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Facilitating wasteful activities discovery in pure service environment through usage of process mining

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Abstract

This paper describes the possibilities of using process mining in order to facilitate the discovery of wasteful activities (in terms of lean service) in pure service organizations. The specificities of pure service systems will be analyzed, with special focus on value creation and wasteful activities in service organizations. Existing process mining algorithms can be applied to event logs (cases that have been completed, i.e. "post-mortem" cases) created by Enterprise Systems in order to discover wasteful activities and flow interruptions. Process mining application can also be extended to operational support of lean transformation (partial cases), in order to analyze cases that have not yet been completed ("pre-mortem" cases) and predict the appearance of wasteful activities and to recommend suitable actions for minimizing possible wastes.

Key words: *lean transformation, process mining, wastes*

1. INTRODUCTION

Services now constitute the majority employer and source of income for developed economies, accounting for approximately three quarters of gross domestic product in the USA and UK [1][2][3]. Having in mind the importance of services in today's economy, one can think that the quality of services delivered is at least at the level required by customers. But, researches have reported that majority of customers in USA and UK are not satisfied with the quality of the services they are receiving [4][5][6], and that the level of service quality is in fact declining [7]. Quality decline and the increase of costs are frequently attributed to the way that service companies are organized, and to the way they operate. Service companies often try to replicate Tayloristic approach to organizing company, characteristic to mass-production and manufacturing, which usually includes strict management control, narrow task definition, low skill (and often low pay) workers, etc [8][9][10]. This approach affects process performance, employees' morale, and ultimately decreases the level of service quality. This is why service companies are forced to rethink basic principles that their business is based on.

At the beginning of 1980s it was clear that there's a quality gap between western and Japanese products, with the most pronounced differences observed in automotive sector. International Motor Vehicle Program (IMVP) was established at Massachusetts Institute of Technology (MIT) with the aim to investigate why Japanese car manufacturers were delivering higher quality products at lower costs than their western competitors. This quality/cost difference was attributed to a fundamentally different operating paradigm utilized by Toyota. This Toyota Production System (TPS) was referred to as "lean production" or "lean manufacturing" [11].

Value stream Analysis (VSA) is a tool which can help to implement all five lean principles (Value, Value Stream, Flow, Pull and Perfection) [12]. The main use of VSA is to identify the value stream for a product/service, but it also enables waste to be easily exposed. Wasteful activity is an exception that deviates process from optimal execution. Identifying value streams and exposing wasteful activities in manufacturing systems is somewhat easier than in service systems, since those activities are usually physically visible. With service systems, the activities are usually performed within some form of Enterprise System, which makes them less recognizable. Process mining should be able to construct value stream map from event logs, thus exposing wasted and flow interruptions.

The paper is organized as follows: after a short introduction, a theoretical background on the subject will be given; after that, possibilities of combining process mining with lean application in pure service environment will be given; a short conclusion will be presented at the end of the paper.

2. THEORETICAL BACKGROUND

While lean concept is not so new, process mining is an emerging discipline that offers comprehensive sets of tools to provide fact-based insights and to support process improvements. The evidence of process mining being used in continuous process improvement (CPI) efforts is scarce. Mulvenna [13] states that only with lean processes (devoid of non-value adding activities) IT can support manufacturing philosophies such as Just-In-Time. Process mining breathes life into otherwise static process models and puts today's massive data volumes in a process context. Hence, management trends related to process improvement (e.g., Lean, Six Sigma, TQM, CPI) can benefit from process mining.

2.1 Lean thinking and wasteful activities in pure service environment

Lean production as a post-Teyloristic approach to management has helped manufacturing companies around the world to realize significant quality and cost gains [11][12][14]. However, lean initiatives have mostly been focused on manufacturing, and cases that indicate the successful application of lean concepts in manufacturing organizations are abundant. Lean application to service industry has been usually limited to service context in which physical product exists, where manufacturing companies try to improve value creation through integration of products and services aimed at getting closer to customers and their needs [15], or to a healthcare field while testimonials of successful lean transformation in pure service environment are not that common.

In the mid 1990's, Womack and Jones [12] proposed lean implementation beyond manufacturing context. At first, lean principles were implemented to general supply management [16][17]. Bringing supply chain partners closer to each other has helped in reducing stock throughout the retail supply chain, which resulted in reduction in the costs of holding stocks, reduced write-off costs on perishable items and an increased ability to pull products quickly through the supply chain based on unpredictable customer demand [18][19][20][21]. Lean tools used in manufacturing context were relatively easily transferred to retail supply context, due to the common focus on product flow [22].

Significant results in lean application in service context were achieved in healthcare. The application dealt with the movement of patients through the treatment process, where patients were observed as products moved through a transformation (treatment) process inside the healthcare system. This perspective (although often criticized for treating humans as objects) has allowed the use of established lean tools used in manufacturing context, such as value stream mapping and waste reduction techniques [23][24].

There are several examples of companies successfully transferring lean principles from plant operations to non production areas of organization [25][26][27]. Service industries where lean has been applied include insurance [28], education [29][30], environmental consulting [31], and IT and software development [32]. The use of process mapping in service has been proposed outside of lean application. Womack and Jones [33] have modeled consumers' interaction with the products and services of a company by mapping the process of consumption. The authors state that this approach to mapping the service delivery is highly applicable to any service, being the best way to identify the inefficiency and opportunities for improvements.

Some researches are limited to only certain aspects of leanness. Buzby et al. [34] report on the use of lean to streamline a quotation process in a single company, but focuses only on measuring cycle and takt time of quote processing which was then optimized using general improvements such as increased automation, paperwork reduction and an electronic reminder system to report delays. While this research reported a reduction in cycle time and takt time, it was solely focused on speed and efficiency, thus putting service quality to the background. Sprigg and Jackson [35] conducted a research of call centre management, focusing only on two key features of lean: process simplification through work standardization and workflow improvement through extensive usage of electronic monitoring systems in order to improve efficiency. Some authors analyzed the applicability of lean tools other than value stream mapping for improvement has been considered. Maleyeff [36] found significant overlap in the process system of manufacturing and service organizations (such as structural similarities and common problems, such as waste) by analyzing 60 service systems.

Five fundamental lean principles mentioned above do not always apply in service system in obvious and explicit way [36]. For instance, many service systems are by nature pull systems, since service rendering is usually initiated by customer. Spear and Bowen [37] defined four fundamental principles (based on the Toyota Production System) that may be well suited for understanding how Lean principles are generally applicable. The principles are as follows:

1. All work shall be highly specified as to content, sequence, timing, and outcome;
2. Every customer-supplier connection must be direct, and there must be an unambiguous yes or no way to send requests and receive responses;
3. The pathway for every product and service must be simple and direct; and
4. Any improvement must be made in accordance with the scientific method, under the guidance of a teacher, at the lowest possible level in the organization.

Four goals of any improvement are to make things easier, better, faster, and cheaper, in that particular order [38]. Lean focuses on adding value and eliminating waste through simplification, quality improvement, and lead time reduction; cost reduction is a natural outcome. Lean principles are being applied in order to obtain value for the customer through the elimination of waste (muda - 無駄). Wasteful activities are treated as exceptions that can deviate process from optimal execution. Taichii Ohno [39] identified seven types of waste common to every manufacturing system: transportation, inventory, unnecessary motion, waiting, over-processing, over-production, and defects. Other sources have proposed additional wastes, like underutilized people (latent skills) [40]. The original seven wastes have often been redefined to better fit the organization, circumstances, external pressures, etc. In order for wastes to fit better with the service system, the original seven wastes could be redefined as follows [41][36]:

1. Delay – time wasted either directly in queue, or waiting for information to be transmitted;
2. Duplication – re-entering data, repeating details on forms, answering queries from several sources within the same organization;
3. Unnecessary movement – queuing several times, lack of one-stop, unnecessary physical transport of information;
4. Unclear communication - wastes of seeking clarification, confusion over product or service use, wasting time finding a location that may result in misuse or duplication;
5. Resource inefficiencies – includes the management of personnel, equipment, materials, or capital in ways that are wasteful;
6. An opportunity lost to retain or win customers – a failure to establish rapport, ignoring customers, unfriendliness, and rudeness
7. Errors/Mistakes – omissions that cause work to be redone.

The proposed list is general, and provided in no particular order. The final list should be tailored with specificities of concrete service system in mind.

2.2 **Process mining**

Process mining is a process management technique that allows the analysis of business processes based on event logs. Process mining is an emerging discipline providing comprehensive sets of tools to provide fact-based insights and to support process improvements. Process mining emerged in the last decade [42][43] but the roots date back about half a century [44][45][46]. Agrawal et al. [47] first introduced the usage of process mining in the context of workflow management. The α algorithm, which is now considered to be the basic algorithm for process mining, was the first algorithm to truly capture concurrency in business process [48][49][50][51]. This technique has difficulties in dealing with noise (parts of the log that are incorrect or incomplete) and incompleteness (logs not containing all possible routes) in event logs, so more advanced process mining algorithms were developed, such as *genetic process mining* and *heuristic mining*, that can deal better with noise and incompleteness [52][53][54]. The goal of process mining is to use event data to extract process-related information, e.g., to automatically discover a process model by observing events recorded by some enterprise system [49][55].

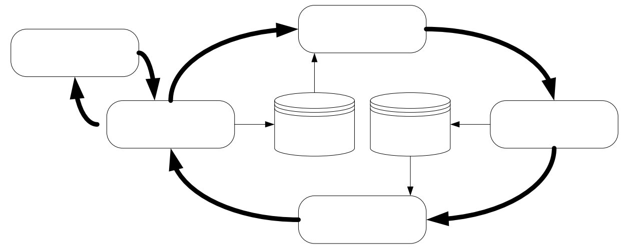

Figure 1. The BPM life-cycle

To position process mining, it is good to start with describing the so-called BPM life-cycle (Figure 1) [49][55]. The life-cycle describes the different phases of managing a particular business process. BPM life-cycle will be explained in parallel with PDCA (Plan-Do-Check-Act, sometimes referred to as Deming cycle/wheel or Shewhart cycle, shown in Figure 2), an iterative four-step management method used in business for the control and continuous improvement of processes and products [56][57][58]. PDCA is essential tool for lean transformation, and it is interesting to note many similarities between PDCA cycle and BPM life-cycle.

Figure 2. PDCA

BPM life cycle, shown on Figure 1, consists of four phases, similar to the phases of PDCA cycle:

1. Design phase/Plan – the process is designed/modeled in this phase; the objectives and processes necessary to deliver results in accordance with the expected output (the target or goals) are established in Plan phase;
2. Configuration/implementation phase/Do - model is transformed into a running system; plans are implemented, processes are executed in the Do phase;
3. Enactment/monitoring phase/Check - processes are running while being monitored by management to see if any changes are needed (some of the changes are handled in the adjustment phase); actual results (measured and collected in Do phase) are measured and compared against the expected results (targets or goals from the Plan phase) to ascertain any differences;
4. Diagnosis/requirements phase/Act - evaluates the process and monitors emerging requirements due to changes in the environment of the process (e.g., changing policies, laws, competition); corrective

actions on significant differences between actual and planned results are being taken. While the differences are being analyzed in order to determine their root causes.

As it can be seen on figures 1 and 2, process models play significant roles in design and configuration/implementation phases, i.e. in Plan and Do phases, while data plays dominant role in enactment/monitoring and diagnosis/requirements phases, i.e. in Check and Act phases.

Process mining goes beyond mere process discovery, and event logs can be used to conduct three types of process mining:

1. Discovery – producing process model from event log without using any a-priori information;
2. Conformance – existing model is compared to event log of the same process (checking if reality, as recorded in the log, conforms to the model and vice versa);
3. Enhancement – extending or improving an existing process model using information about the actual process recorded in some event log (changing or extending a-priori model).

In order to perform process mining, it is assumed that it is possible to record events in a way that (i) each event refers to an activity (i.e., a well-defined step in the process), (ii) each event refers to a case (i.e., a process instance), (iii) each event can have a performer also referred to as originator (the person executing or initiating the activity), and (iv) events have a timestamp and are totally ordered [59]. Process mining is usually identified only with control-flow discovery. However, event logs usually have much more information, i.e. events and cases can have any number of additional attributes, such as resources used in the process execution, timestamps, costs, etc. All these attributes can be used to extend the existing model. According to additional attributes existing in event log, following perspectives can be mined [55]:

1. Control-flow perspective (How?) – focuses on ordering of activities; goal is to find a good characterization of all possible paths, and to present it in some graphical process modeling notation (Petri nets, BPMN, EPC, etc.);
2. Organizational perspective (Who?) – focuses on resources used in process execution; to either structure the organization by classifying people in terms of roles and organizational units or to show the social network;
3. Case perspective (What?) – focuses on properties of process instance; case can be characterized by its path in the process, by the originators working on it, or it can be characterized by the values of the corresponding data elements;
4. Time perspective (When?) – focuses on timing and frequency of events; when events bear timestamps it is possible to discover bottlenecks, measure service levels, monitor the utilization of resources, and predict the remaining processing time of running cases.

Process mining is relatively new discipline, and the evidence of it being used in continuous process improvement (CPI) efforts is scarce. There are researches that combine process mining and lean (process activity analysis), but the results are limited to a specific application, and activities aren't being treated from value creation point of view [60]. Value Stream Mapping (VSM) is primarily used as a tool for identifying wasteful activities. VSM has been used in service environment, but the problem can occur since some of activities can be concealed within the Enterprise System used by the company. The result can be process map that is incomplete or inaccurate. Process mining can extract model that describes the reality. This model is more suitable for activity analysis, and can be translated in Value Stream Map in needed.

3. APPLYING PROCESS MINING TO WASTEFUL ACTIVITIES DISCOVERY

There are certain limitations to *manual* process analysis in a pure service environment:

1. Processes are invisible - When entering a factory floor, it can clearly be seen who is working and what is he working on. In an office one can see people interacting with their computers, but it's not clear what they are working on;
2. Reality is different than people think - Everyone only sees a part of the process with little knowledge about what happens before and after; there's a perceived image of what process looks like on one side, and then there's a *real* process on the other side (Figure 3);
3. People have different opinions about where the problem is - Because everyone has a subjective view on what is happing, people often have different opinions about where the problem is.

Applying process mining to wasteful activities discovery can be divided into three parts:

1. Analyzing wasteful activities in pure service organizations, and devising a list of wastes characteristic for a particular line of business (organization);
2. Analyzing the existing process mining algorithms in order to test its fitness for discovering wasteful activities and flow interruptions;
3. Extending process mining application to operational support of lean transformation.

3.1 Analyzing wasteful activities in pure service organizations

Lean service researches are usually limited to only certain aspects of leanness, such as value stream mapping, takt and cycle time reduction, process simplification, work standardization, etc., but not too many researchers focus on improving processes in service environment by eliminating wasteful activities.

Maleyeff [36] found significant overlap in the process system of manufacturing and service organizations (such as structural similarities and common problems, such as waste). While the list of wastes common to every manufacturing system proposed by Ohno is generally accepted (with little or no adjustment), the list of wastes identified within service companies can vary significantly from author to author. Although value adding vs. non-value adding activities sounds like common sense, studies by the Lean Enterprise Research Centre (LERC) at the Cardiff Business School have shown that for a typical UK service company only about 1% of activities add value, about 49% of activities don't add value but are necessary, and around 50% of activities don't add value and are not necessary [61]. Many organizations concentrate most of their effort to improve the mere 5% of value adding activities, which is in most cases a difficult and expensive task.

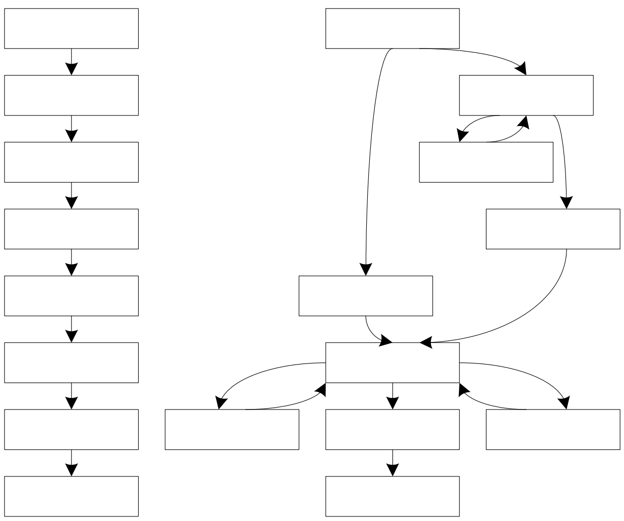

Figure 3. What employees think process looks like vs. what process *really* looks like

While connections between categories of waste found in manufacturing systems and those found in service systems can be made, many of the categories would be much less important in a service system. The terminology used in service systems would also be inconsistent with terms used typically in manufacturing (i.e. service systems are usually unfamiliar with defects, inventories, and over-production). Although there were attempts to create general list of wastes found within service systems, only a few efforts were made with creating a list of wastes for specific services [36].
The procedure for classification would consist of creating the exhaustive list of specific wasteful activities for each of the service systems being researched, analyzing how often each specific activity was repeated, then combining the resulting list into similar categories of wasteful activities. The aim is to devise a list of (possibly) 7 categories of wasteful activities (in order for the list to resemble the one developed by Ohno, the aim is to identify 7 categories of wasteful activities, but the actual number may vary if needed) for each service system.

3.2 **Testing the existing process mining algorithms' fitness for discovering wasteful activities and identifying value stream maps**

Most important outcome from process mining perspective is the discovery of the main process flow [59]. Mulvenna et al. [13] state that only with lean processes (devoid of non-value adding activities) IT can support manufacturing philosophies such as Just-In-Time. Process mining breathes life into otherwise static process models and puts today's massive data volumes in a process context. Hence, management trends related to process improvement (e.g., Lean, Six Sigma, TQM, CPI) can benefit from process mining. These approaches have in common that processes are "put under a microscope" to see whether further improvements are possible. VSM is one of key lean tools used for analyzing processes from value adding point of view. Although VSM has its own set of rules, other graphical process models can also be used for analyzing the impact that wasteful activities have on process execution, weather they have been represented as Value Stream Maps or not. Process mining can help extracting process map from log files in conditions of lower process visibility that prevail in service systems. Extracted process maps can later be translated in Value Stream Maps by using the appropriate notation. Process mining can particularly be useful in discovering hidden activities (the ones that employees weren't even aware of), idle times, high process variations, etc.
Heller and Stehn [60] suggest that process efficiency can be improved by using process mining in pre-design phase in off-site housing projects. They've analyzed the ratio between the number of logged activities and minimum number of activities needed to complete the project. However, they haven't analyzed the nature of those activities (from value adding point of view), and it is not entirely clear how minimum number of activities should be determined. This means that, even when the ratio equals one, process can be inefficient from customers point of view. Van der Aalst [55] states that process mining can help to analyze deviations and inefficiencies by providing new insights and generating various ideas for process improvement, but offers little evidence of using process mining in CPI context (projects such as Lean or Six Sigma).
Van der Aalst [55] suggests five step approach to process mining, which can be utilized for extracting value stream maps from event logs:

1. Step one – obtain an event log;
2. Step two – create or discover a process model;
3. Step three – connect events in the log to activities in the model;
4. Step four – extend the model by adding organizational perspective, time perspective, case perspective, and any other perspective depending on the information in the log (for example, information on risk and costs);
5. Step five – return the integrated model.

The integrated model depicts reality, as it is based on factual data extracted from the event log, and is therefore more precise than the model devised by human. The integrated model can be used as input for various tools and approaches, with CPI being one of them. Integrated model represents all possible paths that were logged. That is why, at this stage, case perspective of process mining is very important since it can help understanding the impact that wasteful activities can have on process performance. Case perspective connects extracted model with individual process instances which can help process analysts to understand circumstances under which wasteful activities have occurred, as well as the impact that those activities have on process efficiency.

3.3 Extending process mining application to operational support of lean transformation

Most process mining techniques analyze events that belong to cases that have already completed which makes guiding cases that are still in the pipeline impossible. Data in event logs can be partitioned into “pre mortem” and “post mortem” event data. “Post mortem” data refer to information about cases that have completed, i.e., these data can be used for process improvement and auditing, but not for influencing the cases they are referring to. “Pre mortem” data refer to cases that have not yet completed. With this kind of data, it may be possible that information in the event log about cases they are referring to can be exploited to ensure the correct or efficient handling of this case.

Process mining techniques can be used to make predictions about the future of a particular case and guide the user in selecting suitable actions. Predictions are being made for the running case that is still generating events, and is therefore described by a partial trace. Operation support is forward looking in its nature, and consists of three activities:

1. Detect – comparing partial trace with a normative process model; if non-value adding activity or activity that might disrupt the flow is being performed, or if a deviation from the value adding route is detected, alert can be generated;
2. Predict – making predictions by comparing current case with similar cases that were handled before (predicting costs, remaining flow time, delays, non-value adding activity execution, flow disruptions, etc.);
3. Recommend – guiding the user in selecting the activities that are to be executed next (in order to minimize costs, delays, resource usage, flow time, etc.);

The idea is to add data mining techniques to process mining, and apply them to event logs. The exception analysis (i.e. wasteful activities) problem can be mapped to a classification problem, where process instances are the objects that belong to either the "normal" or to the "exceptional" class. Characteristics of exceptional activities will be identified in the first part of the project, and those characteristics should be mapped to classification rules. Exceptions could be predicted by identifying the characteristics of exceptional instances, and by then checking whether a running process instance has those characteristics (for example, the analysis can determine that wasteful activities can occur with certain instances of processes, with specific services or customers involved).

4. CONCLUSION

Process mining is an emerging discipline providing comprehensive sets of tools to provide fact-based insights and to support process improvements, and the evidence of it being used in continuous process improvement efforts is scarce. VSM is a lean tool that is primarily used for identifying wasteful activities. VSM has been used in service environment, but creating a Value Stream Map of a process operating in pure service environment can be difficult since some of the process activities can be concealed within the Enterprise System used by the service system. The result can be process map that is incomplete or inaccurate.

Process mining can extract model that describes the reality. This model is more suitable for analyzing non-value adding activities, and can be translated in Value Stream Map if needed. The model derived in this way should be able to facilitate lean transformation of companies operating in pure service environment.

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Olakšavanje otkrivanja nepotrebnih aktivnosti u pružanju usluga putem upotrebe *process mining* tehnike

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Rezime

Ovaj rad opisuje mogućnosti upotrebe tehnike „process mining“ kako bi se pojednostavilo otkrivanje nepotrebnih aktivnosti (u smislu lean usluge) u organizacijama koje samo pružaju usluge. Analizirani su sistemi pružanja usluga, sa posebnim ostvrtom na stvaranje vrednosti i nepotrebnih aktivnosti u organizaciji usluga. Postojeći algoritmi process mining tehnike mogu da se primene na „event logs“ (slučajeve koji su završeni, tj. „post-mortem“ slučajeve) koje stvaraju Sistemi Preduzeća kako bi otkrili nepotrebne aktivnosti i prekide toka rada. Primena process mining tehnike može takođe da se proširi na operacionu podršku lean transformacija (delimični slučajevi) kako bi se analizirali slučajevi koji još uvek nisu završeni („pre-mortem“ slučajevi) i kako bi se predvidela pojava nepotrebnih aktivnosti i preporučile odgovarajuće aktivnosti za smanjenje mogućih gubitaka.

Ključne reči: *lean transformacija, process mining, gubici*