. Related works

Business process design methods that utilize simulation to predict its risk and performance have been proposed as follows.

Jin et al. [1] proposed a method for simulating multiple projects by agent-based simulation and predicting the construction period, cost, and quality. This method represents the reporting and instructional relationships among the teams that make up the organization, the processing order and information dependencies among tasks, and the relationships between teams and tasks in a visually understandable format, and the simulations also consider the characteristics of human resources such as organizational characteristics and skills in the prediction. Moser et al. [2] proposed an agent-based simulation model consisting of scope, human resources, activities, and the relationships among these components to predict the three constraints of project management: project scope, cost, and construction period. Ying et al. [3] proposed a supply-demand matching model to integrate various manufacturing resources and capabilities distributed as social infrastructure into an integrated manufacturing service that meets a specific demand and Fei et al. [4] proposed its simulation. These studies mainly aim to design business processes that are adapted to specific demands, taking into account the supply-side environment, e.g., resources, energy, infrastructure, and their associated uncertainties.

Suzuki et al. [5][6] proposed a business process visualization model that considers the relationship between business processes and the market, which is the source of the demand they process, a simulation system (PMT: Process Management Tool) that considers information dependencies among operations and human resources.

## 2. Proposed method

### *2.1. Selecting the simulation tool*

Before deciding the simulation tool to use, target performance and its affecting factors were considered. In this study, we decided to choose processing time (the time required from the generation of a request to the completion of that request) as one of performance measures. Then, as the affecting factors for the processing time, workload and processing capability were considered and further broken down into detailed factors as shown on Table 1. As a result of considering the above affecting factors, a simulation tool (PMT: Process Management Tool) developed in a previous study[5][6] was employed. In the tool, each team was modeled as an agent and the simulation was executed by the agent being event driven.

**Table 1.** Factors affecting request processing time.

| 1. Workload | 2. Processing capability |
|---|---|
| 1.1 Request frequency | 2.1 Team formation<br>2.1.1 Number<br>2.2.2 Skill level |
| 1.2 Demand fluctuation | 2.2 Team allocation to operations |
| 1.3 Operation characteristics<br>1.3.1 Exception frequency<br>1.3.2 Information request frequency<br>1.3.3 Work volume<br>1.3.4 Work complexity<br>1.3.5 Work Priority | |

### 2.2. Overview of the proposed method

Our proposed methodology is shown in Figure 2. First, a design scenario (DS) was created as an input to the simulation. The design scenario consists of a model of a market and its corresponding process. In our simulation model, the market is a demand model in which requests to be processed by a process are generated, and the process is a model in which requests are processed. First, we modeled them according to the current business process (basis scenario), and then we prepared multiple design scenarios in which the design parameters were changed for the current situation. Next, after setting the simulation period, operating conditions, and other simulation settings for these design scenarios, the simulations were executed. After the simulations were completed, statistical data on the performance of each design scenario, such as processing time, amount of work in process, and work breakdown, were output. Based on the output results, the effectiveness of each design parameter (DP) was verified, and if a design scenario that achieves the goal was found, the desired business process design was completed. If the target goal was not achieved, then the design scenarios that were more promising for the goal were selected, the necessary modifications were added, and the verification through simulation was repeated until the goal was achieved.


**Figure 2.** Simulation flow of the proposed method

### 2.3. Build a basis scenario model (as-is business process model) for validation

In this section, it is explained how to model the basis scenario (as-is business process), which is the basis for developing various alternatives (design Scenarios) to the current situation. In this case study, a business processof an IT system department was subjected.

1.) Modeling market

In this business process, the demands associated with client PCs, security systems, network systems, periodic audits, and users were processed. The 6 entities that had these demands were defined as demanders.

Figure 3. shows a model of the relationship between the demanders and processes on the screen of the simulation tool. The ellipse represents a demander, the rectangle represents a process, and the straight line connecting the ellipse and rectangle represents the route in which generated requests are passed to the corresponding operations.

Figure 4. shows a model of the relationship between the demand for client PCs as demander and the process in the screen of the simulation tool. In our simulation model, demand is a generator of requests to be processed by the corresponding operations. The model describes that “Client PCs” as a demander has potential demands such “PC license management”, “security software license management”, “application software license management”, and “virus infection response”. As mentioned in the introduction, they are

potential tasks for the business process and considered the sources of requests. The rectangle on the left represents demand, the rectangle on the right represents process, and the straight line connecting the two rectangles represents the route in which generated requests are passed to the corresponding operations. The straight line connecting each of the rectangles on the left side represents the order in which the demands are actually activated. The demands generate requests to be processed only when the demands are activated. This order between demands models cyclical demand fluctuations, in which demand activation is repeated at regular intervals. Demand with non-periodic demand fluctuation characteristics is modeled in the setting of variance in the frequency with which the requests are generated. Each demand is defined by the demand activate duration, the request generating frequency, and its variance. Total 30 demands of the 6 demanders were modeled in the same way as described above.

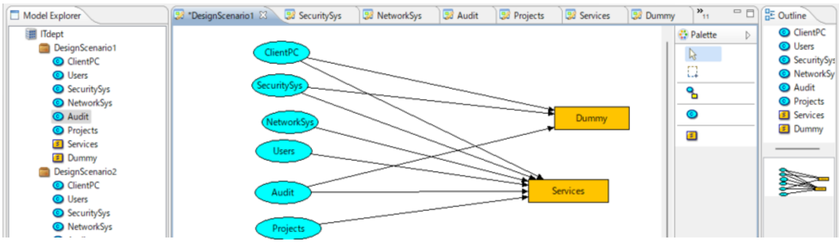



**Figure 3.** Modeling market with demanders

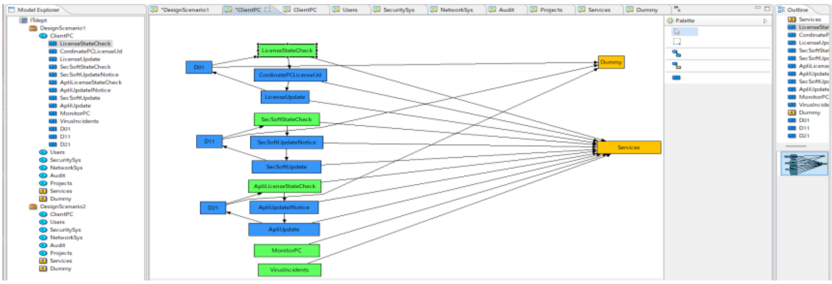


**Figure 4.** Modeling detailed market with demands of “Client PC” as a demander

2.) Modeling process

Figure 5. shows the architectural model of the process in the simulation tool. The process is represented by teams (represented by ellipses), operations (represented by rectangles), conditional branches (represented by diamond), starting and ending points (represented by circles), and relationships among the elements. The straight lines connecting the teams represent the reporting and directing relationships. Decisions about exceptions that occur probabilistically in the processing of requests and corresponding actions are sent and received among teams through these lines. The lines connecting the teams to the operations represent the team allocations to the operations to be processed. Unprocessed requests received by an operation are routed to the team, and requests that have been processed by the team are routed to the operation through the line. The lines connecting the start point, end point, condition separation, and operations represent the order in which requests received from the demand are processed. All requests that are received by the process move from the start point to the end point. There are three types of conditional branches: branches where the processing order is determined by the demander that generated the request, branches where the processing order is determined

by the type of demand, and branches where the processing order is determined by probability. The straight lines with arrows (dashed circles) connecting the operations represent the information dependencies among the operations and simulate information coordination (e.g., communication) between the teams in charge of the operations associated with these lines. Teams are defined by number of people, skill level, and skill type, and operations are defined by required skills, processing complexity, frequency of information coordination, and nominal workload.

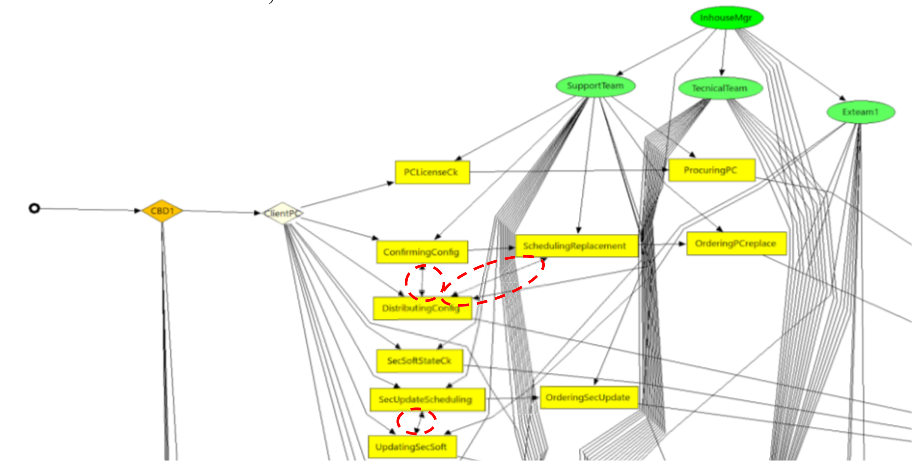



**Figure 5.** Modeling process (a part of process flows for a demander "Client PC")

## 2.4. *Output of the simulation*

The simulation tool used in this study outputs the predictions as shown in Table 2. In the case study, we focused only on the processing time and it was defined as the time *($D_p$)* elapsed from the time when the request is generated by the demand *($T_g$)* to the time when all necessary processing is completed by the process *($T_f$)*.

$$D_p = T_f - T_g \tag{1}$$

**Table 2.** Output of the applied simulation tool

| Objective | Evaluating Measures | Scope of the measure |
|---|---|---|
| Productivity | Cost | Entire Process |
| | Revenue | |
| | Throughput | Process by demand |
| | Process Time | |
| Quality | Coordination Quality | Process by team |
| Bottleneck | Work In Process | Process by team or operation<br>Entire Process |
| Work Breakdown | Direct work, Decision, Rework, Coordination work, Idle | Process by team |

## 2.5. Simulation settings

Simulations were performed with the settings shown below.

1. simulation period: approx. 2 years, repeating 518 times with 7-hours workday as a daily unit (3,624 hours = 5 days/week x 7 hours/day x 103.5 weeks)
2. occurrence of exceptions: None
3. occurrence of information request: Yes (by all team members attendance)

## 3. Case study

### 3.1. *Objective of the case study*

The subject of this case study is a business process for the IT systems department of a company responding to 30 demands. Each demand has its own goal for the processing time, and the objective of this case study is to realize a business process in which the average processing time for all the demands is within their respective goals.

### 3.2. *Validating basis scenario model*

This section describes the validation of the basis scenario model which was modeled in the previous chapter. The validation was conducted by comparing actual of typical demand requests under standard workloads and simulated processing times (Table 3.). The actual processing times were based on the perception of a representative staff engaged in the process. The basic scenario was verified by the fact that the actual was within the 95% confidence interval obtained from the simulation results.

**Table 3.** Actual process time at standard workload and simulated confidence intervals (hours)

| Demands No. | 2.5 Percentile | 97.5 percentile | Actual | Demand No. | 2.5 Percentile | 97.5 percentile | Actual |
|---|---|---|---|---|---|---|---|
| 1 | 0.11 | 8.11 | 0.8 | 16 | 0.06 | 71.64 | 0.8 |
| 2 | 0.06 | 4.79 | 0.8 | 17 | 0.10 | 17.52 | 0.8 |
| 3 | 0.11 | 21.69 | 0.8 | 18 | 0.02 | 22.25 | 0.8 |
| 4 | 0.02 | 4.38 | 0.8 | 19 | 0.33 | 20.18 | 5.6 |
| 5 | 0.04 | 3.56 | 0.8 | 20 | 0.33 | 34.48 | 3.2 |
| 6 | 0.11 | 21.5 | 0.8 | 21 | 0.33 | 28.61 | 3.2 |
| 7 | 0.02 | 4.88 | 0.8 | 22 | 0.96 | 20.61 | 5.6 |
| 8 | 0.04 | 4.51 | 0.8 | 23 | 4 | 4 | 4 |
| 9 | 0.11 | 21.31 | 0.8 | 24 | 0.25 | 0.25 | 0.25 |
| 10 | 0.45 | 18.84 | 5.6 | 25 | 0.70 | 13.70 | 5.6 |
| 11 | 9.45 | 39.01 | 11.2 | 26 | 7.00 | 7.17 | 7.0 |
| 12 | 0.1 | 71.78 | 3.2 | 27 | 1.0 | 1.0 | 1.0 |
| 13 | 0.38 | 68.21 | 5.6 | 28 | 0.33 | 15.89 | 5.6 |
| 14 | 0.26 | 18.66 | 5.6 | 29 | 0.36 | 20.75 | 5.6 |
| 15 | 0.70 | 58.37 | 5.6 | 30 | 0.33 | 15.89 | 5.6 |

The requests with demand numbers 23, 24, and 27 are out of this research subject.

### 3.3. *Building various alternatives (to-be scenarios) based on the basis scenario*

Four design parameters were defined as candidates for changes to be made on the varified basis scenario model (Table 4.) and 16 desgin scenarios including basis scenario were prepared as combinations of those desing parameters (Figure 7.). The basis scenario kept all design parameters Option 1.

**Table 4.** Morphological matrix for the target service business process

| Design Parameter: DP | Option 1(Not) | Option 2 (Done) |
|---|---|---|
| DP1: Rules for selecting the next request to be processed | Keep original | Select by priority |
| DP2: Method for forming a team | Keep original | Move a worker from one team to another |
| DP3: Team allocation to operations | Keep original | Divide a team according to the demand fluctuation type |
| DP4: Simplifying organization | Keep original | Integrate 2 teams with similar skills |

### *3.4. Evaluation criterion*

The ratio of the number of demands that achieved the target *($N_{acv}$)* to the number of all demands *($N_{dmd}$)* was defined as the target achievement ratio *($R_{acv}$)*, and this was used as an evaluation index for the design scenario to evaluate the effect of the design parameters on processing time.

$$R_{acv} = \frac{N_{acv}}{N_{dmd}} \tag{2}$$

## 4. Results and discussion

### *4.1. Searching promising process designs*

First, the goal achieved rates for all design scenarios (DS) are compared, and promising design scenarios, effective design parameters (DP), and their settings are discussed. Figure 6. shows the simulation predictions of the design parameter settings and goal achieved rates for each scenario. Naturally, the design scenario with the higher goal achieved rate is a more promising business process design for achieving the goal of processing time than the other scenarios. In the results, the goal achieved rate for DS12, DS13, DS15, and DS16 is more than 90%, which indicates that they are the most promising design scenarios (business process designs) in terms of achieving the target processing time. Regarding team size, three of the four promising design scenarios had three teams.

| DS | DP1 | DP2 | DP3 | DP4 | No of Teams |
|---|---|---|---|---|---|
| Basis | Op 1 | Op 1 | Op 1 | Op 1 | 3 |
| DS2 | Op 1 | Op 1 | Op 1 | Op 2 | 2 |
| DS3 | Op 1 | Op 1 | Op 2 | Op 1 | 4 |
| DS4 | Op 1 | Op 1 | Op 2 | Op 2 | 3 |
| DS5 | Op 1 | Op 2 | Op 1 | Op 1 | 3 |
| DS6 | Op 1 | Op 2 | Op 1 | Op 2 | 2 |
| DS7 | Op 1 | Op 2 | Op 2 | Op 1 | 5 |
| DS8 | Op 1 | Op 2 | Op 2 | Op 2 | 3 |
| DS9 | Op 2 | Op 1 | Op 1 | Op 1 | 3 |
| DS10 | Op 2 | Op 1 | Op 1 | Op 2 | 2 |
| DS11 | Op 2 | Op 1 | Op 2 | Op 1 | 4 |
| DS12 | Op 2 | Op 1 | Op 2 | Op 2 | 3 |
| DS13 | Op 2 | Op 2 | Op 1 | Op 1 | 3 |
| DS14 | Op 2 | Op 2 | Op 1 | Op 2 | 2 |
| DS15 | Op 2 | Op 2 | Op 2 | Op 1 | 5 |
| DS16 | Op 2 | Op 2 | Op 2 | Op 2 | 3 |

settings of 4 design parameters for each scenario
DP: Design Parameter
DS: Design Scenario
Op: Option

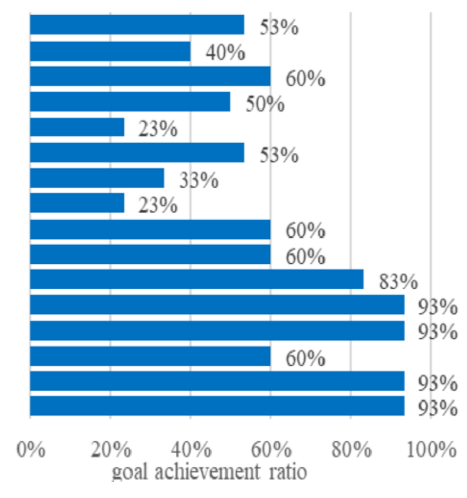



**Figure 6.** Ratio of the demands achieving goal.

### *4.2. Specifying effective design parameters.*

Figure 7 shows the effects of changing (improved rate of target achievement ratio) the state from Option 1 to Option 2 on the goal achieved rate for each design parameter. The results show that changing the setting of DP1 from option 1 to option 2 has a significant effect on the goal achieved rate. Changing the setting of DP3 from Option 1 to Option 2 also has some effect on the target processing time. Furthermore, changing the settings of both DP1 and DP3 to Option 2 was predicted to have a greater effect than changing either one of them. On the other hand, changing DP2 or DP3 had little effect on achieving the target processing time. These effects are observed on the 4 promising design scenarios.

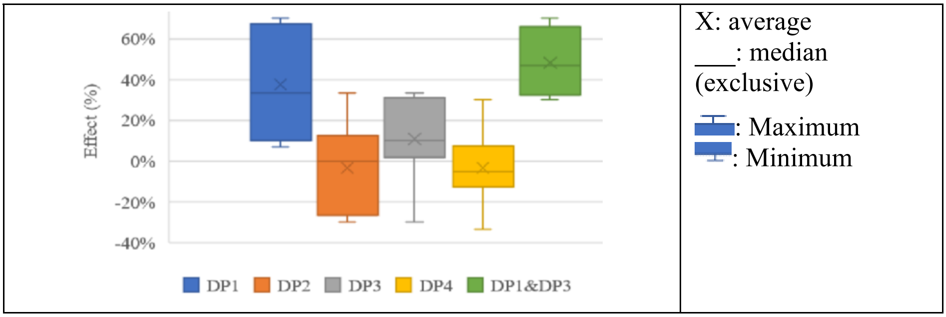



**Figure 7.** Effect of design parameters on achieving goal processing time

## *4.3. Configuring efficiently with explored knowledge.*

Finally, for each demand that did not meet the target processing time in the promising design scenarios, measures to improve the process were examined.

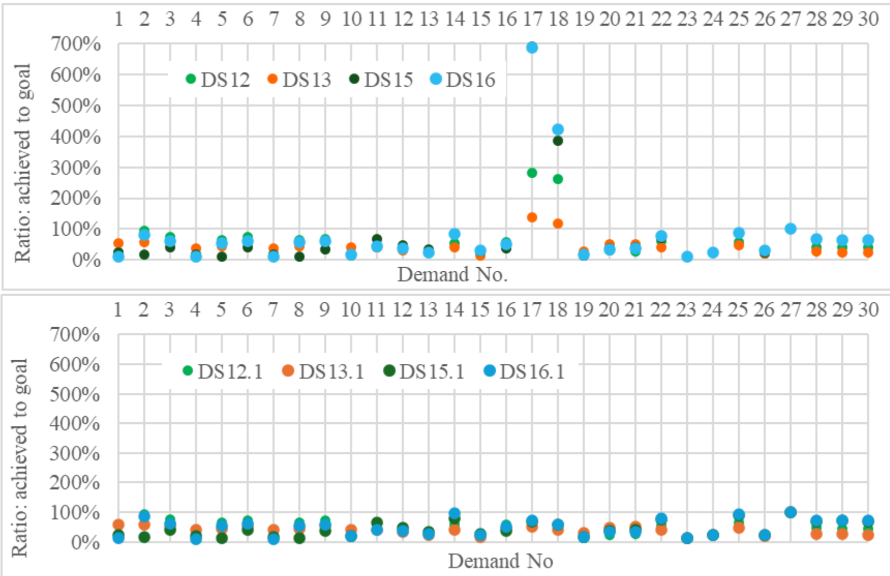



**Figure 8.** Ratio of average predicted process time to goal for each demand.

The top panel of Figure 8. shows the ratio of the predicted average processing time to the goal processing time (vertical axis) for each demand (horizontal axis), expressed as a percentage, for the promising design scenarios found in the previous section. In this graph, if the ratio of predicted processing time to goal time is less than or equal to 100%, it means that the goal was achieved. The prediction results show that in all promising design scenarios, the processing times for the requests from the 17th and 18th demands did not meet the goals. Therefore, the most effective of the four design parameters, Design Parameter 1 (Priority-based request selection), was focused on, and changes were made to those design scenarios to increase the priority of operations related to those two demands. The simulation results are shown in the bottom panel of Figure 8. The design scenarios with these changes to DS12, 13, 15, and 16 are designated DS12.1, DS13.1, DS15.1, and DS16.1, respectively. The simulation predictions show that these design changes worked, resulting in a successful search for four business processes that satisfy the goal processing time for all demands.

Through the above discussion, the findings in designing this business process include: prioritized processing of operations related to emergency and acyclic demand, division of work teams according to the characteristics of demand fluctuations, and 3 teams.

## 5. Conclusion and future works

The proposed simulation-based design method for service business process proved to be effective for different types of demands and fluctuation in the case study.

Firstly, the case study validated that the proposed method was effective to appropriately model a large number of demands with different demand variablity charactristics for a service business process. Secondly, the case study validated that the proposed method was effective to allocate human resources to operations that satisfy both the constraints of skill matching (matching skills possessed by human resources with those required for operations) and the goals imposed on the service business process. Furtheremore, the case study validated that the proposed method was effective to decide the appropriate size of a team in a service business process.

As the next research works, examining the knowledge effectiveness found through the simulation-based approach with case studies comparing the design activities of two different designer groups with and without the knowledge will be examined. Furthermore, the method for finding the most promising business process with accumulated design knowledge derived from the simulation will be examined.

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