ICIC Express Letters
Part B: Applications
Volume **7**, Number **1**, January **2016**

ICIC International ©2016 ISSN 2185-2766
pp. **43–49**

COMPARATIVE EVALUATION OF QUANTITATIVE EFFECTS OF INFORMATION SYSTEMS IMPLEMENTATION

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Received June 2015; accepted August 2015

Abstract. *This paper presents a new method for evaluating the effects of newly implemented information systems quantitatively based on process mining techniques. Furthermore, in order to facilitate a comparative analysis of an existing system and a new system, we propose a configuration tool that can be used conveniently for visual comparison of changed activities, resources, organizers, and so on between processes of the two systems. Actual business processes can be discovered from event logs or transaction records produced by information systems using the process mining techniques. In addition, process mining provides various functionalities, such as performance analysis, and pattern analysis. These functionalities are used to propose a framework for quantitatively analyzing and comparing the performances of the newly implemented information system and the existing system. The framework can be utilized for the performance verification of newly implemented information systems in various industries.*
Keywords: Process mining, Information systems, Quantitative effects, Comparative evaluation

1. **Introduction.** Operations and management of an organization heavily rely on information systems (ISs) and investments in information systems implementation have been increased. Therefore, managers eagerly want to know the effects and ROI (Return on Investment) of ISs implementation [1,3,8,11].

Previous researches on the evaluation of investments in ISs are focused on qualitative methods, such as empirical user surveys on the effects of ISs implementation [2,4,6,9,12]. However, these researches failed to suggest a proper method for verifying the benefits of new ISs quantitatively, so decision makers or managers of an organization cannot depend on such researches and they are requiring quantitative performance analysis methods [8,12], especially in profit oriented ways. There have been researches on ROI of ISs in the economic perspectives [1,3,11].

The object of process mining is to extract the significant process-related information from event logs generated by the PAISs (Process Awareness Information Systems) in companies. It can discover business process models in reality rather than the expected process models and suggest improvement directions while BPM aims to (re)design, execute, implement, monitor and improve business processes [15-17].

This paper presents a new method for quantitatively evaluating ISs implementation using process mining techniques. The proposed method provides a framework for evaluating and comparing a legacy system and a newly implemented IS in the process oriented viewpoint. The framework is composed of three major phases: data preparation, data analysis, and conclusions. It is expected that managers can utilize the proposed framework in order to verify the effects or benefits of newly implemented ISs quantitatively and in process-centric way [10].

The paper is organized as follows. Section 2 describes related work on process mining and evaluation of ISs. Section 3 presents the evaluation framework for comparing the existing system and new system. Section 4 explains the GUI of the configuration tool for identifying the checklist for comparing the two systems and briefly introduces the verification of the actual case. Finally, Section 5 offers conclusions.

2. **Related Work.**

2.1. **Process mining.** Process mining generates the significant information on the perspective of process by using real event logs from ISs. Commonly, the process mining has three main types of functions: discovery, conformance, and enhancement [15-17]. The first type is the discovery which can produce several process models such as control-flow models, and organization models. It is usually performed during the initial analysis phase and process models can be discovered with the modeling notations such as Petri-net, C-net, and BPMN using the α-algorithm, Heuristic miner, and Fuzzy miner [5,15-18]. The second type of process mining is conformance checking. It compares existing process models and discovered behaviors from the event logs and measures the gap between the model and reality. The third type of process mining is enhancement which has two sub types: repair, extension [15-18].

2.2. **Evaluation of ISs.** Until now, most existing researches on the evaluation of ISs are focused on qualitative methods, such as surveys, VOC (Voice of Customer), interview, and ROI of the new ISs. Especially, qualitative evaluations by empirical users are difficult to be relied upon by decision makers or managers in their business [1,3,8,12]. Besides, they are eager to identify the economic performances such as ROI of the new ISs [1,3,11].

Mans et al. proposed a process-oriented methodology for evaluating the impact of IT systems on a business process ahead of its implementation. By comparing with the 'As-Is' process from event logs in reality and 'To-Be' process simulated by CPN tools, they assess the effects of the IT system of digital dentistry [10]. However, the analysis of 'To-Be' process was not based on real data in their approach. 'To-Be' process was redesigned from the previously validated 'As-Is' simulation process model. We propose a new method for quantitatively analyzing and comparing the effects of a newly adopted information system and its corresponding existing information system.

3. **Comparative Evaluation Framework.**

This section presents the proposed framework for comparatively evaluating the legacy system and new system. Figure 1 depicts the framework composed of three phases (data preparation, data analysis, and conclusions).

In the data preparation phase, data requirements, data extraction from ISs, and preprocessing of extracted data are performed to enhance the accuracy and validity of the data analysis. Especially, utilizing the data column definition for accurate data extraction and pre-processing data from the data preparation are performed in order to reduce the gap of domain knowledge between domain experts and process analysts. The data analysis phase is composed of collection of data conversion, analyses of various perspectives, and creation of a comparison checklist. The created comparison checklist can be used to identify the differences of the quantitative performances between the two systems easily.

The detailed procedures of the data preparation and data analysis phases are presented as extended frameworks in Figures 2 and 3, respectively. In the conclusions phase, interpretation and discussion of the analysis results are performed, and further analysis or research direction can be determined and suggested.

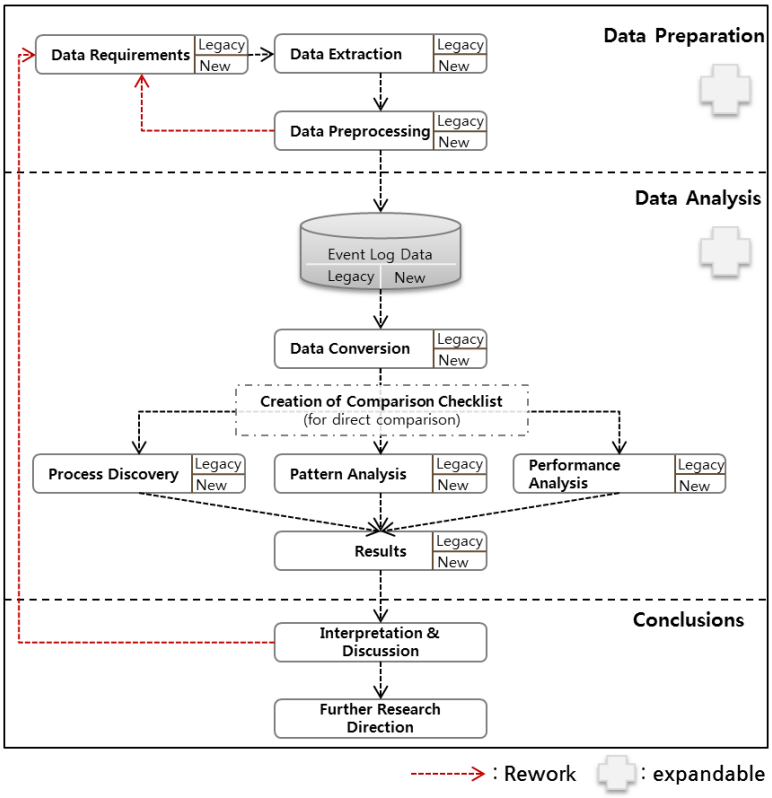

FIGURE 1. Comparative evaluation framework

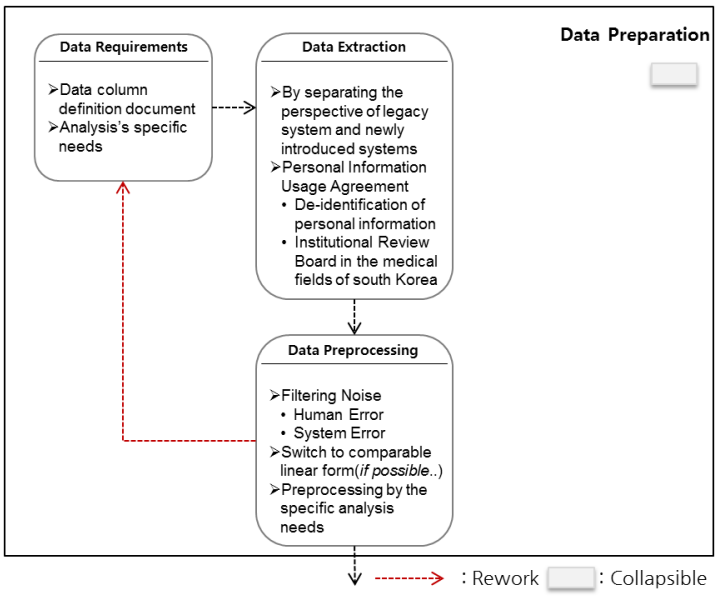

FIGURE 2. Composition of data preparation phase

3.1. **Data preparation phase.** The data preparation phase is composed of collection of data requirements, data extraction from ISs, and preprocessing of extracted data. In particular, analysts should clearly know the data attributes of the legacy system and new system by creating the data column definition document, and they should clarify the purpose of the analysis in the data preparation phase. Figure 2 presents the details of the information to be considered at each step of the data preparation phase.

The previously used information system is set up as a comparison group to identify the effectiveness of the new information system in this study. It is required to prepare specific information of data column about each system in the data requirements step. Analysts can understand the data attributes easily from 'data column definition' which is created through the continuous feedback with domain experts. During the migration of systems from the legacy system to the new system, activities, resources, equipment and so on can be added or removed. Therefore, a clear definition and understanding of this change is required. Such a definition may be a critical step in reference to analysis for the total duration, working time, waiting time, and so on. In addition, the clear definition of the analysis purpose and analysis needs accordingly in the data requirements step enables to derive the valuable results.

Data preprocessing is performed in order to remove noises and filter the data for proper analysis prior to analysis. The analyst should be able to clarify the definition and criteria of the noises and also detect them on the same basis in the event logs of systems for the quantitative comparison. In general, noises are classified into human errors and system errors. The analyst may doubt some types of noises such as missing value, and excessive outliers. However, it is very difficult to accurately recognize whether it is a noise or not. Therefore, to clearly remove noises for more reliable analysis, the analyst should communicate with domain experts about the data column definition.

3.2. **Data analysis phase.** Data conversion, creation of comparison checklist, process discovery (control-flow perspective), and analysis of pattern and performance on process are performed in data analysis phase. In the data conversion step, the event log is transformed into MXML (Mining eXtensible Markup Language) or XES (eXtensible Event

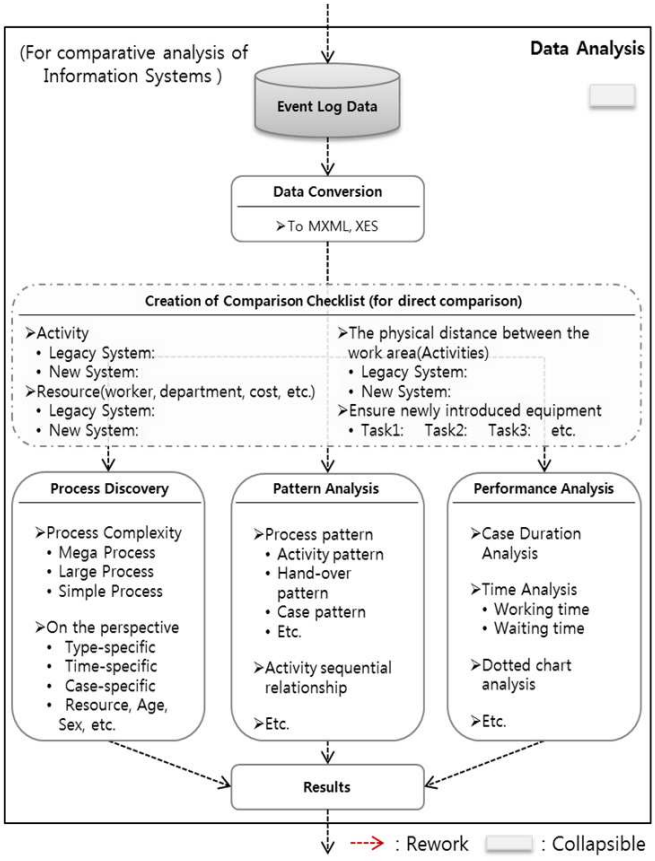

FIGURE 3. Composition of data analysis phase

Stream) format and a checklist for comparison of the legacy system and new system is created [13,19].

The comparison checklist shown in Figure 3 is used to identify the differences between the two systems affecting the quantitative performances of the system. For example, some change in activities, resources or equipment can affect the performance of the new system. Through the comparison checklist, the effects of the newly implemented system can be analyzed and interpreted properly by comparing and analyzing the business processes of the two systems based on the process mining techniques, such as process discovery, pattern analysis, and performance analysis.

When the data used for analyzing have relatively short columns and properties, it can be easily obtained by using spreadsheet software such as MS-Excel. However, it is not easy to identify the variation of attributes if there are many attributes, such as activity, resource, and equipment. In Section 4, we present a configuration tool for automatically creating the checklist in order to identify the two systems with GUI (Graphical User Interface).

Quantitative effectiveness of the new system can be analyzed by the three types of process mining analyses: process discovery, pattern analysis, and performance analysis. The process discovery aims at extracting business process models automatically from the event logs. Process models can be discovered by tracking the event logs of the existing system and the new system and comparative analyses from various perspectives can be performed. The pattern analysis can be executed in order to find process patterns, sequential relationship among the activities. In addition, it can be used to compare the patterns of processes. The performance analysis can be used to measure and compare various KPIs (Key Performance Indicators) such as time, cost, and frequency in the perspectives of activities, resource, and organizer [14,18].

4. **Configuration Tool.** In this section, a configuration tool for creating the checklist to compare the two systems is presented and a verification case is described. If there are lots of attributes such as activity, resource, and equipment, or the number of instances of such attributes is very big, it is difficult to identify the change of attributes. In order to solve this problem, the comparison checklist – a configuration tool in Figure 4 can be used. The more details of tool description can be found in [7].

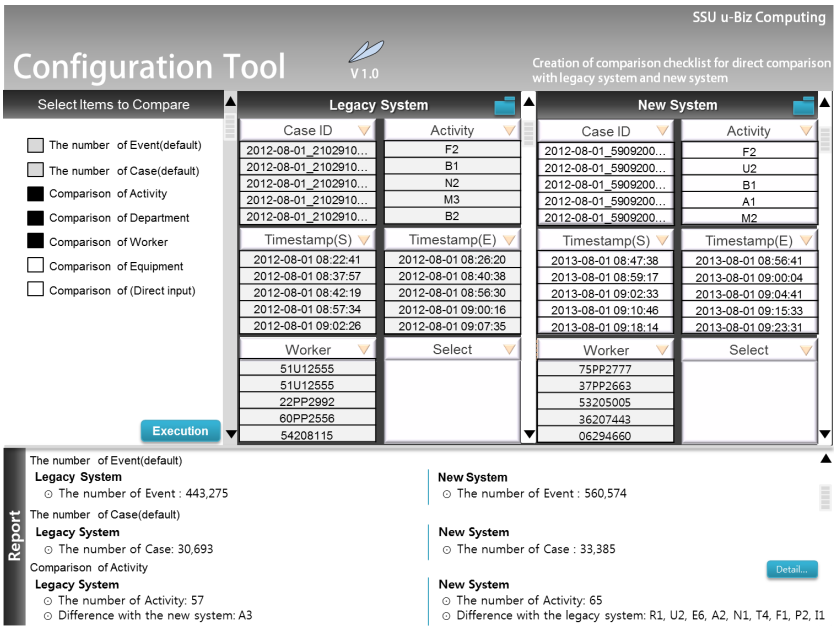

FIGURE 4. The GUI of configuration tool

In order to evaluate the effects of the new information system implementation, it should be thoroughly studied for the changes in the environment between the systems. Field survey, interviews, and so on can be very annoying or burdensome jobs to staffs in the field, and they can cause interference with business. The proposed configuration tool can be used as a support tool to minimize the interference mentioned previously [8,9,12].

The configuration tool can be applied to various fields. For example, a distribution center that has applied the RFID (Radio Frequency Identification) technology can attempt to analyze the effects of the RFID system quantitatively by comparing the existing system and the new RFID system. As many organizations such as hospitals, shopping malls, and entertainment businesses are adopting IoT (Internet of Things) technologies, the tool proposed in this paper can be applied to the analysis of the effects of the new information technologies including Beacon, NFC, and other smart devices.

To verify the configuration tool and proposed evaluation framework, we performed an application case study. The results are shown in Figure 5. Figure 5(a) illustrates a spaghetti process model discovered from the log data of the existing system. Similarly, Figure 5(b) is a process model discovered from the event log of the new system. Figure 5(c) shows a comparison report with charts and tables.

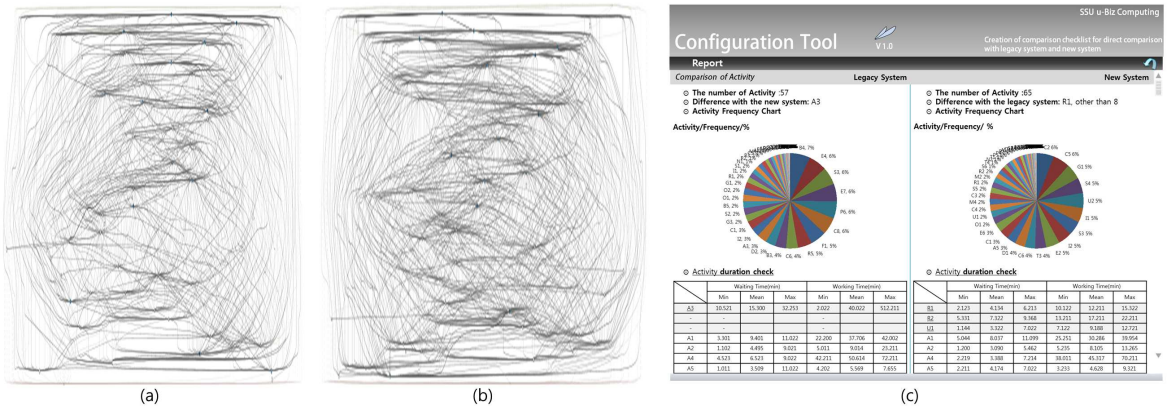

FIGURE 5. An application case of analyzing the effects of a new system: (a) discovered process of the legacy system, (b) discovered process of the newly implemented system, and (c) application of the configuration tool

5. **Conclusions.** We proposed a new method for quantitatively evaluating the effects of newly implemented ISs based on process mining. The proposed method is composed of three phases such as data preparation, data analysis, and conclusions. In the data analysis phase, a configuration tool for creating the comparison checklist can be used prior to main analysis work. Popular process mining tools such as ProM and Disco can be used for the analysis in our framework.

We have applied the method to an industry, and verified the applicability of our method using real event logs from their ISs. Managers in the business could know the effects of the newly implemented information system using the proposed method. In the future, we will introduce the result of this case study after solving the issues on security and privacy.

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