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Araştırma Makalesi - Research Article

Process Mining Methodology for Digital Processes under Smart Campus Concept

Akıllı Kampüs Konsepti Altında Dijital Süreçler İçin Süreç Madenciliği Metodolojisi

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ABSTRACT

Digital transformation affects universities as well as many industries. Universities are increasingly using various digital resources and systems to manage their knowledge. The smart campus, on the other hand, supports informed decision-making by integrating these resources and systems. Process mining provides real insights for digital transformation, allowing processes to be examined more transparently. This study aims to examine the proposed project implementation processes related to the smart university with the process mining methodology. For this purpose, 32 completed projects submitted to İzmir Bakırçay University Scientific Research Projects Coordinatorship (BAPK) with the proposed methodology adapted from Deming's continuous improvement cycle were examined. The data are taken from two different pages in the project automation system. According to the research findings, Projects are grouped into three categories: Guided Projects (GDM, 5 projects), Graduate Thesis Projects (TEZ, 5 projects), and Career Start Support Projects (KBP, 22 projects). 40.6% (13 projects) of the applications went directly to the project review stage, while 19 (59.4%) needed procedural correction. Considering the time from the creation of the application of 32 projects to the signing of the contract, it is seen that the arithmetic average of the cycle time is 15.1 weeks, and the median average is 52.5 days. The notable difference between arithmetic and median mean is that very few projects are of long duration. Procedural adjustments affect project evaluation cycle time by an additional 14 days. The carelessness or lack of knowledge of the applicants extends the cycle time of the process from 15 days to 53 days. The total duration of unnecessary waiting time in the process is 17 days. This study primarily proposes that non-digital processes should be digitized as soon as possible.

Keywords- Process Mining, Smart Campus, Digital Transformation, Process Management

ÖZ

Dijital dönüşüm, birçok endüstriyi etkilediği gibi üniversiteleri de etkilemektedir. Üniversiteler, sahip olduğu bilgiyi yönetmek için, çeşitli dijital kaynaklardan ve sistemlerden giderek daha fazla faydalanmaktadır. Akıllı kampus ise, bu kaynakları ve sistemleri entegre ederek, bilinçli karar verme sürecine destek olur. Süreç madenciliği, süreçlerin daha şeffaf incelenmesine olanak tanıyarak, dijital dönüşüm için gerçek öngörüler sunar. Bu çalışma, akıllı üniversite ile ilgili önerilen proje uygulama süreçlerini, süreç madenciliği metodolojisi ile incelemeyi amaçlamaktadır. Bu amaç doğrultusunda, Deming'in sürekli iyileştirme döngüsünden uyarlanan önerilen metodoloji ile İzmir Bakırçay Üniversitesi Bilimsel Araştırma Projeleri Koordinatörlüğü (BAPK)'ye sunulan ve tamamlanmış 32 proje incelenmiştir. Veriler proje otomasyon sisteminde yer alan iki farklı sayfadan alınmıştır. Araştırma bulgularına göre; Projeler, Rehberli Proje (GDM, 5 proje), Lisansüstü Tez Projeleri (TEZ, 5 proje) ve Kariyer Başlangıç Destek Projeleri (KBP, 22 proje) olmak üzere üç kategoride gruplandırılmıştır. 32 projenin başvurusunun oluşturulmasından sözleşmenin imzalanmasına kadar geçen süreye bakıldığında çevrim

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süresinin aritmetik ortalamasının 15,1 hafta, medyan ortalamasının ise 52,5 gün olduğu görülmektedir. Aritmetik ve medyan ortalama arasındaki dikkate değer fark, çok az projenin uzun süreli olmasından kaynaklanmaktadır. Prosedürel düzeltmeler proje değerlendirmesinin döngü süresini fazladan 14 gün etkilemektedir. Başvuru sahiplerinin dikkatsizliği veya bilgi eksikliği, sürecin döngü süresini 15 günden 53 güne kadar uzatmaktadır. Süreçteki gereksiz bekleme süresinin toplam süresi 17 gündür. Bu çalışma öncelikle, dijital olmayan süreçlerin mümkün olan en kısa sürede dijitalleştirilmesi gerektiğini önermektedir. Başvuruların %40,6'sı (13 proje) doğrudan proje inceleme aşamasına geçerken, 19'u (%59,4) prosedürel düzeltmeye ihtiyaç duymuştur.

Anahtar Kelimeler*- *Süreç Madenciliği, Akıllı Kampüs, Dijital Dönüşüm, Süreç Yönetimi

I. INTRODUCTION

Institutions, cities, and nations show great interest in smart cities and sustainable development to do better the living standards and life quality of their people in many ways [1]. There are many definitions of smart cities in the literature. Barba-Sánchez et al. [2] defined the use of information technologies for the analysis of local regions as a smart city. Another research argued that this city should do better the life quality of life of the city dwellers and that smart city applications should be developed for this purpose [3]. Richter et al. [4] argued that smart city applications should be used in order to keep the infrastructure of the city productive and information technologies should be used for this. Giffinger et al. [5], information technology can be experienced in various sectors with the use of smart cities can be said. Hollands [6] defended the necessity of a population with creative and innovative thinking power for the formation of those cities and stated that the realization of those cities would occur automatically. Bakıcı et al. [7] defined smart cities as regions with technological infrastructure. All definitions have one thing in common. This point is that the use of information technologies is necessary to realize and develop smart city plans. Smart cities can thus be designed.

The term "smart campus" integrates different information system platforms. Unlike the traditional campus, cloud computing, IoT, and internet technologies link teaching, research, and management of campus and campus resources to create a unified knowledge management platform [8]. With the developments in technology, such as the IoT, universities; can track critical resources, improve access to information, create more innovative plans, and design safer campuses [9]. Based on the various challenges faced by universities and cities, it is stated that smart cities have similarities with smart campuses [10]. Some features such as users, events, and connections on smart campuses are considered a self-sufficient small city [11].

The higher education environment has undergone a continuous and rapid digital transformation. Like many industries, higher education institutions need a particular transformation to survive in this era of the digital revolution [12]. Higher education institutions have a large amount of information about their students, programs, and facilities. Universities are increasingly connected to networks of technical applications, with new digital resources and systems to manage this information [13]. At the same time, universities have a significant role in developing a sustainable society with the responsibility of training science-technology talents, knowledge transformation, and technical innovation [14]. A smart campus is defined by its skill to realize a more informed deciding process by integrating various IT devices and applications. A university should have six intelligence areas to highlight the characteristics of a smart campus. These are iLearning, iManagement, iGovernance, iSocial, iHealth and iGreen [15]. iManagement is concerned with the campus's more physical aspects and general management, such as building management systems, building maintenance systems, fire alarm systems, facial recognition and identification, smart card system, and smart access and control system [16]. For example, an IoT lighting control system can automatically adjust lighting levels in classrooms and offices; a central maintenance system can perform self-ameliorating in the event of plant failure; a fire alarm system can trigger the fire alarm and direct people to the nearest exit point [15]. The management of processes enables organizations to create a competitive advantage by defining and demonstrating the maturity level of the process [17].

Process mining allows for transparency in real processes, providing insights for fact-based digital transformation [18]. Process mining resources make an important contribution to the digital transformation process by maintaining communication and collaboration among the participants [19]. Process mining tools can be used to explore underlying processes, reduce complexity and make them more efficient [20, 21]. Beyond that, process mining helps identify solution strategies and select appropriate measures for strategy implementation. Essentially, the identification of the potential for improvement of efficiency, speed, agility and compliance, which are key success factors, by process mining makes digital transformation possible [21].

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Process mining is a discipline that enables organizations to discover, analyze and do better their business processes, supported by many data mining algorithms and techniques [22]. The increasing use of information systems in business process studies is a suitable baseline for process mining because process mining tools exploit formed traces of activities conducted and noted with digital technologies [23]. One of the key benefits of process mining results is that it reveals in detail how a business process works [24]. With process mining, the personnel responsible for the process can be analyzed, bottlenecks can be discovered, staff productivity can be found, and case-based cycle times can be determined [25]. The main goal of process mining is to do better business processes by applying analytical tools.

A. Process Mining

Processes are critical to controlling the operations in companies. They are often complicated due to many reasons. However, processes in companies have a standard feature. They yield data called the event data produced in process event logs. The analysis of event logs enables various possibilities for enhancing processes. Table 4 illustrates a basic event log, including data about *event attributes*. The event log underlying traces are$L = \{\langle a,b,c,d\rangle, \langle c,d,b,a\rangle, \langle b,a,d,c\rangle, \langle d,c,b,a\rangle\}$ and they are represented by `case IDs' 1, 2, 3, and 4, respectively. We suppose that the set of attributes is fixed and the function *attr* maps pairs of events and attributes to the corresponding values. For each *event e*, the log holds the case ID *case(e)*, the activity name *act(e)*, and the set of attributes described for *e*, e.g., *attr(e; timestamp)* or *attr(e; resource)*. For instance, for the event log in Table 1,*case*(e_7) = *C2*, *act*(e_7) = *a*, *attr*(e_7*; timestamp) =17-09-2022 10:28pm", and attr*(e_7*; resource) = "Gamze"*.

Table 1. Simple event log

Event	CaseID	Activity	Timestamp	Temperature	Resource	Cost	Risk
1	C1	c	17-09-22 9:08	25	Mert	34	Low
2	C2	c	17-09-22 17:03	27	Mine	17	Low
3	C2	a	17-09-22 18:32	28	Mustafa	31	Medium
4	C1	a	17-09-22 7:01	25	Sevgi	44	Low
5	C1	b	17-09-22 7:06	27	Gokhan	42	Low
6	C1	d	17-09-22 9:18	26	Pelin	55	Medium
7	C2	d	17-09-22 17:28	25	Gamze	42	Low
8	C2	b	17-09-22 17:40	25	Pelin	55	Low
9	C3	c	18-09-22 9:18	29	Mert	19	High
10	C4	d	18-09-22 17:03	29	Mustafa	29	High
11	C4	c	18-09-22 17:28	28	Nesrin	15	High
12	C3	b	18-09-22 2:01	27	Sevgi	20	Medium
13	C3	a	18-09-22 7:06	26	Mert	30	High
14	C3	d	18-09-22 9:08	30	Sevgi	31	Medium
15	C4	b	18-09-22 17:40	29	Sevgi	35	High
16	C4	a	18-09-22 18:32	30	Pelin	55	Medium

The input for process discovery is an event log. This study focuses on the control-flow perspective of a process, which means data corresponding to the temporal relation of activities the for the sake of understandability. Process discovery algorithms use an event log as input and create a process model as an output. This paper considers the directly-follows graph annotated with the frequencies as a process discovery method. In such a graph, nodes symbolize activities and arcs express a view of causality. Activities *a* and *b* are connected if *a* is frequently followed by *b*. Mathematical notation of a directly-follow graph is given as follow:

Let L be an event log. The directly-follow graph of L is $G(L) = (A_L \rightarrow_L, A_L^{start}, A_L^{end})$, where

$A_L = \{a \in \sigma | \sigma \in L\}$ gives the activity sets in L, and σ indicates the traces, a sequence of activities in the log L,

$\rightarrow_L = \{(a,b) \in A \times A | a >_L b\}$ presents the directly-follow relations,

$A_L^{start} = \{a \in A | \exists_{\sigma \in L} a = first(\sigma)\}$ and $A_L^{end} = \{a \in A | \exists_{\sigma \in L} a = end(\sigma)\}$ show the set of start and end activities, respectively.

Figure 1 depicts the directly-follow graph of event log L given in Table 1.

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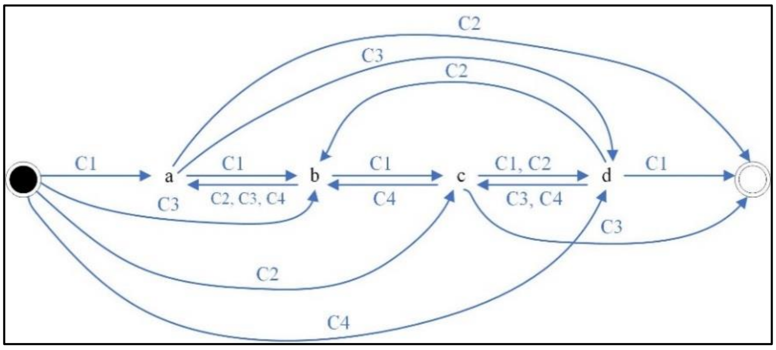

Figure 1. Directly-follow graph of event log *L*

This study aims to examine the proposed project implementation processes related to the smart university by creating directly-follow process maps. In this way, the number of applications according to faculties and departments, how often the activities in the process are seen, and the critical activities that extend the cycle time will be determined.

The remaining part of the paper is as follows. Section 2 summarizes the literature considering smart university and digital transformation and process mining concepts. Section 3 explains the proposed methodology. It was adopted from Deming's continuous improvement cycle. Section 4 presents a real-world implementation of the proposed methodology. Finally, the study concludes with Section 5.

II. RELATED WORKS

A. Smart University and Digital Transformation

The result of the practice of integrating cloud computing and the internet of things (IoT) is the smart campus [26]. Education in a smart environment supported by smart technologies, making use of smart tools and smart devices, can be considered smart education [27]. Elements such as the cloud computing, wireless networks, radio frequency identification (RFID), mobile terminal, and IoT are fundamental parts of the smart campus [10]. Most colleges and universities use the development models of smart campuses, such as campus common card systems, student information inquiry on phones, and campus-sharing bicycle systems [28]. Lin et al. [29] suggested that it is possible to access campus applications from anywhere via the Internet of Things technologies. Alvarez-Campana et al. [30] advocated the testing of the internet of things by using the technologies at the first stage in universities and then integrating them into cities. Chieochan et al. [31] identified a prototype area in their study at Maejo University. They used sensors to measure moisture in this area. These moisture data obtained with IoT technologies were stored. Jain et al. [32] used automation technologies to provide remote access to universities. They argued that areas without remote access were inefficient.

Higher education all over the world is undergoing digital transformation [33]. Significant investments in technology and infrastructure regarding the irresistible power of digital technologies have been encouraged [34].In the last few years, many proposals have emerged in the field of digitization and interconnection of educational assets [1]. Cisco initially developed a framework that connects various building domains under a single Internet Protocol (IP) network as part of companies' digital transformation [35]. In 2016, this model was designed for the education sector. This model has components such as campus operations center, smart parking, telepresence in classrooms, and building optimisation/analytics. Xiao [33] found that in the strategic development plans of the top 75 universities in China, digitalization, as perceived by universities, includes instrumentality (e-campus construction and implementation) and modernization (sustainability and efficiency innovations in teaching and learning).

From the related work above, process management under smart campus and digital transformation concepts is still a gap in this field.

B. Process Mining in Universities

Learning management systems (LMS), which use has increased in recent years, strongly impact educational research. LMS stores data on the activities of all students at a certain level of detail [36]. Examples of systems that store event logs are virtual learning environments, student enrollment procedures, Mass Open Online Courses (MOOCs), access to educational material logs, Intelligent Course Systems (ITSs) [37]. Examination and discovery of goings in event logs created by educational environments are provided by educational process mining (EPM). EPM aims to do better the training process by utilizing the information extracted from the records in the model to ease a better understanding of the process [38].

Bogarínet al. [39] analyzed data from 84 undergraduate students who followed an online course using Moodle 2.0 to develop EPM. Ayutaya et al. [40], in their research, discuss a heuristics-driven process mining algorithm. A student enrollment event log consisting of 299 cases and 569 events were used for this research. Ayutaya et al. [40] used EPM tools to examine how students use learning resources, students' compliance with homework, and the relationship between students' behavior and final grades. An LTL-based model checking tool was used to analyze moodle logs. Etinger et al. [41] aimed to discover frequent behavioral patterns in event logs. The discovered process model is the starting point for evaluating the usage behavior of Moodle LMS. Etinger [42] strived to reveal the relationship between user behavior that creates online course usage patterns and students' grades. Doleck et al. [43] applied process mining to the online" modeling and simulation" course at the Faculty of Informatics. He determined students' diagnostic reasoning processes and learner behaviors related to outcomes. The research was conducted at BioWorld, a computer-based learning environment that supports students in solving medical problems and receiving formative feedback. Deeva and Weerdt [44] aimed to discover local patterns in data representing learning processes with process mining techniques. Real-life event logs from JMermaid, an intelligent learning environment, were used to teach information system modeling. Ramaswami et al. [45] evaluated educational data mining methods to increase the predictive accuracy of student academic performance in a course environment at the university. They also integrated process mining features to determine their effectiveness in improving the accuracy of forecasts. Dolak [46], explored using process mining techniques to explore students' navigational paths, activities, and behaviors in LMS Moodle. Data from 701 students following an online course consists of 32 984 events and 33 activities. Salazar-Fernandez et al. [47] used process mining techniques with a curriculum analytics approach to understanding the educational trajectories of higher education students.

Table 2 provides a summary of the related works, including smart university and digital transformation and process mining in universities.

Table 2. Related works

Study	Domain[1]	Purpose
[30]	SUDT	The study describes the main features of the IoT platform offered in the engineering schools of the Universidad Politécnica de Madrid and the technological challenges faced, with a special emphasis on the platform's functionality, services, and potential offerings.
[32]	SUDT	The study presents the automation techniques and a module that works for a room automation and ease of access to appliances with digital control.
[28]	SUDT	Addressing the smart campus construction of the China University of Electronic Science and Technology, it explores the construction of the smart campus and the innovative, practical situation of student studies.
[29]	SUDT	The study proposes CampusTalk, which provides convenient access to cyber and physical devices through the web technology.
[48]	SUDT	The study aimed to evaluate the future scalability of the smart university and its potential to automate other fields and to show a smart university model.
[33]	SUDT	The study examined how the role of digitalization was framed in the strategic development plans of the top 75 universities in China.
[49]	SUDT	The study presents an overview of the content of the multi-component electronic education environment of the master's education in Applied Informatics from the perspective of personnel, technology, and educational resources.
[50]	SUDT	The study focuses on expressing a systematic approach to designing the concept of a smart university and proposes a smart university model.
[51]	SUDT	The study examined the process of managing the digital transformation of the university using analytical tools. It shows that the management decision-making process in a smart university should be based on Big Data-based approaches and technologies
[52]	SUDT	The study aimed to analyze the features of the digital university model to determine the criteria for evaluating the usability of the digital transformation process.
[39]	PM	The study proposes to use clustering to improve educational process mining. To obtain more specific and accurate student behavior models, it is recommended to use data from Moodle's diaries separately for each student group/cluster.
[53]	PM	The study aimed to analyze the navigation path of the university's website to increase its usability and comfort level based on a process mining technique.
[54]	PM	The study suggests analyzing students' careers with process mining techniques. The paths followed by students from enrollment to undergraduate degree were analyzed by process mining technique.

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[46]	PM	This study explores using process mining techniques to discover students' activities, navigation paths, and behaviors in LMS Moodle.
[55]	PM	This paper reports on the findings that proposed a novel learning analytics methodology that combines three complimentary techniques (agglomerative hierarchical clustering, epistemic network analysis, and process mining).
[56]	PM	This study aimed to examine the interaction between psychological well-being (PWB) and self-regulated learning (SRL) as students plan and reflect on approaches to achieving their academic goals for nine consecutive weeks.
[47]	PM	The study presents a program-level approach to curriculum analytics. The training trajectories of the courses with a high failure rate were created using process mining techniques.

[1]SUDT: Smart University and Digital Transformation, PM: Process Mining in Universities

Previous studies indicated that process mining significantly impacts process management in university processes as a part of smart campus, especially iManagement mentioned before. This study fills the gap in a niche process in universities, the evaluation of scientific research projects, by proposing a new process mining methodology under the smart campus concept.

III. METHODOLOGY

This study uses a framework developed at Izmir Bakircay University [57, 58], which was built on especially the existing information systems of the university (automation, personnel, procurement, web services, etc.). The smart campus framework includes three main stages. (Readers can look at the details from the studies cited above). The last stage supports the framework for the sustainability of the smart campus through real-time data analytics, monitoring, reporting, and performance measurement module.

Figure 2 indicates the process mining methodology for digital processes under the smart campus framework. The proposed methodology follows the Deming's constant improvement cycle, Plan, Do, Check, Act, for implementing process mining. While the Plan step is a common step for any quality improvement research, the remaining steps were equipped with some smart campus ingredients such as real-time data analytics, visualization, recommendation, performance management, and reporting, shown in red and bold.

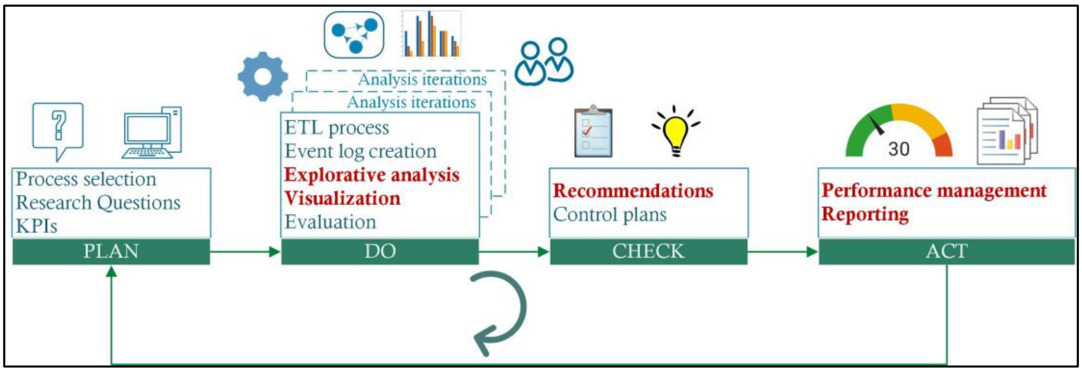

Figure 2. Process mining methodology for smart campus concept

IV. CASE STUDY

B. Plan

The process that will be analyzed using process mining can be determined by either interviewing process owners or prioritizing with some decision-making techniques such as TOPSIS and VIKOR. This study selected the process of evaluation of scientific research projects by interviewing. Research questions (RQs) were defined as follows:

i. How does the number of applications change concerning the faculties and departments?

ii. How frequent are activities in the process executed?

iii. Are there any critical activities that extend the cycle time?

Key performance indicators (KPIs) were specified as follows:

i. The number of loops and self-loops in the process

ii. The duration of unnecessary waiting time

C. Do

The data were extracted from the project automation systems from two different pages. The activities related to the project transactions were obtained from one page, and other attributes such as faculty and department were extracted from another page. Both data from two pages were combined by considering project ID as the primary key. After some preprocessing steps, combined project data was converted into an event log that includes a case ID, timestamp, and activity.

1) Research Question 1 Descriptive Statistics: Before the process mining analysis, descriptive statistics were calculated to summarize the event log as explorative analysis. The details of the 32 completed projects between 18.09.2020 – 23.06.2022 have been examined. Projects were grouped into three categories: Guided Project (GDM, 5 projects), Graduate Thesis Projects (TEZ, 5 projects) and Career Start Support Projects (KBP, 22 projects). Table 3 shows the distribution of the projects applied by faculties and departments.

Table 3. Basic statistics of faculties and departments

Faculty of Engineering and Architecture	10	**Faculty of Economics and Administrative Sciences**	4
Computer Engineering	2	Economics	1
Biomedical Engineering	4	Business	3
Electrical and Electronics Engineering	1		
Industrial Engineering	1	**Medical School**	9
Fundamental Science	2	Surgical Medical Sciences	3
		Clinical Medical Sciences	3
Faculty of Arts and Sciences	5	Basic Medical Sciences	3
Geography	2		
Psychology	1	**Faculty of Health Sciences**	4
Sociology	1	Language and Speech Therapy	1
History	1	Nursing	1
		Physical Therapy and Rehabilitation	2

2) Research Question 2 Frequency Perspective: Figure 3 shows that the process flow of the applied projects. The thickness of the arrows increases when the number of transitions between two nodes increases. Similarly, the darkness of the colors in the nodes increase when the number of executed activities increases. All processes start with "Project creation" activity by the project owner and go on with submitting the project. These projects are either directly reviewed or requested some revisions in terms of mandatory requirements. 40.6% (13 projects) of the applications went directly to the project review stage, while 19 (59.4%) needed procedural corrections. Seven project applications (21.9%) received more than one correction. After the "Project review" stage completes, projects are evaluated thoroughly by experts considering technical details. While 81% of projects (26 applications) went directly to the contract stage, corrections were requested from six applications. The activity of "Requesting revision" was performed 15 times, although these revisions were requested for only six projects. The reason is that some projects require more than one revision, seven times in total. It means there is a re-work (loop) in the revision step. After some re-works, three out of six projects were accepted. However, reviewers also requested some revisions for the remaining three projects, which caused another loop.

3) Research Question 3 Performance Perspective: Figure 4 presents the performance measures of the process. Considering the period from the creation of the application of 32 projects to the signing of the contract, it is seen that the mean duration of the cycle time is 15.1 weeks, and the median average is 52.5 days. The notable difference between arithmetic and median average is that few projects have long duration.

Because applications were made via the website, activity durations are seen instant. The application system records only click timestamps. Therefore, it is noteworthy to observe the duration between activities. Receiving more than one correction between "Waiting for re-edit" and "Re-edited" causes a 33.1 hour-increase in cycle time. These are also activities without added value for the Coordinatorship of Scientific Research Projects (BAPK) personnel. The first procedural corrections made by the project coordinators took an average of 11.6 days. This resulted in an average delay of 13.5 days for 13 project applications not in need of correction. In other words, procedural corrections (starting with the "Waiting for re-edit" activity) affected the cycle time of the project evaluation by extra 14 days. When we look at the root cause of this delay, we see that 4 out of 10 applications that caused the delay (receiving procedural correction) came from medical school. As it was discussed from the frequency perspective, six out of 32 projects need revisions. In the first re-work step among "Requesting revision",

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"Approving revision" and "Receiving revision", there is an extra 13.1-day duration affecting the cycle time negatively. Fortunately, three out of six projects were accepted after 6.3 days on average. On the other hand, the remaining three projects can be determined as the bottleneck of the project evaluation process with high durations. These three projects required 26 days to receive reviewers' comments. Then they again followed the same steps. But the worst time consumption occurred for the acceptance of these projects due to several reasons. If the owners of these projects completed the required revision before sending reviewers, the mean duration of the cycle time would be 75 days instead of 15 weeks.

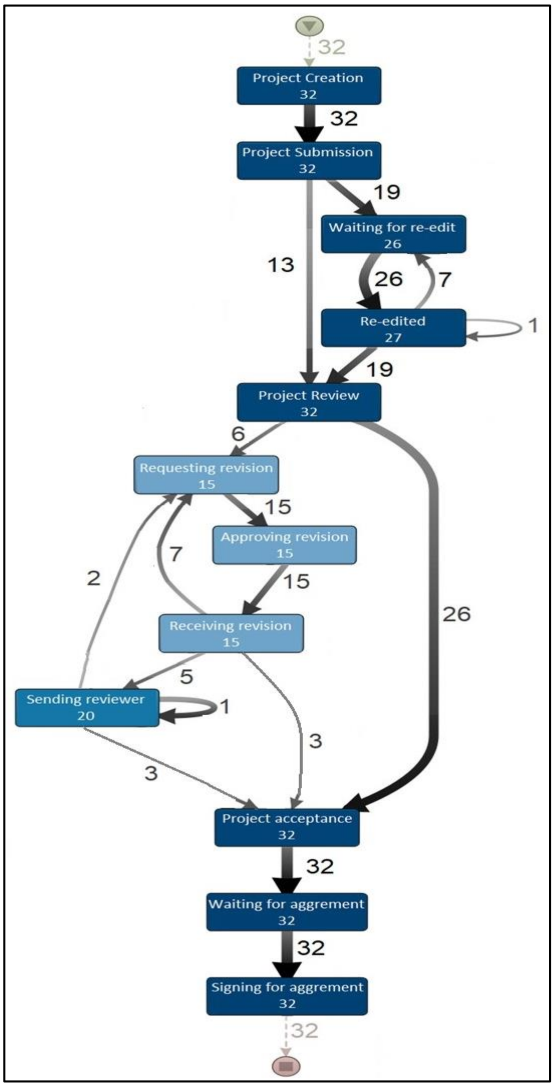

Figure 3. Activity occurrence perspective of process

Figure 5 shows the process flow of the projects sent to the reviewers. Only GDM-coded applications were sent to the reviewers for technical evaluation. It was seen that there was no project sent to the reviewers without procedural correction. In other words, all applications that were sent to reviewers were received at least one procedural correction by BAPK personnel before sending to reviewers. After the reviewers' comments, two projects completed the desired corrections in the first time, while the remaining three projects received more than one correction. The time between sending to the reviewers and waiting for the agreement took an average of 51 days. The average duration of reviewers' evaluation is 26 days. However, a self-loop with 3.6 day-duration shows that reviewers received a procedural correction from the coordinatorship personnel. After accepting the project, the agreements were signed in 39.7 weeks. This duration was 51.6 days when considering all projects.

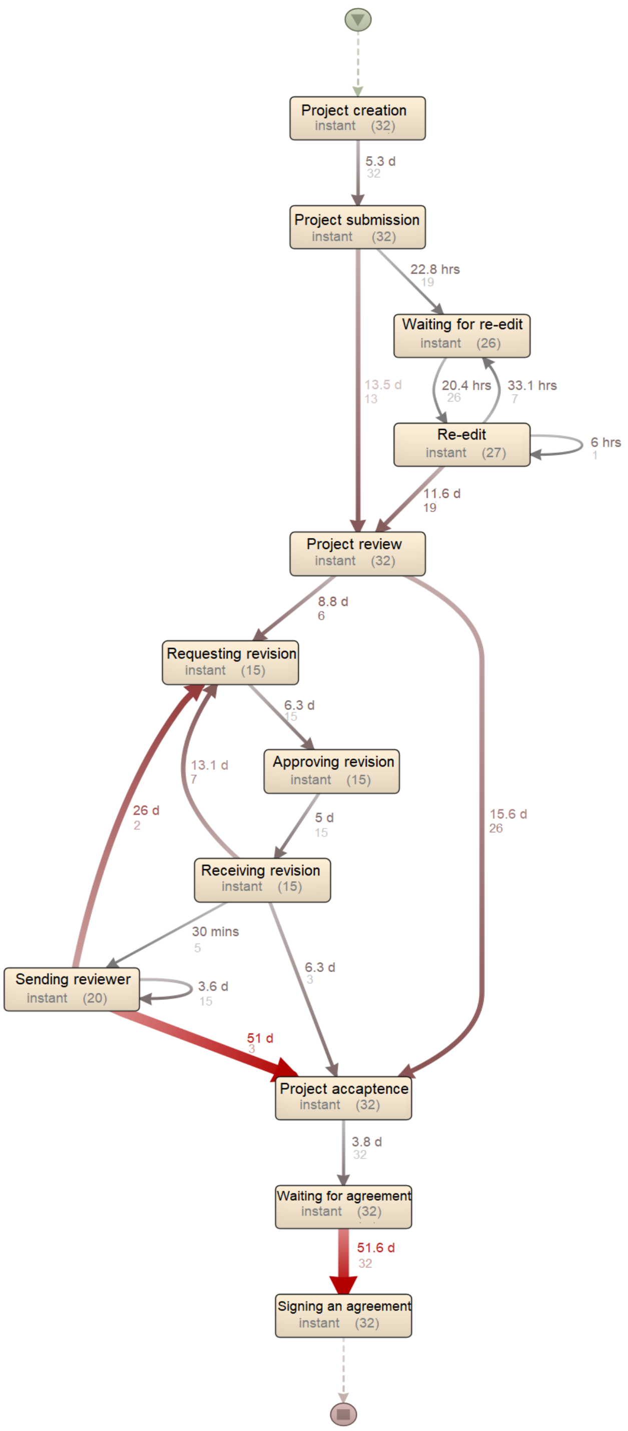

Figure 4. Time perspective of process

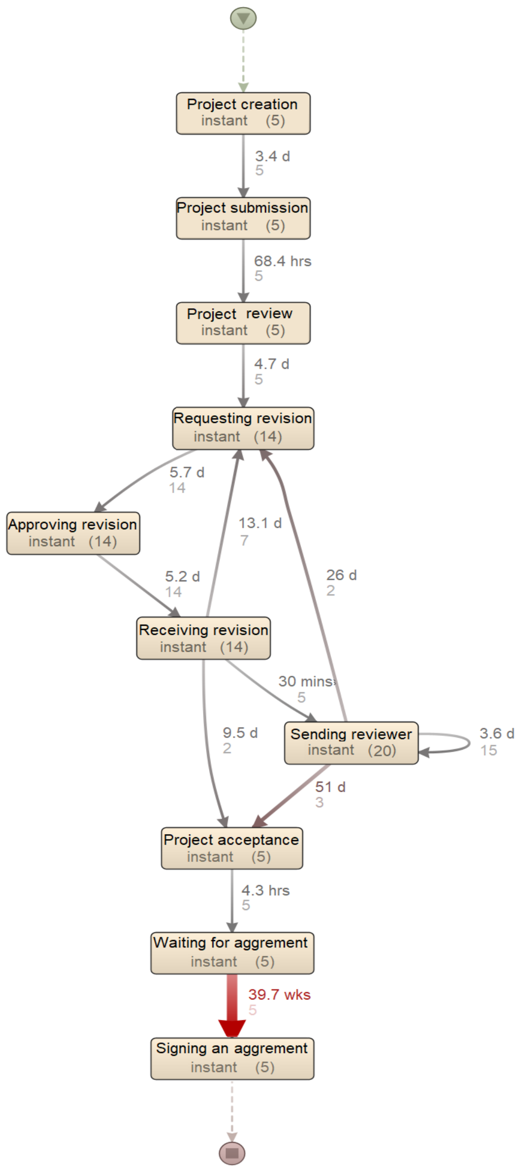

Figure 5. Processes sent to reviewers

D. Check

This sub-section includes process improvement recommendations with a control plan. An ideal process refers to a process that does not include any kind of waste and can be shown by an activity set. In this study, it can be described as follows: Project creation, Project submission, Project review, Project acceptance, Waiting for agreement, Signing an agreement. If all applications conformed to the ideal process, the cycle time could be just

38 and 45 days on median and arithmetic average, respectively. However, the carelessness or insufficient knowledge of the applicants extends the cycle time of the process from 15 to 53 days. It also creates an extra workload for BAPK personnel, which is regarded as a waste.

BAPK personnel should check the estimated project cycle time during the application. If the personnel think the project will probably exceed the average duration, it should be noted and accelerated. Redundant loops are among the most critical factors in extending the average time. The personnel also should avoid these loops while executing the project activities.

E. Act

Performance management and reporting are made considering the KPIs as mentioned earlier. In the process, there are two self-loops for the activities "Re-edited" and "Sending reviewer". Editing loop (Waiting for re-edited, Re-edited), revision loop (Requesting revision, Approving revision, Receiving revision) and revision from reviewers' loop (Requesting revision, Approving revision, Receiving revision, Sending reviewer) are the loops that existed in the process. Therefore, the number of loops and self-loops is five. For example, decreasing KPI 1 may be possible by eliminating the self-loop "Re-edited".

Deviations from the ideal process also show unnecessary waiting time in the process. The total duration of unnecessary waiting time in the process is 17 days. For example, applications that do not need an edition directly go to "Project review" activity. However, these projects wait for the other projects that need editions for the "Project review". It means that there is an unnecessary waiting time of about six days.

V. CONCLUSION AND DISCUSSION

Along with digital transformation, digital technologies and data-oriented methodologies also serve smart campuses. This study aims to analyze project application processes by the proposed process mining methodology related to the smart university. Process mining was applied in the Coordinatorship of Scientific Research Projects at Izmir Bakircay University.

First of all, this study suggests that non-digital processes should be digitized first as soon as possible. Then many data-based methods can be applicable, such as process mining, data mining and machine learning.

Preventing or reducing procedural correction is an important issue. As a more general preventive action, the parts controlled by BAPK personnel can be prepared as a stimulant in the digital environment if possible. If not, a checklist can reduce the cycle time by an average of 13.5 days (12% of current cycle time).

Another point that will improve the process is reducing the revisions required by reviewers for the second time, which occurred 15.6% of applications. Because sending reviewers requires 26 days on average, more than one "Sending reviewer" activity should be occurred just one.

Although it is expected that after the "Project accepted" activity, the "Signing an agreement" activity should not be too long, 55.4 days lasted to start the project officially. Project coordinators should be reminded to sign an agreement once a week, or due date of less than 30 days can be defined and declared to applicants.

Some processes have digitizing and automating convenience. Future studies can investigate whether the process is reasonable for robotic process automation (RPA). If it is sensible, RPA can reduce cycle time and cost.

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