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Comprehensive Simulation and Redesign System for Business Process and Organizational Structure

SEUNGHOON LEE, INJUN CHOI, HOKYEOM KIM, JITAEK LIM, AND SANGHYUN SUNG
Department of Industrial and Management Engineering, Pohang University of Science and Technology (POSTECH), Pohang 36763, South Korea

Corresponding author: Sanghyun Sung (flyparis@postech.ac.kr)

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ABSTRACT Even though the extremely uncertain current global business environment requires organizations to change their business processes and organizational structures to adapt to their extremely uncertain and complex environments, existing methodology and system cannot support this problem. This paper presents a comprehensive simulation and redesign system to simulate business processes and organizational structure simultaneously and derive the most process-oriented organizational structure efficiently. The methodology and system suggested in this study can predict the effects of changing business processes and organizational structures through the simulation and derive appropriate and practical organizational structures that execute current processes efficiently through the genetic algorithm. Existing business process researches have the limitations that they rarely have considered the effects of organizational structure on the performance, and this study have outstanding academic contribution in solving the problem systematically using simulation and optimization techniques.

INDEX TERMS Business process simulation, business process analysis, organizational redesign, business process, organizational structure.

I. INTRODUCTION

Many organizations now face a complex and dynamically changing environment because of globalization, frequently changing markets, and more intense competition. Therefore, organizations need to continuously innovate their business processes and organizational structure, which should be aligned with their strategy and business model to adapt to these fluctuating environments.

Numerous efforts and research to determine successful business process innovation (BPI) have been conducted in many academic and industrial areas. The information technology that handles business processes, such as business process re-engineering (BPR), process innovation (PI), workflow management system (WfMS), and business process management system (BPMS), have been researched and developed for managing and innovating business processes for the last few decades [1]–[5]. Furthermore, process mining, a data-driven approach for business process analysis, has been researched for extracting meaningful insights from business process execution results [6]–[8].

Even though many organizations have conducted BPR or PI projects, 50% to 70% of them failed to achieve the expected performance [9]. Researchers indicate that the main reason for the failure of existing BPR or PI projects is that only business processes have been analyzed without considering other organizational factors, such as the organizational structure, even though these factors significantly affect business process execution and performance [1], [4], [9]–[15]. In particular, business processes and organizational structures have been designed and researched independently despite their interrelationships [10], [16]. As shown in Figure 1, an identical business process can be executed differently according to different organizational structures and human resources who execute these tasks. *Performer_C* is managed by *Manager_C* in *Organizational_Structure_A* whereas he/she is managed by *Manager_B* in *Organizational_Structure_B*. In the identical situation where *Task_A* is assigned to *Performer_B* and *Task_B* is assigned to *Performer_C*, *Organizational_Structure_A* has longer communication channels to transfer the work between *Performer_B* and *Performer_C*

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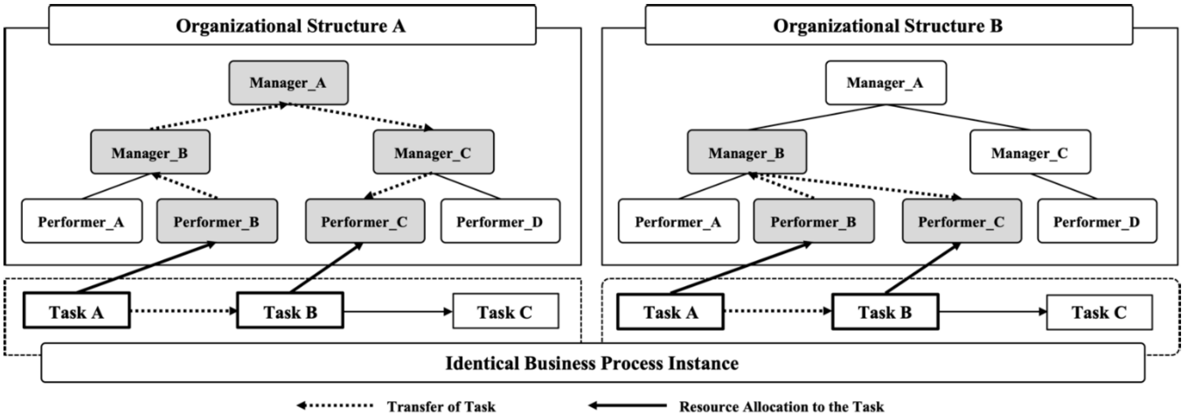


FIGURE 1. Different executions of identical business process instance on different organizational structures.

than *Organizational_Structure_C*, Even for the identical business process and task allocation, business process is executed in different ways according to their organizational structures.

Thus, business innovation activities, such as BPR and PI, should consider organizational structure to derive more realistic and effective redesign alternatives.

However, most research has focused on business process optimization without reflecting the features of the organizational structure and human resources that influence the business process performance [5], [6], [17], [18]. Although some process mining research have been attempted to derive organizational information from event and process logs, only limited organizational information was derived from their analysis since the process log and data model were not designed to support the integrated analysis of business processes and organizational structure simultaneously [7], [19], [20].

Most existing approaches do not consider a data model to analyze business processes and the organizational structure simultaneously [5]. For comprehensive organizational analysis, a data model that can incorporate other organizational information such as resource availability, task capability fully needs to be designed. Moreover, existing business process simulation approaches also do not consider organizational structures [10]–[12], [21]–[24].

In this research, to overcome the limitations of existing business process researches and systems that didn't reflect effects of organizational structure at all, the system is developed for simulating business process with effects of organizational structure and deriving the process-oriented organizational structure. Through the system presented in this study, many researchers and enterprises could predict the effect of changes in business processes and organizational structures in advance, also find the organizational structure that is suitable for current business processes.

This remainder of this paper is organized as follows. Section 2 describes the existing literature related to this research. Section 3 describes our methodology to simulate, analyze, and redesign business processes incorporating the effects of the organizational structure. Section 4 describes the validation result of our methodology and the system architecture of the implemented system. Finally, Section 5 presents our conclusions and contributions.

II. RELATED WORK

The definitions of the business process, task, and transfer-of-task employed in business processes and organizational structures are provided. The workflow management coalition (WFMC) organization defines a business process as "a set of one or more linked procedures or activities which collectively achieve a business objective within the context of an organizational structure defining their functional roles and relationships" [25]. A task is an atomic process that cannot be further divided [26]. A transfer-of-task is required to manage the coordination between tasks [27]. An organizational structure is defined as "the sum total of the ways in which an organization divides it labor into distinct tasks and then achieves coordination among them" [28].

A. EFFECTS OF ORGANIZATIONAL STRUCTURE ON BUSINESS PROCESS EXECUTIONS

Existing BPR and PI projects imply that their expected results cannot be achieved if business processes were not designed in correspondence with the organizational structures [1], [4], [9]–[14]. As shown in Figure 1, business processes are performed differently depending on their organizational structure. Although some studies have considered the structures [10], [29]–[31], they have limited themselves to variables such as changing the number of employees and grouping them around their tasks.

The processes can be modeled by process event log data with process mining and process analytics technology [7], [32]. Using these technologies, bottlenecks or structural problems of existing business process can be detected, and these processes can then be updated to enhance their business processes. However, business processes are executed by human resources who can execute each task in each business process instance based on the organizational structure. The most important limitation of existing research is that the organizational structure was not considered in their analysis [33]. Thus, it is difficult to improve their business performance without considering their organizational structure.

To overcome these limitations of existing research, Hearn *et al.* suggested the process and organization fit index (POFI) model to evaluate the fit between business processes and organizational structure [4]. This POFI model measures the total coordination overhead expenses by calculating vertical coordination overheads between different departments for business process executions quantitatively. This research is meaningful in that it considers the organizational structure and the business process in an integrated perspective, however, the POFI model does not consider the availability and task capability of each resources.

B. DATA MODEL FOR INCORPORATING BUSINESS PROCESSES AND ORGANIZATIONAL STRUCTURE

An increasing amount of information about business process execution is recorded by information systems such as ERP, CRM, BPMS in the form of so-called ''event logs'' (e.g., transaction logs, audit trails) [33]–[36].

Recently, process mining research has considered not only the control-flow perspective, but also the organizational perspective as an important aspect for analyzing organizations [7], [17], [19]. However, the inter-related effects between organizational structure and business processes have not been considered. Although big data was considered to improve business processes, the organizational structure was not considered in their research [6], [17], [37].

In addition, the information about organizational structure was very restricted because of their limited process logs [19], [38], [39]. Although the integrated organizational ontology that can represent various relationships between organizational units was suggested to complement these limitations, it does not define the types of organizational units nor quantitatively evaluate the effects of various organizational unit relationships on business process performance [40]–[44].

To overcome these limitations, the data model that incorporates the business process information and organizational structure information such as task capability and availability of human resources.

C. EVALUATION AND REDESIGN METHODOLOGY OF BUSINESS PROCESS AND ORGANIZATIONAL STRUCTURE

There have been some attempts to overcome the limitation of previous research efforts. Reference [22] discussed the impact of organizational resources to consider them in the modeling of business processes. Reference [10] addressed the theoretical gaps between BPR and organizational restructuring (OR) in organizational change and proposed the ''process re-engineering-oriented organizational change exploratory simulation system'' (PROCESS) for facilitating organizational change in BPR and OR simultaneously. However, they considered only a partial perspective of organizational structures, such as organizational resources and departments. Reference [5] suggested the modeling framework for business processes reengineering using big data analytics. However, they also did not consider the organizational structure. Furthermore, they did not address how to incorporate the effects of the organizational structure into business process analysis.

Reference [4] suggested an approach for evaluating the fit between business processes and organizational structures in terms of the overhead incurred by organizational structures for transfers of tasks in business processes. This approach, however, only considered the concept of transfers of task, and it did not represent the integrated evaluation methodology of both business processes and organizational structure. Reference [45] proposed a business process simulation model considering the transfer of task that occurs during business process execution. However, both studies did not consider the characteristics of human resources such as resource availability and task capability. Moreover, they did not consider redesigning the process or organizational structure. In particular, even though most studies use the simulation techniques to more effectively predict the effects of process redesign [23], [35], [45]–[49] and business analysts simulated redesigned processes to validate the processes and identify possible problems caused by the changes in process [10], [23], [24], [47], [50], existing methodologies do not consider business process and organizational structure comprehensively to redesign them.

To evaluate and redesign the business process and the organizational structure comprehensively, a comprehensive data model for business process simulation incorporating the effect of their organizational structure must be defined, and also the simulation system must be developed using the proposed data model as an input.

III. BUSINESS PROCESS AND ORGANIZATIONAL ANALYTICS

A. SIMULATION SYSTEM FOR BUSINESS PROCESS AND ORGANIZATIONAL STRUCTURE

1) REQUIRED DATA MODELS FOR THE SIMULATION

From the perspective of business process and organizational structure, data definitions are provided by dividing the necessary elements into 4 categories: 1) Business Process, 2) Organizational Structure, 3) Performer, and 4) Manager; the four categories are defined in Table 1 below.

In the *Process Definition*, business process models operated by the company, their generation time distribution in which each process model generates a new process instance, and the control-flow probability of exclusive task combination is included.

In the *Performer Definition*, tasks that each performer can executes and their task capability how long it takes to perform each task is included. In particular, the effect of the individual capability of each performer on the performance of

TABLE 1. Data definition for business process simulation.

Data Definition	Description
Business Process Definition	➢ Task configurations (type of tasks and control-flow information) ➢ Generation time distribution of each business process
Performer Definition	➢ Task execution capability of performers ➢ Task execution time distribution of performers
Organizational Structure Definition	➢ Type of resource (Performer or Manager) ➢ Relationships of resources in organizational structure
Manager Definition	➢ Availability (available probability and their time distribution) of managers ➢ Their transfer-of-task time distribution

the process can be derived by this definition. Further, all time distributions are assumed to have a triangular distribution.

Organizational Structure Definition defines the types of resources (Manager or Performer) and their relations in the organization. In this study, a performer exists only at the lowest level of organizational structure, and a manager exists at higher level than the performer to manage performers. The transfer-of-task between performers is executed according to the path defined in the Organizational Structure Definition.

The *Manager Definition* defines the probability of availability, unavailable time distribution, and available time distribution of each manager. It is assumed that the manager can participate in tasks except business process management. To reflect this feature, the availability of the manager is changed randomly. Therefore, even if a transfer-of-task occurs, if the current manager is unavailable, the transfer-of-task cannot be proceeded.

In this study, four definitions for business process simulation reflecting the effect of the organizational structure are suggested. These data definitions can be effectively extracted from various enterprise information systems such as ERP and BPMS.

2) BP SIMULATION PROCEDURE WITH EFFECTS OF ORGANIZATIONAL STRUCTURE

In the previous subsubsection, the four data definitions were presented to simulate a business process with the effects of organizational structure. Even though there are already business process simulation procedures in the existing research, they do not fit our suggested data models and consider the effect of organizational structure. Therefore, a new business process simulation procedure needs to be designed. For the sake of clarity, the example of this procedure is illustrated in Figure 2.

The business process models defined in *Process Definition* will create a new process instance according to the defined process generation time distribution. Tasks that can be performed by Performers and their task execution time distributions are defined in *Performer Definition*. Among the performers who can perform *Task_A*, *Performer_A* is selected, and it takes as long as the time required for the task execution time distribution of *Performer_A*. Further, *Performer_D* is also selected to execute *Task_B*. Then, the transfer-of-task between *Performer_A* and *Performer_D* is defined by the *Organizational Structure Definition*. Managers between *Performer_A* and *Performer_D* are (*Manager_B, Manager_A,* and *Manager_C*), and all managers should execute the transfer-of-task. All manager is assumed to perform other management tasks in their organization except transfer-of-task in Business Process. Therefore, the availability of managers is changed based on the *Manager Definition*. If the manager must perform the transfer-of-task at present, but he is unavailable at that time, then transfer-of-task cannot be performed. After all transfer-of-tasks from *Performer_A* to *Performer_D* have been performed, *Performer_D* can execute *Task_B*.

1) Generate new *Process_A* Instance based its process generation time distribution which is defined in Process Definition
2) Assign *Task_A* to *Performer_A*, then *Performer_A* executes *Task_A*.
3) *Manager_B* is unavailable when *performer_A* completes *Task_A* because Manager_B is unavailable at that time
4) *Manager_B* become available, then *Manager_B* executes transfer-of-task between *Task_A* and *Task_B*
5) *Manager_A* executes transfer-of-task between *Task_A* and *Task_B*
6) *Manager_C* executes transfer-of-task between *Task_A* and *Task_B*
7) Assign *Task_B* to *Performer_D*, then *Performer_D* executes *Task_B*.

3) BP SIMULATION SYSTEM FRAMEWORK

In this subsubsection, the implemented system to simulate the business process automatically according to the BP simulation procedure is described. The architecture of this BP simulation system is shown in Figure 3.

This system requires four definitions (*Process Definition, Organizational Structure Definition, Manager Definition,*

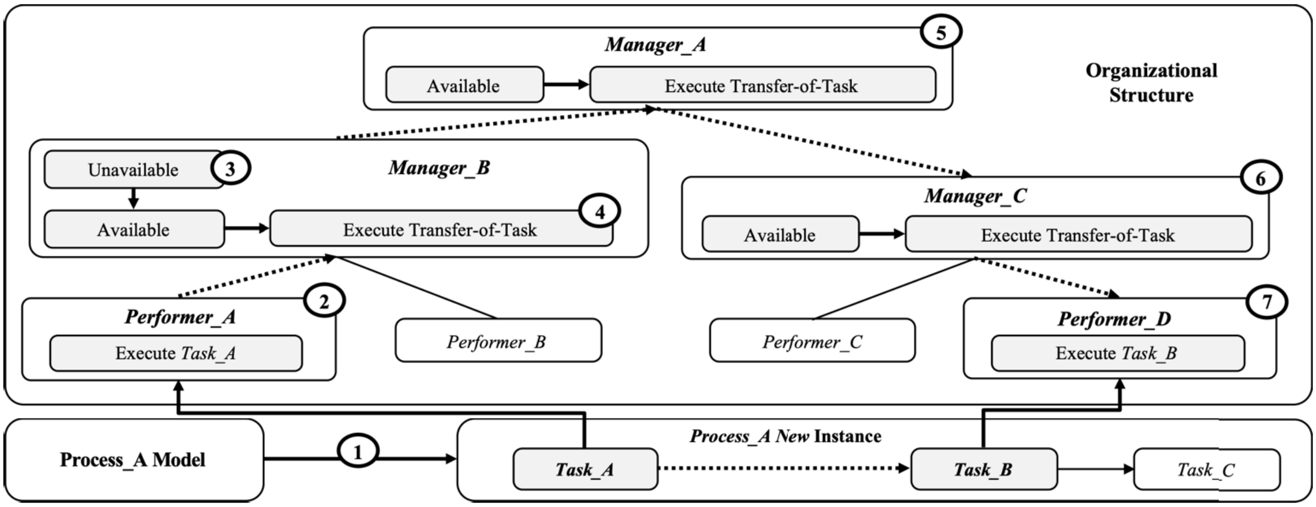


FIGURE 2. Example of BP simulation procedure.

Performer Definition) to run the simulation. New process instances are created by their generation time distribution periodically, and each process instance also creates a new task and transfer-of-task. The task and the transfer-of-task are assigned to a performer who can execute each task, and the manager who executes the transfer-of-task, respectively. All tasks and transfer-of-task in each process instances are completed, and the corresponding process instance is also terminated. When the simulation is finished, all log data generated in this simulation is accumulated in the database, and the data are extracted to the.csv format. This simulation system is developed using the programming language, *python* and its libraries, especially simulation library *simpy*.

In addition, this system supports the methodology to find the process-oriented organizational structure by evaluating the fitness of each organizational structure.

B. METHODOLOGY FOR FINDING PROCESS-ORIENTED ORGANIZATIONAL STRUCTURE

There exists a large number of resources in a real enterprise. As the number of resources in an organization increases, so the number of applicable organizational structure exponentially. There also exists huge amount of organizational structure alternatives which could be applied to their organization. Therefore, it is necessary to develop a methodology that derives the most process-oriented organizational structure among the various organizational structure alternatives efficiently.

For that efficiency, a genetic algorithm (GA) is used to search the optimal solution effectively. A GA is a metaheuristic methodology inspired by the natural selection process that belongs to evolutionary algorithms (EAs). The GAs are commonly used to generate high-quality solutions to search problems; further, they have been used to discover a business process model from event logs [51], find the optimal business process [52], [53], and find a valid business process reference model [54]; however it has not been applied to find the optimal organizational structure. The organizational structure refers to the communication channel used when resources perform each task of a business process. The global structure and local structure of the organizational structure both affect these communications and the business process performance, the genetic algorithm is the most efficient method to search process-oriented organizational structure for considering both of them in a balanced way. The Framework of methodology for finding process-oriented organizational structure is shown in Figure 4.

1) FITNESS: PROCESS-ORIENTATION

The most appropriate organizational structure can be defined differently depending on the context and purpose of the company. The objective of this study is to find a process-oriented organizational structure designed to perform more process instances in a given simulation time. As shown in Figure 5, various candidates of organizational structure are simulated to execute the same business process model and evaluate how many process instances each of the organizational structures are performed to determine the suitability of the organizational structure.

$$\sum_{i}^{n} (ProcessCount_i) * (ProcessWeight_i)$$

$$n = num.of\ \ Process\ Models$$

2) MUTATION

In this study, we define three mutation methods that are used in the search of solutions in the GA. In the case of the first method—mutation by changing edge randomly—the new organizational structure is explored by randomly changing the existing organizational structure, and it is used as a

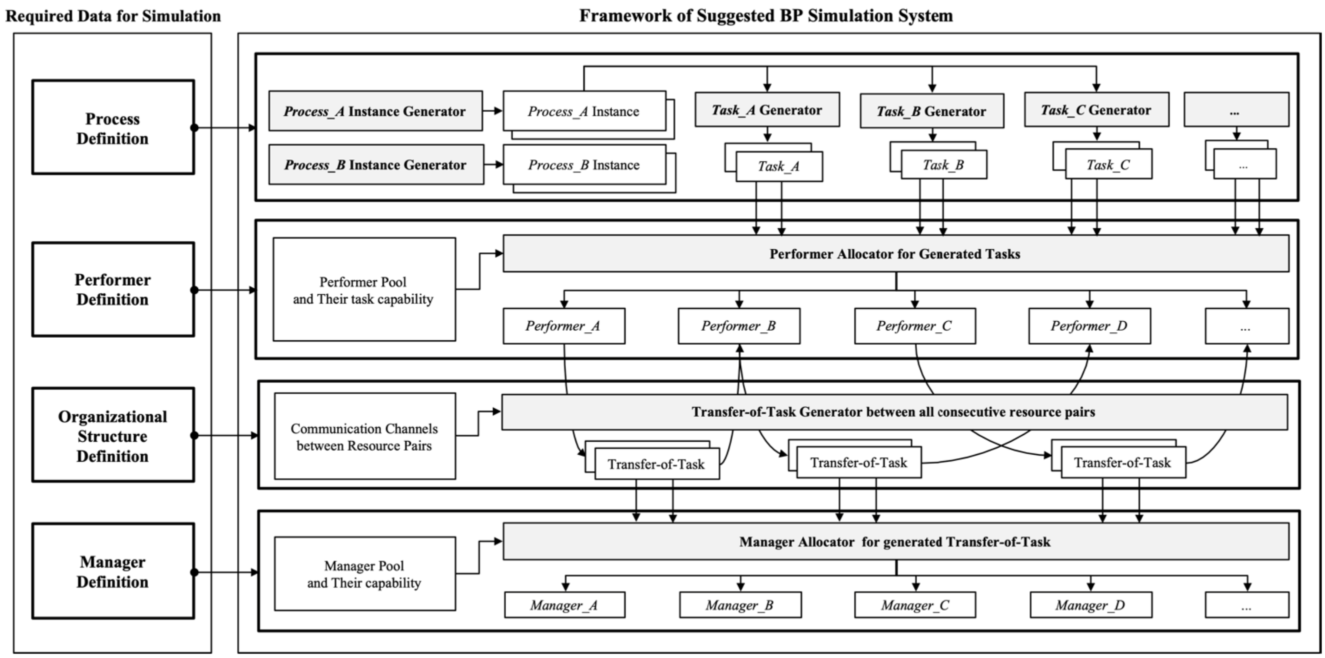


FIGURE 3. Business process simulation system architecture.

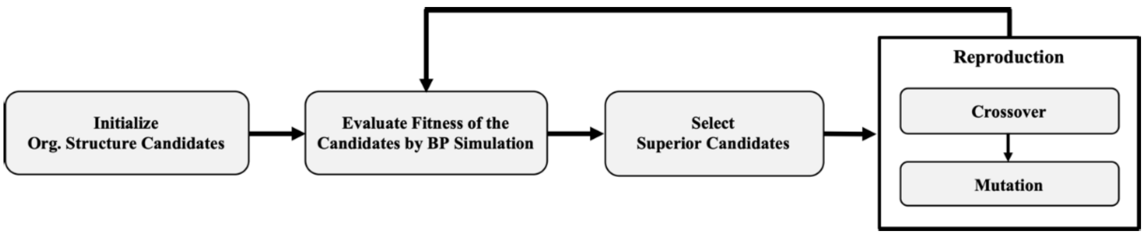


FIGURE 4. Framework of methodology for finding process-oriented organizational structure.

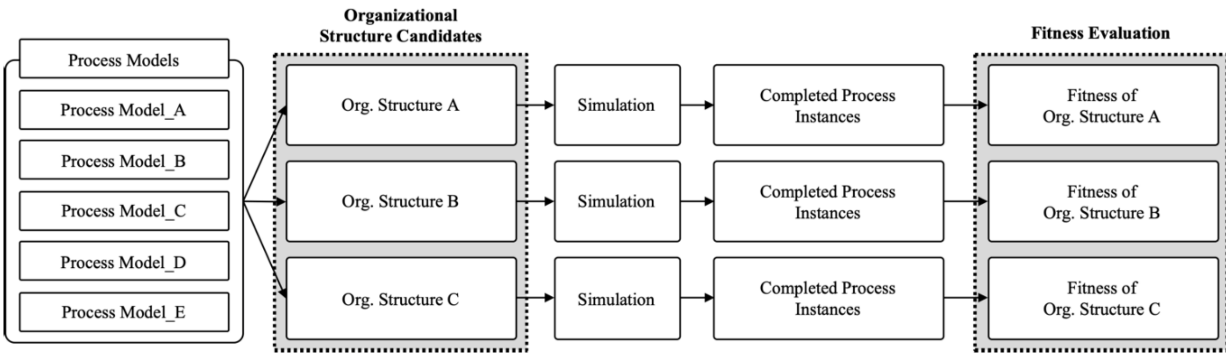


FIGURE 5. Fitness evaluation of organizational structure by BP simulation.

benchmark algorithm. As shown in Figure 6, various relations existing in the organizational structure are randomly changed to form a new organizational structure, and the following steps are performed.

1) Remove the relationship in the existing organizational structure randomly
2) Add new relation between resource pair to the organizational structure randomly
3) Derive new organizational structure candidate

In the second method—mutation by making bottleneck resource pair closer—a new organizational structure is derived using the resource pair that spends a considerable

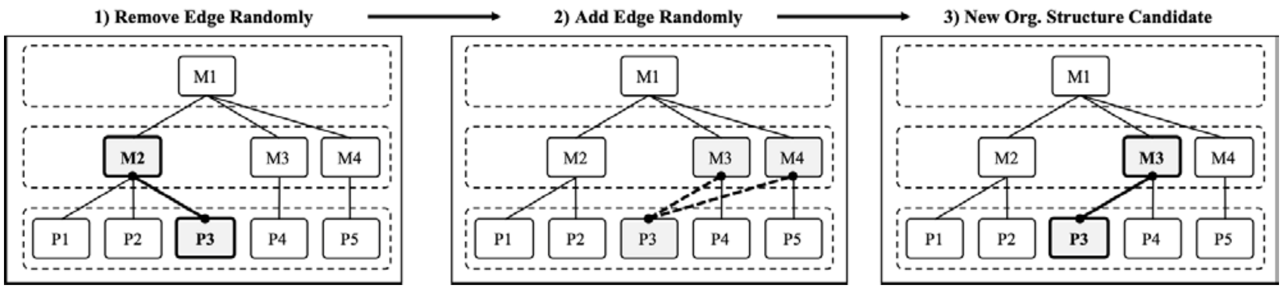


FIGURE 6. Procedure of mutation by changing edge randomly.

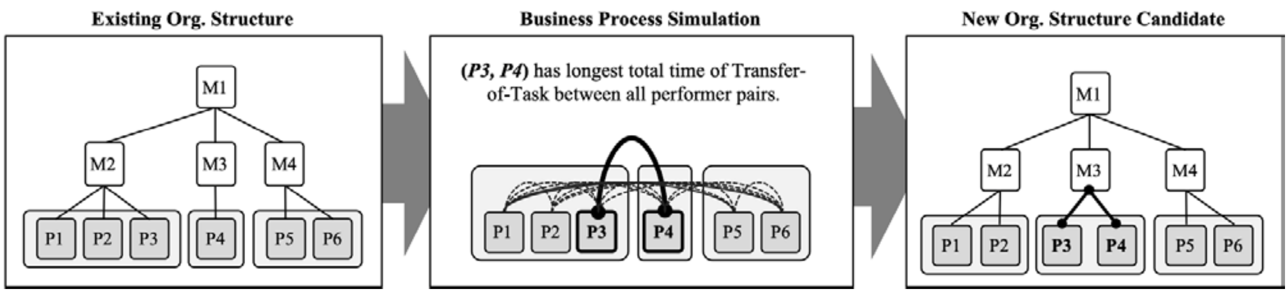


FIGURE 7. Procedure of mutation by making bottleneck resource pair closer.

amount of time in their transfer-of-task be located closer. As it was shown in Figure 7, summation of transfer-of-task time between P3 and P4 are much longer than other pairs. Then, the organizational structure could be mutated to make P3 and P4 be closer in order to reduce the whole transfer-of-task time. Then, new organizational structure candidate is derived by moving P3 under M3, a manager of P4.

The summation of the transfer-of-task of all resource pairs at the same level is calculated by analyzing the process log. Resource pairs that have a longer transfer-of-task time than others have a high possibility to be a bottleneck to hinder process executions. Therefore, that kind of resource pairs should be close by managing them using the same manager to process instances faster.

In the third method— Edge Betweenness Centrality (EBC)-based mutation—can be used to efficiently find an appropriate process-oriented organizational structure when there are considerable human resources in the organizational structure.

Complete bipartite network weighted by average transfer-of-task time is created between each resource level. A virtual edge that does not exist in the current organizational structure is estimated using the weighted (summation of transfer-of-task time) sum of their shortest path divided by their shortest path length. Then, by analyzing the edge betweenness centrality for this network, the higher the edge betweenness centrality, the more likely is the edge to be mutated. This mutation method is expected to work for an organizational structure with a considerable number of human resources. Procedure of EBC based mutation is following and it is shown in Figure 8.

1) Calculate all edge weight (sum of Transfer-of-Task time between resources)
2) Estimate weight of virtual edges which do not exist in the existing organizational structure using the weighted sum of their shortest path divided by their shortest path length.
3) Add edge which has the highest edge betweenness centrality and remove the existing edge
4) Derive mutated organizational structure

3) CROSSOVER

In the crossover step, a new organizational structure is created by exchanging the manager-structure and the performer-structure existing in the organizational structure, such as in Figure 9, to search for a new organizational structure. Performer-structure means all resources of the bottom level in the organizational structure, and manager-structure means all resource and their relations except performer-structure.

IV. VALIDATION AND PROTOTYPE

A. VALIDATION OF THE METHODOLOGY

To validate the suggested methodology to find the process-oriented organizational structure in this study, this methodology was applied for small and medium virtual enterprises. As mentioned previously, the possible solution of organizational structures would be large if there are a considerable number of human resources. To validate the superiority of our methodology, two case studies were conducted for each of the small and medium organizations. Even though we had requested to lots of company for the data about their

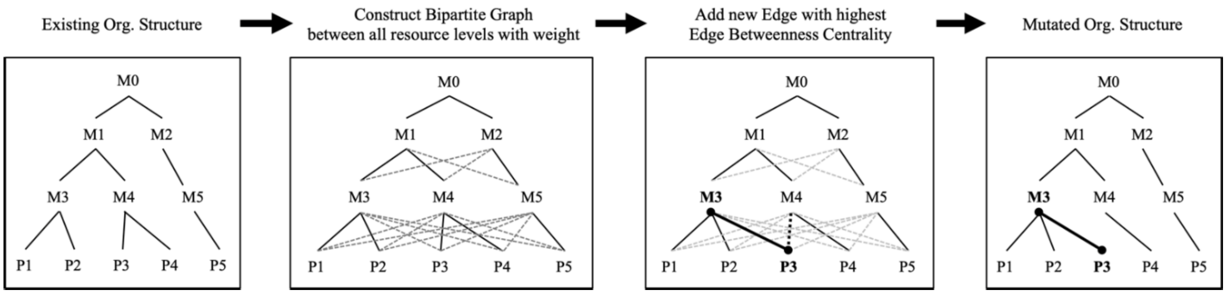


FIGURE 8. Procedure of edge-betweenness-centrality based mutation.

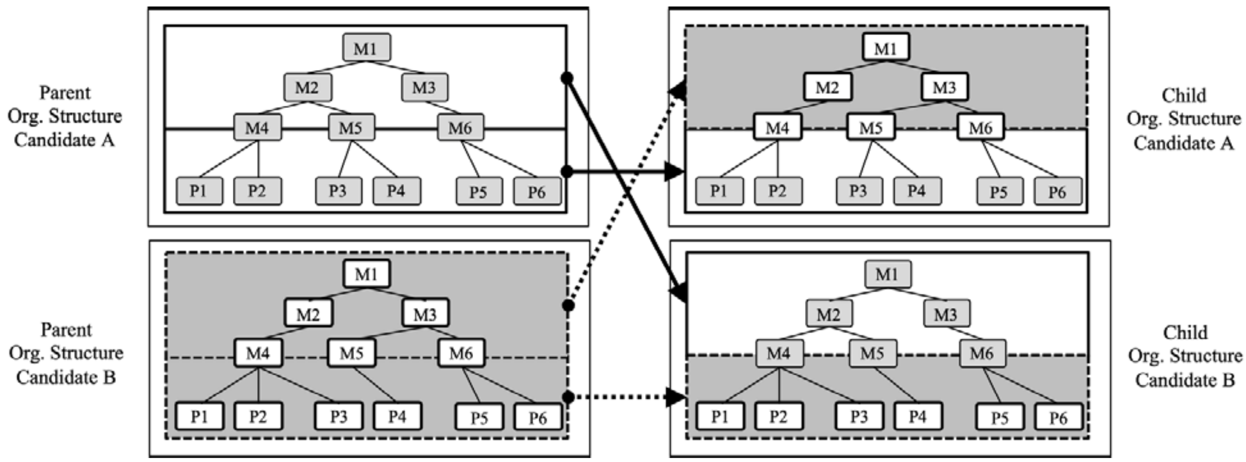


FIGURE 9. Procedure of crossover.

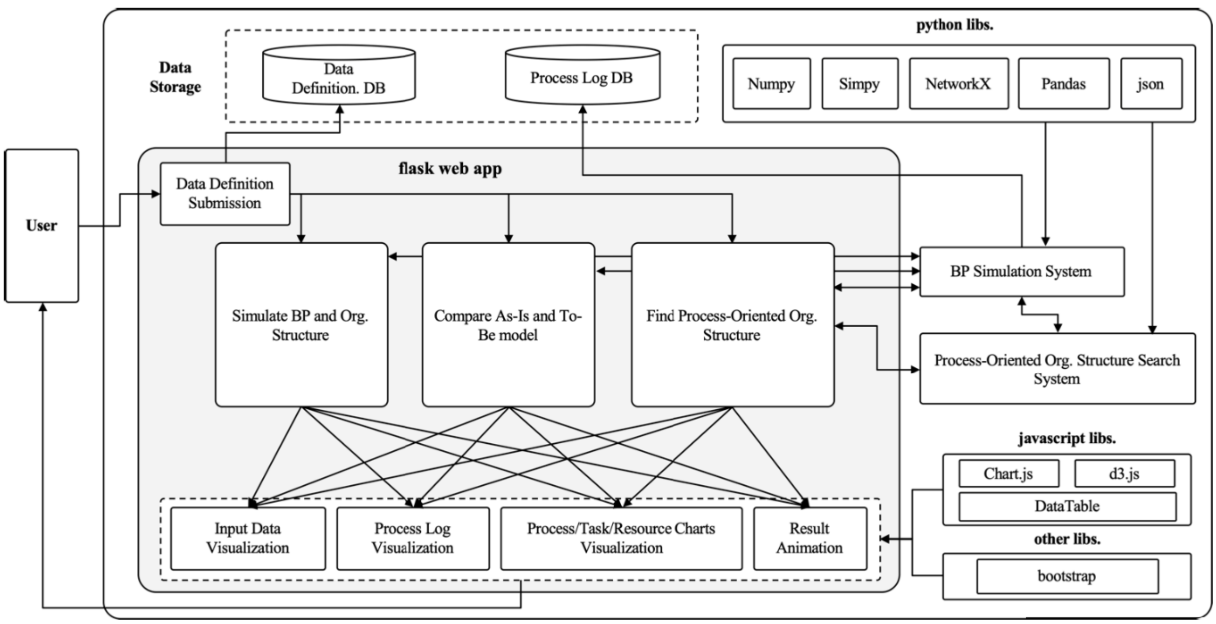


FIGURE 10. Architecture of suggested business process and organizational structure simulation and redesign system.

business process and organizational structure in order to validate the methodology and system presented in this study, it was difficult obtain because they are very confidential data for most companies. Therefore, all data definitions including business processes and organizational structure were designed by referring to the interviews of the relevant people.

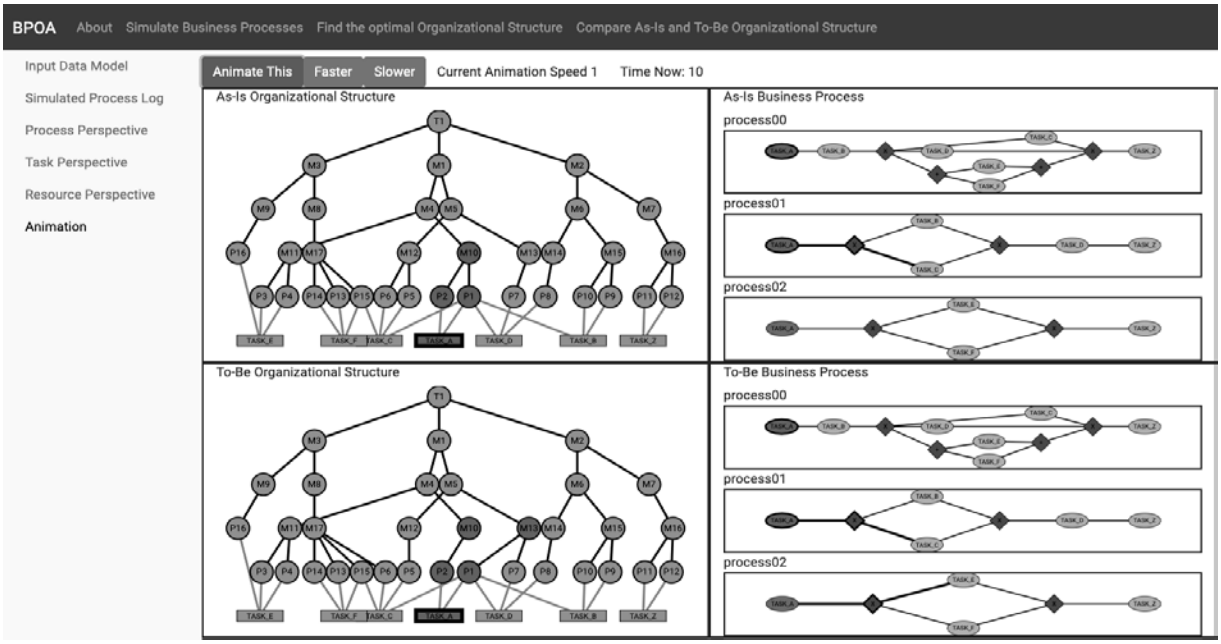


FIGURE 11. **Screenshot of the implemented comprehensive simulation and redesign system for business process and organizational structure.**

TABLE 2. **Description of data definitions for case study.**

Data Definition	Description	
	Small Organization	*Medium Organization*
Process Definition	5 Process models with different task configuration and generation time distributions ex) *Task_A ➔ Task_B ➔ XOR(Task_C, Task_D, AND(Task_E, Task_F) ➔ Task_Z*	
Performer Definition	21 performers with different task capabilities	37 performers with different task capabilities
Manager Definition	9 managers with different availability and transfer-of-task capabilities	14 managers with different availability and transfer-of-task capabilities
Organizational Structure Definition	Resources in Each level: 1, 2, 7, 21	Resource in Each level: 1, 3, 10, 37
Genetic Parameters		
Generation_N	10	10
Mutation_N	8	8
Crossover_N	8	8
Survival_N	8	8
Simulation _time	1000	500

TABLE 3. **Validation result.**

	Mutation Method		
	Mutation by changing edges randomly (benchmark)	Mutation by Making bottleneck Resource pair closer	Edge betweenness centrality(EBC) based Mutation
Small Enterprise	69.0	**129.0**	**88.0**
Medium Enterprise	20.0	**39.0**	**30.0**

Case-studies for the small-sized and medium-sized companies were conducted respectively to validate the methodology for finding the process-oriented organizational structure. The descriptions of each applied data definitions and the genetic parameters are as listed in Table 2.

Value in Table 3 means the number of completed business process instances in each simulation experiment. As shown in Table 3, we found that the two mutation methods suggested in this study were much more effective than the benchmark random mutation method. The methodology is also good for both small enterprise and medium enterprise. The organizational structure derived by the suggested methodology would execute more business processes than the existing organizational structure or the other solutions.

Even though this case studies were conducted by limiting the genetic parameter to a small value, sufficient results were obtained. In a further study, sensitivity analysis will be conducted to understand how genetic parameter have impact on the result. Through sensitivity analysis for genetic parameters, it can be understood how parameter works to find process-oriented organizational structure and adjust the parameter to find the organizational structure efficiently for various organizational structure. Moreover, the more case study for a large-scale company will be conducted to validate this methodology and system.

B. PROTOTYPE AND SYSTEM ARCHITECTURE

Most of the previous studies in the business process field haven't considered the organizational structure, and thus failed to manage the various changes within the enterprise systematically. In order to extend and encourage the existing studies, the prototype system including all the methodology presented in this study were implemented. This system especially will be expected to be a cornerstone for many researchers who develop methodologies to effectively analyze and redesign various elements of the organization in the future.

The system architecture of this system is shown in Figure 10. The prototype system was developed using the programming language *python* and the related libraries (*Numpy, Simpy, NetworkX, Pandas, json*) were employed to perform business process simulation based on the suggested data definition and to explore the optimal process-oriented organizational structure in the back-end. In particular, each service is implemented on the web by *flask*, python lightweight WSGI web application framework. Moreover, the visualization of various charts in the perspectives of Process/Task/Resource and the animation of the simulation result are developed using programming language *Javascript* and related libraries *d3.js* and *chart.js*. The entire system is developed as a web system to be used by companies and researchers. In this implemented system, Business Process and Organizational Analytics (BPOA), a screenshot to compare the business process simulation between As-Is model and To-Be model is shown in Figure 11.

Through this BPOA system, users can easily comprehend what changes occur when organizational structures or business processes are redesigned. In addition, it is also possible to find which organizational structure is better suited to carry out current business processes and how effective it is.

V. CONCLUSION

In this paper, Business Process and Organizational Analytics to analyze and manage performance of enterprise from the perspectives of business process and organizational structure is proposed. This study comprised the following three detailed studies.

First, four data definitions reflecting on business process and organizational structure were defined to simulate the business activities of companies. The four data definitions are <Process Definition>, <Performer Definition>, <Manager Definition>, and <Organizational Structure Definition>. The proposed four data models support the simulation considering various aspects such as the characteristics of the process, the task capability of the human resource in the organization, and the organizational structure.

Second, the system that can perform business process simulation using the suggested data definition as an input is implemented. In particular, the existing business process simulation methodologies and systems do not consider the organizational structure and have not achieved meaningful results. On the other hand, the characteristics of the organizational structure and resource availability were reflected in this study. This system can also be used to identify how an organization's process performance changes over a variety of situations, including: 1) changes in processes, 2) changes in organizational structure, and 3) changes in the task ability of resources.

Third, the methodology for exploring the most process-oriented organizational structure is developed. Previous studies have failed to find and validate process-oriented organizational structure. In this study, a simulation system reflecting the effects of the organizational structure is developed and also the methodology for searching the most process-oriented organizational structure is suggested. It is expected that this system will be useful for exploring the process-oriented organizational structure when the situation of the organization changes in the future.

Thus, this study suggests a system and methodology to simulate the enterprise from the perspective of business process and organizational structure. Especially, it is implemented as web system for practical use.

REFERENCES

[1] T. H. Davenport, *Process Innovation: Reengineering Work Through Information Technology*. Cambridge, MA, USA: Harvard Business Press, 1993.

[2] W. M. P. van der Aalst, A. H. M. Ter Hofstede, and M. Weske, "Business process management: A survey," in *Proc. 1st Int. Conf. Bus. Process Manag.* (Lecture Notes in Computer Science), vol. 2678, 2003, pp. 1–12.

[3] W. M. P. van der Aalst, B. F. van Dongen, J. Herbst, L. Maruster, G. Schimm, and A. J. M. M. Weijters, "Workflow mining: A survey of issues and approaches," *Data Knowl. Eng.*, vol. 47, pp. 237–267, Nov. 2003.

[4] S. N. Hearn and I. Choi, "Creating a process and organization fit index: An approach toward optimal process and organization design," *Knowl. Proc. Manage.*, vol. 20, no. 1, pp. 21–29, 2013.

[5] G. Park, L. Chung, and L. Khan, "A modeling framework for business process reengineering using big data analytics and a goal-orientation," in *Proc. 11th Int. Conf. Res. Chall. Inf. Sci. (RCIS)*, 2017, pp. 21–32.

[6] A. Polyvyanyy, C. Ouyang, A. Barros, and W. M. van der Aalst, "Process querying: Enabling business intelligence through query-based process analytics," *Decis. Support Syst.*, vol. 100, pp. 41–56, Aug. 2017.

[7] W. Van Der Aalst, *Process Mining: Discovery, Conformance and Enhancement of Business Processes*. vol. 2, Heidelberg, Germany: Springer, 2011.

[8] A. J. M. Weijters, W. M. P. van der Aalst, B. F. van Dongen, C. W. Günther, R. S. Mans, A. A. De Medeiros, and H. M. W. Verbeek, "Process mining with ProM," in *Proc. 19th Belgian-Dutch Conf. Artif. Intell. (BNAIC)*. Utrecht, The Netherlands: Utrecht Univ., 2007, pp. 420–425.

[9] R. Gardner, *The Process-Focused Organization: A Transition Strategy for Success*. Milwaukee, WI, USA: Quality, 2004.

[10] C. K. Chen and C. H. Tsai, "Developing a process re-engineering-oriented organizational change exploratory simulation system (PROCESS)," *Int. J. Prod. Res.*, vol. 46, no. 16, pp. 4463–4482, 2008.

[11] R. L. Daft, *Organization Theory and Design*. Cincinnati, OH, USA: South-Western, 2004.

[12] M. Hammer and S. Stanton, "How process enterprises really work," *Harvard Bus. Rev.*, vol. 77, pp. 108–120, Nov. 1999.

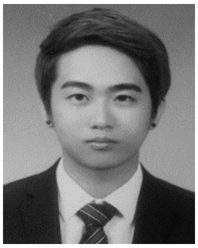
[13] F. D. Harvey, *Re-Engineering: The Critical Success Factors*. London, U.K.: Business Intelligence, 1995.

[14] D. Marchand and M. Stanford, "Business process redesign: A framework for harmonizing people, information and technology," in *Business Process Change: Reengineering Concepts, Methods and Technologies*. Hershey, PA, USA: IGI Global, 1995, pp. 35–56.

[15] H. Smith and P. Fingar, *Business Process Management: The Third Wave*, vol. 1. Tampa, FL, USA: Meghan-Kiffer, 2003.
[16] C. Shin and J. Park, "Classifying social enterprises with organizational culture, network and socioeconomic performance: Latent profile analysis approach," *J. Open Innov. Technol. Market Complex.*, vol. 5, no. 1, p. 17, 2019.
[17] A. Vera-Baquero, R. Colomo-Palacios, and O. Molloy, "Business process analytics using a big data approach," *IT Prof.*, vol. 15, no. 6, pp. 29–35, Nov. 2013.
[18] W. Liu, P. Wang, Y. Du, M. Zhou, and C. Yan, "Extended logical Petri nets-based modeling and analysis of business processes," *IEEE Access*, vol. 5, pp. 16829–16839, 2017.
[19] W. Zhao and X. Zhao, "Process mining from the organizational perspective," in *Proc. Adv. Intell. Syst. Comput.* Berlin, Germany: Springer, 2014, pp. 701–708.
[20] B. Lee, J. H. Park, L. Kwon, Y. H. Moon, Y. Shin, G. Kim, and H. J. Kim, "About relationship between business text patterns and financial performance in corporate data," *J. Open Innov.*, vol. 4, no. 1, p. 3, 2018.
[21] J. Becker, M. Kugeler, and M. Rosemann, Eds., *Process Management: A Guide for the Design of Business Processes*. Berlin, Germany: Springer-Verlag, 2013.
[22] N. Russell, W. M. van der Aalst, A. H. Ter Hofstede, and D. Edmond, "Workflow resource patterns: Identification, representation and tool support," in *Advanced Information Systems Engineering*. Berlin, Germany: Springer, 2005, pp. 216–232.
[23] J. Barjis and A. Verbraeck, "The relevance of modeling and simulation in enterprise and organizational study," in *Workshop on Enterprise and Organizational Modeling and Simulation* (Lecture Notes in Business Information Processing). Berlin, Germany: Springer, 2010, pp. 15–26.
[24] J. Januszczak and G. Hook, "Simulation standard for business process management," in *Proc. Winter Simul. Conf.*, 2011, pp. 741–751.
[25] P. Lawrence, "Workflow handbook," in *Workflow Management Coalition*. New York, NY, USA: Wiley, 1997
[26] W. M. P. van der Aalst and K. van Hee, *Workflow Management: Models, Methods, and Systems*. Cambridge, MA, USA: MIT Press, 2002.
[27] T. W. Malone and K. Crowston, "The interdisciplinary study of coordination," *ACM Comput. Surv.*, vol. 26, no. 1, pp. 87–119, 1994.
[28] H. Mintzberg, *The Structuring of Organisations: A Synthesis of the Research*. Englewood Cliffs, NJ, USA: Prentice-Hall, 1979.
[29] A. Greasley, "Using process mapping and business process simulation to support a process-based approach to change in a public sector organisation," *Technovation*, vol. 26, no. 1, pp. 95–103, 2006.
[30] G. Zülch and T. Grobel, "Shaping the organization of order processing with the simulation tool FEMOS," *Int. J. Prod. Eco*, vols. 46–47, pp. 251–260, 1996.
[31] A. Rozinat, R. S. Mans, M. Song, and W. M. P. van der Aalst, "Discovering simulation models," *Inf. Syst.*, vol. 34, no. 3, pp. 305–327, May 2009.
[32] J. Vom Brocke and M. Rosemann, *Handbook on Business Process Management*. Heidelberg, Germany: Springer, 2010, p. 3.
[33] S. Sakr, Z. Maamar, A. Awad, B. Benatallah, and W. M. P. van der Aalst, "Business process analytics and big data systems: A roadmap to bridge the gap," *IEEE Access*, vol. 6, pp. 77308–77320, 2018.
[34] X. Gao, "Towards the next generation intelligent BPM–in the era of big data," in *Business Process Management* (Lecture Notes in Computer Science). Berlin, Germany: Springer, 2013, pp. 4–9.
[35] W. van der Aalst and E. Damiani, "Processes meet big data: Connecting data science with process science," *IEEE Trans. Serv. Comput.*, vol. 8, no. 6, pp. 810–819, Nov./Dec. 2015.
[36] S. Fosso Wamba and D. Mishra, "Big data integration with business processes: A literature review," *Bus. Process Manag. J.*, vol. 23, no. 3, pp. 477–492, 2017.
[37] A. Vera-Baquero, R. Colomo Palacios, V. Stantchev, and O. Molloy, "Leveraging big-data for business process analytics," *Learn. Organ.*, vol. 22, no. 4, pp. 215–228, 2015.
[38] M. Song and W. M. P. van der Aalst, "Towards comprehensive support for organizational mining," *Decis. Support Syst.*, vol. 46, no. 1, pp. 300–317, Dec. 2008.
[39] W. M. P. Van Der Aalst, H. A. Reijers, and M. Song, "Discovering social networks from event logs," *Comput. Supported Coop. Work*, vol. 14, no. 6, pp. 549–593, 2005.
[40] R. Sellami, W. Gaaloul, and S. Moalla, "An ontology for workflow organizational model mining," in *Proc. IEEE 21st Int. Workshop Enabling Technol., Infrastruct. Collab. Enterpr.*, Jun. 2012, pp. 199–204.
[41] J. H. Kim and S. Jung, "Study on CEO characteristics for management of public art performance centers," *J. Open Innov.*, vol. 1, no. 1, p. 5, 2015.
[42] K. Nam, B. Kim, and B. Carnie, "Service open innovation; design elements for the food and beverage service business," *J. Open Innov., Technol., Market, Complex.*, vol. 4, no. 4, p. 53, 2018.
[43] F. Bento and L. Garotti, "Resilience beyond formal structures: A network perspective towards the challenges of an aging workforce in the oil and gas industry," *J. Open Innov., Technol., Market, Complex.*, vol. 5, no. 1, p. 15, 2019.
[44] T. Rakthai, S. Aujirapongpan, and K. Suanpong, "Innovative capacity and the performance of businesses incubated in university incubator units: Empirical study from universities in Thailand," *J. Open Innov., Technol., Market, Complex.*, vol. 5, no. 2, p. 33, 2019.
[45] J. Lee, S. Sung, M. Song, and I. Choi, "A business process simulation framework incorporating the effects of organizational structure," *Int. J. Ind. Eng.*, vol. 22, no. 4, pp. 454–466, 2015.
[46] A. Greasley, "Using business-process simulation within a business-process reengineering approach," *Bus. Process Manag. J.*, vol. 9, no. 4, pp. 408–420, 2003.
[47] A. Gregoriades and A. Sutcliffe, "A socio-technical approach to business process simulation," *Decis. Support Syst.*, vol. 45, no. 4, pp. 1017–1030, 2008.
[48] R. Heinrich, P. Merkle, J. Henss, and B. Paech, "Integrating business process simulation and information system simulation for performance prediction," *Softw. Syst. Model.*, vol. 16, no. 1, pp. 257–277, 2017.
[49] W. M. P. Van der Aalst, "Business process simulation revisited," in *Proc. Workshop Enterprise Organizational Modeling Simulation*. Berlin, Germany: Springer, 2010, pp. 1–14.
[50] G. M. Giaglis, R. J. Paul, and V. Hlupic, "Integrating simulation in organizational design studies," *Int. J. Inf. Manag.*, vol. 19, no. 3, pp. 219–236, 1999.
[51] W. M. P. Van der Aalst, A. A. De Medeiros, and A. J. M. Weijters, "Genetic process mining," in *Proc. Int. Conf. Appl. Petri Nets* (Lecture Notes in Computer Science). Berlin, Germany: Springer, 2005, pp. 48–69.
[52] M. Wibig, "Dynamic programming and genetic algorithm for business processes optimisation," *Int. J. Intell. Syst. Appl.*, vol. 5, no. 1, pp. 44–51, 2012.
[53] I. Hofacker and R. Vetschera, "Algorithmical approaches to business process design," *Comp. Op. Res.*, vol. 28, no. 13, pp. 1253–1275, 2001.
[54] B. N. Yahya, H. Bae, J. Bae, and D. Kim, "Generating valid reference business process model using genetic algorithm," *Int. J. Innov. Comput. Inf. Control*, vol. 8, no. 2, pp. 1463–1477, 2012.

SEUNGHOON LEE was born in Cheonan, South Korea, in 1986. He received the B.E. degree in industrial and management engineering (IME) from the Pohang University of Science and Technology (POSTECH), in 2012, where he is currently pursuing the Ph.D. degree in IME with the POSTECH Graduate School. His current research interests include machine learning, network analysis, and process simulation.

INJUN CHOI received the B.S. degree in computer science/statistics from Seoul National University, in 1981, and the M.S. degree in computer science and the Ph.D. degree in management information systems from The University of Texas at Austin, in 1987 and 1991, respectively. He is currently a Professor at the Department of Industrial and Management Engineering, Pohang University of Science and Technology (POSTECH). His research interests include business process management, data and knowledge management, and management information systems.



HOKYEOM KIM was born in Seoul, South Korea, in 1994. He received the B.S. degree from the Department of Industrial and Management Engineering (IME), Pohang University of Science and Technology (POSTECH), in 2016, where he is currently pursuing the Ph.D. degree in IME with the POSTECH Graduate School. His current research interests include information systems and human resource management (HRM).

JITAEK LIM was born in Daegu, South Korea, in 1992. He received the B.S. degree in information technology management (ITM) from the Seoul National University of Science and Technology, in 2017. He is currently pursuing the Ph.D. degree with the Department of Industrial and Management Engineering, Pohang University of Science and Technology (POSTECH). His current research interests include knowledge management, information systems, and natural language processing (NLP).

SANGHYUN SUNG received the B.S. degree in electrical, electronic, and computer engineering from Hanyang University, in 2007, and the Ph.D. degree in technology and innovation management from the Pohang University of Science and Technology (POSTECH), in 2016. His current research study is the entrepreneurial business process (EBP) that reflects how to search and manage the necessary activities, resources, and stakeholders for managing startups, and focuses on role of resource and stakeholder of startup firms on their survival using resource management, organization theory, stakeholder theory, and business process management.