The Design of a Methodology for the Justification and Implementation of Process Mining

Abstract
Process mining techniques allow organizations to extract knowledge from information systems that store process-related data. Process models can be (re)constructed based on process executions, the SOLL and IST position of process executions can be compared, processes can be benchmarked and simulated, and lastly, real-time operational support is provided through detection, prediction and recommendations. The value organizations can derive from these techniques is largely contingent upon the quality of their process data.

Financial specialists are increasingly relying on information technology to support them in their jobs. Process mining yields greater visibility of operations. This paves the way for improved governance and control measures. Conformance checking supports internal and external auditors, compliance specialists, controllers and other related professions through testing whether the process is executed in accordance with the business rules. Process improvement specialists (e.g. lean six sigma professionals) can simulate changes in the process, to test how these changes affect the process. Detection can be used as a signaling tool, allowing organizations to take preventive or corrective measures. Prediction can be used to predict future related process parameters (e.g. workload). Lastly recommendations provide operational employees with advice based on historic process executions.

Van der Aalst (2011b) states the first step in any process mining project is its justification. However, neither the literature review, nor backward searches, provided methods for the justification and implementation of process mining projects. Therefore, this paper develops a method for the justification and implementation of process mining in organizations. A generic process mining business case framework is developed, which organizations can use as a guideline for developing their business case. Additionally, an eight phase methodology is developed, to assist organizations from their early planning stages up until reviewing the implementation.

Keywords: process mining, process intelligence, business case, justification

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1. Introduction

Process mining (PM) is a method that is used to extract information from event logs or directly from databases. Many information systems store process related data in an event log. The event log contains information concerning which process steps are being executed, at what time these steps are executed, and which resource is executing them. Additional data ontologies can be logged, such as cost, information about the process step, or item, et cetera. PM has four areas of application: process discovery, conformance checking, process enhancement and operational support. Process discovery concerns itself with the construction of process models based on the data recorded in the event log. This can yield interesting information on common and rare activities, bottlenecks in the process, employee workload, et cetera. Conformance checking techniques can be employed to compare the discovered process model with the formal process model. This provides diagnostics detailing discrepancies between the two. Process enhancement concerns itself with the improvement of processes. Assumed improvements can be tested through process simulation techniques. Lastly, operational support helps to support business processes in real-time through detection, prediction and recommendation, features within the running processes.

IT investments make up a significant part of most organizations' budgets (Jeffery & Leliveld, 2004). Since 2009 the largest IT investments are taking place in business intelligence (BI) and analytics (Kappelman et al., 2014). Chen et al. (2012) identify PM as one of the emerging disciplines in BI. This makes it likely that part of these new investments go towards PM. However, many IT investments go over budget or are cancelled prematurely, mainly due to costs exceeding the budget (Berghout & Tan, 2013). Additionally, investments in novel technologies, such as PM, have a higher failure rate (Whittaker, 1999; El Aman & Koru, 2008). Fortune and White (2006) identified the development of a business case as a key element of project success. Therefore it seems wise to develop a thorough business case which can serve as the basis for the investment decision. Business cases help organizations to make an informed decision regarding their investment through, among others, detailing the benefits, costs, risks, and the alignment with strategy.

According to Van der Aalst (2011b) the first step in undertaking a process mining project is justification. However, the development of business cases is currently unaddressed within the PM discipline. The richness of the business case is a crucial element in estimating costs and benefits IT investments can bring (e.g. Ward et al., 2008; Whittaker, 1999). Therefore this paper provides a framework on how business cases can be constructed for PM. This results in a comprehensive framework that organizations can use for the justification and implementation of PM. An eight phase methodology is presented to guide organizations through the entire process.

Therefore the contribution is both practical and academic. Organizations that consider investing in PM, are given clear guidelines on how to construct their business case, and are pointed towards important elements to consider within the various items of the business case. The academic contribution is twofold. First, this paper contributes by presenting a methodology for the justification and implementation of PM. This methodology can serve as a basis for further research. Second, by providing organizations with clear guidelines on how to construct business cases, more organizations may choose to apply PM within their organizations. Current literature mainly shows researchers applying PM within organizations. The employment of PM by more organizations, yields extra opportunities, in examining the use and effectiveness these organizations derive from the application of PM techniques.

This paper is organized as follows. Chapter 2 contains a literature review on PM. PM techniques are detailed, event log quality, and process model quality are discussed. Moreover 15 case studies are described to show the business value of PM. Lastly, conclusions are drawn synthesizing the findings in chapter 2. Chapter 3 describes whether IT investments create value, how this value is created, and how this value can be assessed. In chapter 4 the findings from chapter 2 and 3 are used to build a general business case framework for the value assessment of PM. Lastly in chapter 5 the conclusions are detailed, along with the discussion and directions for further research.

2. Process mining

The original goal of this paper was to research the applicability of PM in business settings. In order to do so a systematic literature review was conducted. The approach for undertaking the literature review is detailed below, in chapter 2.1. The rest of this chapter is organized as follows. In chapter 2.2 an introduction is given with regard to PM. In chapter 2.3 the various PM techniques are detailed. In chapter 2.4 and 2.5 respectively event log quality and process model quality are discussed. Chapter 2.6 serves to detail how PM techniques can be applied in practice. Lastly, a conclusion is drawn based on the findings in this chapter.

2.1 Approach

The goal of this paper is to research the applicability of PM in business settings. In order to do so, a systematic literature review was conducted. This paragraph details the approach for the literature review conducted in this paper. The approach in schematic form can be found on the page below, in figure 1.

The following Boolean phrase was used to search: “"process mining" OR “workflow mining” AND ("process discovery" OR "process analysis" OR "conformance checking" OR "process improvement" OR "business process management" OR "business intelligence" OR "control flow" OR "performance analysis" OR "Business process" OR "applications" OR "case study" OR "case studies"”. This search yielded enough results to provide a proper basis to understand the context of PM and its applicability. The context is provided through the keywords: “business process management”, “business intelligence” and “business process” in combination with either “process mining” or “workflow mining”. Its applicability is addressed trough they keywords “process discovery”, “process analysis”, “conformance checking”, “process improvement”, “control flow”, “performance analysis”, “applications”, “case study” and “case studies”. The databases searched were Business Source Premier, Academic Search Premier and Library, Information Science & Technology with the criteria that the journal should be scholarly (peer reviewed), an academic journal, and in the English language.

The following step was downloading and documenting all available papers, unavailable papers and duplicate papers. The next step was reviewing the abstracts of all downloaded papers to assess their relevance for this paper. With the goal of the paper in mind the abstracts were reviewed using the following criteria:

1. PM context
2. PM applicability
3. Real-life event log

These three criteria enforce the goal of the research: to further research the applicability of PM in business settings. Not all three criteria have to be present for the paper to be relevant to this paper. As long as it brought understanding to the context in which PM is being used, or demonstrates relevant applicability, the paper is part of the final set of literature. PM context brought contextual information to thoroughly understand the setting in which PM takes place. PM applicability served to illustrate the applicability of PM, and by using real-life event logs as a criterion, the relevance in business settings was safeguarded. The brief review was conducted through reading the abstract and when necessary, some parts of the paper to verify which criteria applied reviewed paper.

After all papers were subjected to a brief review, a detailed review took place, to further examine the papers and gather additional literature. The gathering of additional papers takes place trough backward searches. Backward searches were conducted to gather additional information, in support or addition to, the literature set from the original search.

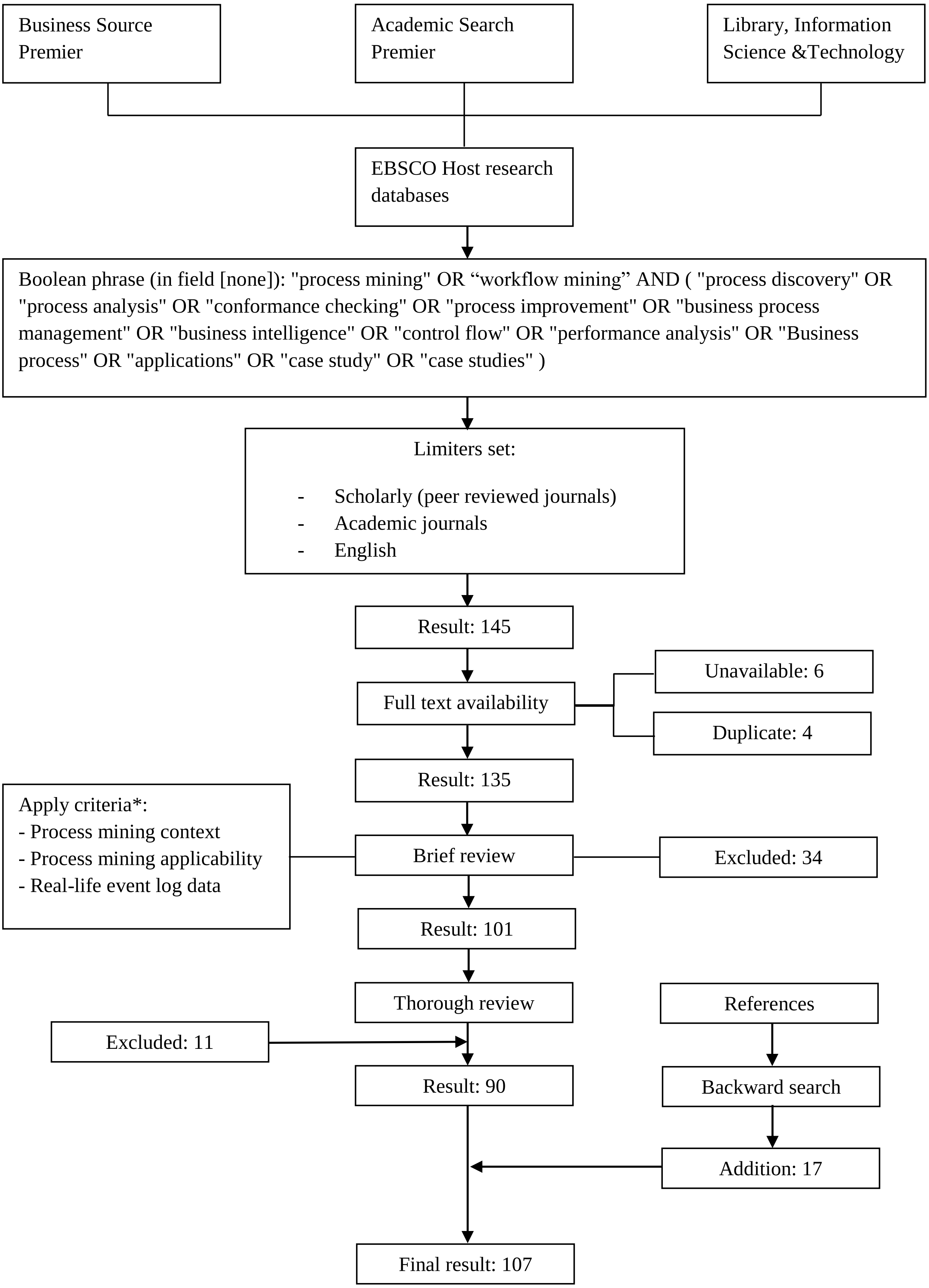

Figure 1: Schematic approach of the literature review on process mining

2.2 Introduction to process mining

PM, in earlier works also referred to as workflow mining, is a relatively young research discipline. Its first application dates back to 1996 where Cook and Wolf (1996) argued that it would be useful for organizations to formalize their processes. However, once a process model was constructed, there was no way to check whether the formal model reflected the reality of day to day business. Therefore, Cook and Wolf (1996) mined a process model from an event log. They referred to this as process discovery, a term still in use to date. Cook and Wolf (1996) also checked whether the discovered log matches the formal model, while allowing the existence of discrepancies, they called this process verification. Nowadays this activity is commonly known as conformance checking. Since then PM has come a long way. In 1999 the IEEE Task Force on Process Mining was established with the purpose to promote PM research, development, education and understanding of PM (Van der Aalst et al., 2011). While the development of PM algorithms is highly technical, the ease of use of PM applications has increased significantly in recent years. One does no longer need to be a programmer in order to apply PM. Various software applications such as ProM and Disco have been developed to make analysis, trough PM, more user-friendly. Searching for "process mining" on Google Scholar yields 9,940 results as of the 11th of September, 2015. Out of these 9,940 results, 6.760 results have been published since 2010. This indicates that the domain of PM is gaining rapid popularity and is increasing in maturity.

PM falls under the umbrella of business intelligence (BI), and more specifically business process intelligence (BPI). BI is the discipline where data is being turned into information from which knowledge can be deduced. This is most commonly achieved through the application of data mining techniques. PM, similar to data mining, also mines data but focuses on a smaller area, namely turning process-specific data into information from which knowledge can be deduced. Also related to PM is business process management (BPM). BPM is a discipline that aims to improve the efficiency of business processes, in other words it concerns the management of business processes. Van der Aalst (2011a) states that PM serves as a bridge between BI and BPM. He states that only few BI-tools offer mature data mining capabilities, and that the tools that do offer mature data mining capabilities do not focus on the processes. Furthermore, he states that the BPM discipline analyzes theoretical models which are often not an accurate representation of the factual process executions. Therefore he claims that PM serves as a bridge between BI and BPM, by combining the actual event data, reflecting the actual path of process execution, and process models prescribing desired behavior.

Once the application is integrated within the IT infrastructure of an organization, it is possible to apply PM techniques in real-time. Through real-time application, PM can be utilized as a business activity monitoring tool. When the application is able to interfere in process executions, this is referred to as complex event processing. By intervening in real-time, problems can be prevented before they materialize (Seufert & Schiefer, 2005). Such an instance can occur when, e.g., a process is being executed that does not fit the defined process model. The real-time support PM techniques offer is elaborated upon in chapter 2.3.4.

Financial specialists are increasingly relying on information technology to support them in their jobs. Process mining yields greater visibility of operations. This paves the way for improved governance and control measures. Conformance checking supports internal and external auditors, compliance specialists, controllers and other related professions through testing whether the process was executed in accordance with the business rules. Detection can be used as a signaling tool, allowing organizations to take preventive or corrective measures. Prediction can be used to predict future related process parameters (e.g. workload). Lastly recommendations provide operational employees with advice based on historic process executions.

Lastly, PM techniques can offer support to other process improvement techniques. Process improvement techniques, such as six sigma, total quality management, continuous process improvement, lean process design, et cetera benefit from PM. The benefit lays in the way information is gathered. Traditionally, this is trough reviewing documents, conducting interviews and making observations (Samilkova et al., 2014). This way, there is still room left for subjectivity, e.g. the reviewed documents might not be up to date, interviews might not tell the full story and observations are subject to the observer's bias. By adding PM into the equation, this subjectivity is removed because PM objectively shows how the process is being executed. However, not all organizations possess event logs with sufficient quality to change the way information is gathered in these process improvement techniques.

Poor quality event logs could lead to poor improvements or even a decrease in process efficiency. Thus, PM is able to support traditional process improvement techniques by determining the IST position, under the condition that the event log is of sufficient quality. Event logs with sufficient quality are assumed to be trustworthy, complete and have well-defined events and attributes (e.g. time or resource).

2.3 Process mining techniques

In this chapter the general applications of PM are described. Respectively process discovery, conformance checking and process enhancement are discussed. The real-time operational support PM provides through prediction, detection and recommendation within running cases is also elaborated upon.

2.3.1 Process discovery

Process discovery is the most known and common application within PM. Process models are traditionally discovered trough mining of event logs. The big advantage of mining process models from event logs is that there is no room for subjectivity, because the process model is based on the process executions recorded in the event log. In addition to the extraction of process models from event logs, event logs can also be extracted from other sources. For example, De Weerdt et al. (2013) detail the extraction of process models from document management systems.

There are four perspectives to consider in process models: the control-flow perspective, the performance perspective, the role (user) perspective and the case perspective. The control-flow perspective concerns the ordering of events. For example, a random simple event log brings forth the following information about the control-flow perspective: event A is always the starting event and is always followed up by event B, which is followed up by both event C and event D in random order, which both lead to event E where the process ends. This event log would lead to the following very basic representation of a process model:

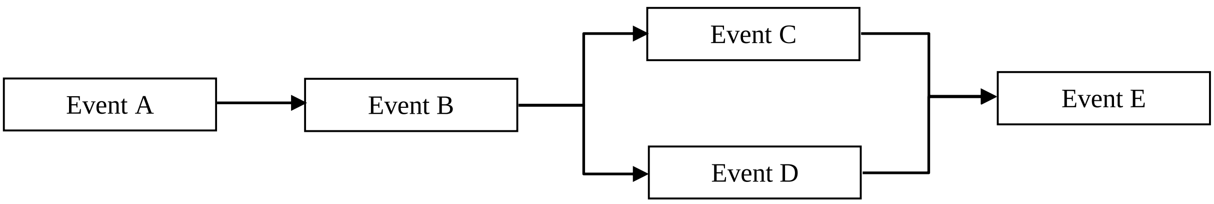

Figure 2: basic representation of a process model

The performance perspective is concerned with analyzing the time perspective of processes. This shows average runtime of process instances and individual bottlenecks. Imagine in figure 2 event C on average takes 30 minutes whereas event D on average takes 8 hours. Event D is then a bottleneck delaying the overall process execution. Discovering the reasons (e.g. not enough resources) underlying this bottleneck, action can be taken to improve process throughput times.

The role perspective deals with the interaction of various users in the process. It shows which process activities are executed by which user. Imagine figure 2 again, the organization has no idea who is executing which process steps, even though their policy prescribes that event A and event C should be executed by a user with function 1, while event B and D should be executed by a user with function 2, and event E should be executed by a user with function 3. Discovery of the role analysis can show whether this is the case or not. One might find for example that event A until event D are randomly executed by users with functions 1 and 2 and that only event E is being executed as prescribed.

Lastly, the case perspective is concerned with individual cases. Discovery of how individual cases are executed (control-flow perspective), the performance of this case (time perspective) and which users are involved in the execution of this case (role perspective) yield insights with regard to the execution of that specific case. These insights can be used to analyze individual cases for varying reasons, ranging from call-center agents helping a customer on the phone till examining major delays in processes.

Additionally, PM techniques are also able to discover invisible tasks in the process model, cancellation regions and decision points. Wen et al. (2010) describe the discovery of invisible tasks: initializing, skipping, redoing, switching and finalizing tasks. Algorithms are able to detect and visualize these tasks, even when they are not present in the event log. The same goes for the discovery of cancellation regions as described by Kalenkova & Lomazova (2014), and decision points as described by Subramaniam et al. (2007). Discovering all the elements described earlier can yield new insights in how processes are being executed. With these insights practitioners are able to improve their process executions and align their process models closer to reality.

The last discovery technique this paper elaborates upon concerns changing process executions. Bose et al. (2014) state process models are usually considered to be in a solid state, while this is not necessarily the case. For example, processes can be influenced by seasonal events or changed legislation. Therefore Bose et al. (2014) have developed an algorithm that is able to detect when a process changes, and is able to localize the activities where the change has occurred. This algorithm is further enhanced by Martjushev et al. (2015) with the ability to detect gradual drifts and identify multiple underlying factors (e.g. season and economic state).

One common problem is that process models discovered are often very complex. Especially when these event logs are produced in flexible, human centric environments. This leads to a low understanding of what exactly is going on in the process. To reduce complexity a trace clustering technique can be employed, grouping similar traces together in clusters. For each of the clusters a process model will then be formed. Typical trace clustering techniques yield a large set of process models reflecting the variants of the business process. Even though it is already less complex than one big process model, there is still room for improvement. García-Bañuelos et al. (2014) therefore have proposed a two-step divide and conquer approach. Step one is similar to traditional trace clustering techniques, clustering traces to generate various variants of the business process. Step two involves splitting these process models by sub-processes. This enhances the knowledge practitioners are able to extract from these process models because they are easier to comprehend.

2.3.2 Conformance checking

The second general PM application discussed is conformance checking. Conformance checking concerns itself with the comparison of two process models. One process model resembles the SOLL position, visualizing how the process should be executed in theory, while the other process model resembles the IST position, visualizing the factual process executions. The IST model is checked for conformance to the SOLL model. Any deviations are shown in diagnostics. Therefore comparing these process models with each other yields insights in whether the processes are being executed as they should.

Recent improvements in conformance checking techniques were made by Munoz-Gama et al. (2014). They developed a method for tackling large event logs. Similar to trace clustering for process discovery, models are made smaller making it easier to process them. Here this process is called decomposition. By partitioning the process model into smaller parts, Munoz-Gama et al. (2014) assert that the conformance checking process is sped up and is able to support conformance checking on a larger scale than before.

Conformance checking is highly useful for auditing purposes. It can speed up the auditing process and several authors showed that conformance checking techniques outperform traditional auditing techniques. Jans et al. (2014) have performed a case study within a bank, auditing previously audited data by the bank's auditors. The application of conformance checking yielded multiple cases suitable for further investigation by the bank's auditors. Among their findings were: cases where payments did not have a matching invoice, violations of segregation of duties and instances where payments were made unsigned and/or unauthorized. All of these violations were not picked up by the internal auditors working at the bank. Based on their findings Jans et al. (2014) state the following benefits of using PM techniques in auditing over traditional auditing techniques:

1. Event logs of good quality are very rich in information. Therefore the analysis can be performed on multiple attributes. Through this it is easier for PM techniques to detect any violations of the prescribed way of execution the process.
2. PM techniques are able to analyze the entire population whereas traditional auditing techniques employ analysis on a random sample.

2.3.3 Process enhancement

The third general application of PM techniques is process enhancement. Based on the diagnostics provided from the application of process discovery techniques and conformance checking techniques practitioners have a realistic insight in how their processes are actually being executed. This insight can be used to improve the process models. The insights from process discovery and conformance checking can be used in conjunction with various process improvement techniques, such as six sigma, total quality management and the application of lean methodology. Subsequently, it can be verified whether the suggested improvements have the desired effects through process simulation. Centobelli et al. (2015) detail how these simulation techniques can be used to simulate a risk aware design by integrating conformance checking measures. The simulated results can be compared with the current results to determine the effectivity and efficiency of the suggested conformance checking measures. Various case studies will later detail (in chapter 2.6.5) how processes can be enhanced in practice through the application of PM.

2.3.4 Operational support

The fourth, and final general application of PM techniques covered, is operational support. PM techniques have matured greatly since their introduction at the end of the last millennium. This offers new functionalities and increased performance. One of these new functionalities is operational support. PM is able to support the execution of running business processes trough prediction, detection and recommendation.

Van der Aalst et al. (2011) illustrate how PM techniques can be used to predict the remaining time on running cases. When historic data of the running process is available in the event log an algorithms is able to predict, based on historic results, the remaining time of that running case. Van der Aalst et al. (2011) use a simple regression technique to determine the remaining the time left on a running case. This technique is improved by Senderovich et al. (2015) who integrate the analysis of queuing information and congestion in the prediction. Queuing information refers to information in line of: when activity D can only start once B and C are completed, yet only activity B is completed in the running case this can cause extra delays. Integration of congestion techniques calculate the remaining time based on the amount of processes being executed at that time and the stage they are in. Senderovich et al. (2015) have found that the integration of these techniques increased time prediction accuracy by 25 to 40 percent. Another prediction technique developed in PM is the prediction of new activities. Kang et al. (2011) developed an algorithm that predicts probable follow-up activities for running cases based on historic event data. With this information managers are able to anticipate on expected changes.

Detection as operational support can be seen as a real-time form of conformance checking. However, there are some differences. Real-time conformance checking checks the compliance of unfinished traces, e.g. the analysis starts from the first process activity and in case of any deviations an immediate response should be created by the system, responding to the violation that occurred. Van den Broucke et al. (2014) have developed an approach to apply real-time conformance checking and validated their results by implementing this feature in a case study. Detection however does not only refer to conformance checking. Detection is broader, as it can respond to any process metric. E.g. an organization sets a threshold of 800 active processes. Once this threshold is reached the detection plugin creates a pop-up, alerting the manager.

Lastly, PM is able to provide recommendations to operational employees, based on historic process data. For example Conforti et al. (2015) implemented a system generating recommendations for insurance agents. The system recommends them which tasks to perform next. This is done by traversing trough decision trees of past process executions which consider process data, resources, task duration and task frequency (Conforti et al., 2015). Real-time recommendation techniques are currently in their novel stage. Further improvement is needed to make it sufficiently viable to be implemented in business.

2.4 Event log quality

Process data is found in event logs. Process ware information systems generate event logs as the processes are being executed. Event logs are sometimes also referred to as transaction logs or audit trails. In this paper the term event log will be consistently used. Nowadays, many information systems found in larger organizations, such as enterprise resource planning systems (ERP), workflow management systems, business process management systems, et cetera, are process aware. Therefore their event log can be analyzed trough PM. However, the quality of analysis trough PM is highly contingent upon the quality of the event log. Van der Aalst et al. (2012a) have developed a ranking system to assess the quality of event logs used for PM analysis. The higher the quality of the process data, the higher the quality of the PM analysis. Van der Aalst et al. (2012a: p. 9) propose the following ranking system:

Level	Characterization
*****	Highest level: the event log is of excellent quality (i.e., trustworthy and complete) and events are well-defined. Events are recorded in an automatic, systematic, reliable, and safe manner. Privacy and security considerations are addressed adequately. Moreover, the events recorded (and all of their attributes) have clear semantics. This implies the existence of one or more ontologies. Events and their attributes point to this ontology. Example: semantically annotated logs of BPM systems.
****	Events are recorded automatically and in a systematic and reliable manner, i.e., logs are trustworthy and complete. Unlike the systems operating at level ***, notions such as process instance (case) and activity are supported in an explicit manner. Example: the events logs of traditional BPM/workflow systems.
***	Events are recorded automatically, but no systematic approach is followed to record events. However, unlike logs at level **, there is some level of guarantee that the events recorded match reality (i.e., the event log is trustworthy but not necessarily complete). Consider, for example, the events recorded by an ERP system. Although events need to be extracted from a variety of tables, the information can be assumed to be correct (e.g., it is safe to assume that a payment recorded by the ERP actually exists and vice versa). Examples: tables in ERP systems, events logs of CRM systems, transaction logs of messaging systems, event logs of high-tech systems, etc.
**	Events are recorded automatically, i.e., as a by-product of some information system. Coverage varies, i.e., no systematic approach is followed to decide which events are recorded. Moreover, it is possible to bypass the information system. Hence, events may be missing or not recorded properly. Examples: event logs of document and product management systems, error logs of embedded systems, worksheets of service engineers, etc.
*	Lowest level: event logs are of poor quality. Recorded events may not correspond to reality and events may be missing. Event logs for which events are recorded by hand typically have such characteristics. Examples: trails left in paper documents routed through the organization (“yellow notes"), paper-based medical records, etc.

Table 1: Maturity levels for event logs (Van der Aalst et al., 2012a: p. 9)

Table 1 addresses event log quality. It describes how event log quality is influenced by how and by what data is recorded. Ranging from automatic recording, with multiple attributes (*****), to event logs that are not necessarily a reflection of reality and are recorded manually (*). The levels * to **** are contingent upon the completeness of the process data. Completeness refers to the degree to which an event log contains all executed processes and to which extent the activities in these processes are recorded.

Moreover, the processing of these event logs by algorithms becomes more difficult as more noise is present in the event log. Noise refers to exceptional behavior. If algorithms construct process models that include this exceptional behavior, the process models may not reflect reality. In chapter 2.5 quality dimensions indicating the quality of process models are introduced. One of these quality dimensions is fitness. Fitness indicates which fraction of the process executions is able to be recorded in the event log. As process models should reflect reality, this exceptional behavior should be filtered from the process model. Therefore when the event log contains noise it is unwise to desire a replay fitness close to 1.0.

Lastly, the richness of an event log is an important condition for enabling in-depth analysis. A rich event log points to an event log with multiple recorded ontologies as described at level *****. Jareevongpiboon & Janecek (2013, p. 463) distinguish between the following ontologies:

Ontologies	Description
Task ontology	Concepts of activities performed in the process being analyzed.
Originator ontology	Concepts related to actors performing activities which can be concepts about roles, departments or resources.
Event ontology	Concepts of event for process executions (activities).
Time ontology	Concepts related to data and time which are universal in any domain.
Data attributes ontology	Data attributes are additional info of tasks and they may identify business objects being updated or created in the process.

Table 2: Description of domain ontologies for process mining and analysis as defined by Jareevongpiboon & Janecek (2013, p. 463)

2.5 Process model quality

Another factor determining the quality of PM analysis, is the process model itself. There are various PM techniques available, which all have different ways of processing the event log. There are 4 quality dimensions a process model can adhere to (Buijs et al., 2014):

1. Simplicity: simplicity concerns the understandability of the model. Generally, the size of the event log analyzed, is the main complexity indicator (Mendling et al. 2008). Another main factor of complexity the degree to which a process is standardized. PM in health care often leads to complex process models whereas PM in manufacturing generally leads to well understandable process models. It may be a logical choice to display the process model in its simplest form, but Buijs et al. (2014) state this might harm the fitness, precision and generalization quality dimensions, because complex process models often can only be simplified by changing the behavior recorded in the log.
2. Fitness: fitness concerns the ability to replay an event log on the process model. It describes which fraction of the event log can be replayed on the discovered process model. Recent approaches to measure fitness are described in Adriansyah et al. (2011), Van der Aalst (2013), Cheng et al. (2015), Vázquez-Barreiros et al. (2015) and Ou-Yang et al. (2015).
3. Precision: precision describes the extent to which behavior not recorded in the event log is allowed in the process model. A precise model generally is simpler as it shows a lesser number of paths. Buijs et al. (2014) assert that the framework to measure precision by Munoz-Gama and Carmona (2011) is one of the most robust methods to measure precision. Munoz-Gama and Carmona (2011) measure precision by counting the unused edges in process models. The more unused edges are counted, the less precise the model is, as edges that are unused are not needed to replay the event log.
4. Generalization: all the other quality dimensions involve the analyzed event log and the resulting process model. Generalization goes one step further then this by taking into account the degree to which new process executions will be able to be replayed on the process model. Van der Aalst et al. (2012b) developed a method where it is measured how often a certain state is visited. When it is visited very often and it has only few activities, then it unlikely that the next time a new activity will occur. However, when a state is not visited very often and has many activities, it is likely that new process executions contain behavior which cannot be replayed on the event log because it contains new activities.

Buijs et al. (2014) have done an in-depth analysis of all four quality dimensions and have developed an algorithm that it is flexible with regard to these quality dimensions. This makes it possible to prioritize one quality dimension over the others. Depending on the problems being analyzed using PM techniques, applicants of the technique now have the tools to alter the process model in the way deemed necessary to them, to make it easier to deduce relevant knowledge from it. Van der Aalst (2012) has also researched what makes up a good process model. His findings are too broad to state here but he makes a key quote with which this paragraph on process model quality can be concluded. He states that: "… one should focus on the capability to generate appropriate models based on the questions at hand" (Van der Aalst, 2012, p. 567).

2.6 Applicability of process mining in practice

This chapter shows the business applicability of PM. A set of case studies is selected and detailed. The selection process is described in chapter 2.6.1. This chapter provides an overview of all case studies detailing the business value of PM, identified in the literature review. Additionally, it shows a summary of the contribution of the selected set of case studies. All case studies detail the application of PM, as discussed in chapter 2.3. Where applicable and relevant, conclusions about the discussed case studies are drawn. Case studies are selected on their contribution to the literature. Out of multiple similar case studies the best cited study is selected.

2.6.1 Approach

In this chapter the selection process, determining which case studies are analyzed is detailed. The first step is identifying all case studies within the literature review that illustrate the business applicability of PM. This proved to be more difficult than expected as many case studies operate on the verge between testing algorithms and showing how PM adds value. The table below consists of a list of case studies detailing how PM can add business value. The papers (N= 31) have been categorized on six major themes: general application in production and services, risk management, importance of ontologies, process improvement, healthcare and mining from alternative sources.

Paper	Main contribution
Theme 1: General application in production and services	
Lee et al. (2013)	Application of PM in assembly
Ingvaldsen & Gulla (2006)	Early PM application in business
Van der Aalst et al. (2007)	Early PM application in business
Rozinat et al. (2009)	Application of PM to ASML’s test processes
Karray et al. (2014)	Application of PM to support maintenance
Goedertier et al. (2011)	Application of PM in customer service
Theme 2: Risk management	
Caron et al. (2011)	The role of PM enterprise risk management
Jans et al. (2011)	PM’s value in fraud mitigation
Jans et al. (2014)	PM’s value in fraud mitigation
Wang et al. (2014)	Testing compliance with business rules
Theme 3: Importance of ontologies in PM	
Jareevongpiboon & Janecek (2013)	Showing the added value of ontologies (manual enhancement)
Lee et al. (2014)	Showing the added value of logging infra structure enhancement
Theme 4: Process improvement	
Leyer & Moorman (2015)	Process simulation as a driver for process improvement
Mans et al. (2013)	PM to evaluate the impact of IT
Samalikova et al. (2014)	PM as a data collection tool in process improvement projects
Huang et al. (2012)	Measuring resource allocation with PM
Theme 5: Healthcare	
Mans et al. (2009)	Clustering process data to improve comprehension
Caron et al. (2014)	Clustering process data to improve comprehension
Cho et al. (2014)	Clustering process data to improve comprehension
Rebuge & Ferreira (2012)	Clustering process data to improve comprehension
Wolf et al. (2013)	Clustering process data to improve comprehension
Rovania et al. (2014)	Clustering process data to improve comprehension
Montani et al. (2014)	Clustering process data to improve comprehension
Caron et al. (2014)	Clustering process data to improve comprehension
Delias et al. (2015)	Clustering process data to improve comprehension
Basole et al. (2015)	Clustering process data to improve comprehension
Theme 6: Mining from alternative sources	
Han et al. (2013)	Customer journey mining of websites
Mahmood & Shaikh (2013)	Customer journey mining of automated teller machines
Stuit & Wortmann (2012)	Analyzing e-mail driven processes
Soares et al. (2013)	E-mail mining to discover collaboration methods
De Weerdt et al. (2013)	Process mining from document management systems

Table 3: List of identified case studies on the business applicability of process mining

The set of case studies presented in table 3 all show relevance in business settings. Their contribution goes beyond the application of a technique in a business setting, through describing the added business value. Out of all six themes at least one paper is covered. Where relevant, in order to extent the understanding of PM's business value, additional papers are covered. Additional papers are covered when they have an extra contribution over papers already covered under the same theme. The selection of relevant papers is described per theme.

Out of theme 1: general application in production and services, Van der Aalst et al. (2007), Rozinat et al. (2009), Goedertier et al. (2011) and Lee et al. (2013) are selected. These papers clearly show the general application of PM. All four papers illustrate the application of process discovery and serve as an introduction to how PM can create business value. Ingvaldsen & Gulla (2006) is not selected because its contribution is very similar to Van der Aalst et al. (2007). However, Van der Aalst et al. (2007) have presented more tangible results and insights. Karray et al. (2014) is not covered because its contribution is similar to earlier presented case studies. It focuses on the extraction of business rules which the organization can use for their maintenance process in the future.

For theme 2: risk management, Jans et al. (2011), Caron et al. (2011) and Wang et al. (2013) are selected for showing the significance of PM in risk management. Jans et al. (2011) focuses on fraud mitigation. A follow-up work by Jans et al. (2014) is very similar and therefore is not covered. Although some new insights of that paper are used to put the findings of Jans et al. (2011) into perspective. Caron et al. (2011) is selected for showing how PM can support the enterprise risk management process, thus showing its relevance for risk managers. Lastly, Wang et al. (2013) is selected for clearly showing how PM can support compliance and the assessment of internal controls.

In theme 3: importance of ontologies in PM, Jareevongpiboon and Janecek (2013) and Lee et al. (2014) are selected to illustrate the importance of data ontologies in PM. Jareevongpiboon and Janecek (2013) detail the various data ontologies relevant to PM. They show that the value organizations can derive from PM analysis is strongly contingent upon the process data. However, they also show that when this process data is of poor quality, it can be manually enhanced later. Lee et al. (2014) show that the enhancement of logging infrastructure can create tremendous value. In their case study the production process for garments was increased by over 40 percent.

Theme 4: process improvement, covers the papers of Samalikova et al. (2014), Leyer and Moorman (2015) and Rebuge and Ferreira (2012). Samilkova et al. (2014) is selected for showing how PM can be used to support process improvement methods. The paper presents a realistic point of view of where PM can be used, and where PM cannot be used, to support process improvement methods. Leyer and Moorman (2015) is selected for showing how simulation can be employed to achieve process improvements. They simulated various sequence configurations, e.g. first in first out, last in first out, longest processing time first, earliest due date. They assessed the impact of all these configurations on the process and found that longest processing time first yielded a 40% efficiency increase over the sequence configuration currently in use (first in first out). Huang et al. (2012) show how PM can be used to determine resource allocation measures. Dependent upon the situation organizations can use various measures, measured using PM, to allocate their resources. Lastly, the paper of Mans et al. (2013) evaluates the impact of information technology. Even though the paper shows how PM can be employed to evaluate the impact of information technology, its contribution to understanding the business value of PM is minimal. Namely because the method presented is diagnostic, showing how PM can track improvements of information technology over time.

Theme 5: healthcare, only covers the paper of Rebuge and Ferreira (2012). The application of PM in healthcare, to date, remains problematic. Healthcare is a highly dynamic, complex, ad-hoc, and multi-disciplinary environment. Because of this the logging of events cannot be done optimally. Rebuge and Ferreira (2012) present a methodology that is able to partly overcome this problem. The methodology consist of log preparation (getting the data), inspecting the data (verifying the quality), repeated trace clustering (grouping similar traces together to increase comprehension until a satisfactory level of comprehension has been achieved), and selecting clusters to analyze. All other case studies in theme 5 focus on improvements in trace clustering techniques, different applications in healthcare, and new ways to derive insights from these clustered traces.

Lastly, theme 6: mining from alternatives sources, covers the papers of Mahmood and Shaikh (2013), and De Weerdt et al. (2013). Han et al. (2013) and Mahmood and Shaikh (2013) show how PM can be used to improve the customer experience. By mining the steps customers take organizations are able to create insight with regard to their though process and preferences. Mahmood and Shaikh (2013) is selected over Han et al. (2013) for its inventive use of journey mining and for showing tangible results. Stuit and Wortmann (2012) and Soares et al. (2013) both show how PM can be used to mine collaborative patterns from e-mail traffic. Neither paper is selected because essentially they are performing social network analysis. This is already covered by Van der Aalst et al. (2007) and Goedertier et al. (2011). Lastly De Weerdt et al. (2013) is selected for showing the application of PM to an information system that normally would not be suitable.

Now that the selection process of case studies is covered, the table below sets out the practical relevance of the selected papers (N = 15). This serves as a summary on how these case studies were able to add business value to the case organization. All case studies are later detailed in their respective chapters in the order they are listed, below in table 4. The case studies described below show organizations the rough scope of how PM can be applied in their organization.

Paper & domain	**Practical relevance**
Theme 1: General application in production and services	
Van der Aalst et al. (2007)	• PM analysis identified norms were unexpectedly not met by the case company. • PM is able to discover process models that are aligned with reality, highly informative and not too complex. • PM is able to identify how users interact with each other within processes. • The quality of PM analysis is improved when domain experts are involved in the analysis.
Rozinat et al. (2009)	• This case details the application of PM on a high flexible process with 720 different activity types. • PM analysis identified that certain activity types were more likely to detect errors, causing the entire process to restart. • PM analysis also identified idle times after certain test processes. Avoiding these idle times would speed up the process. • PM analysis on historic data might be dated by the time it is finished in highly flexible environments. An iterative way might be more suitable for these environments.
Goedertier et al. (2011)	• Applying PM in human centric processes such as customer service proved difficult as not all PM algorithms were able to deal equally well with the noise in the event logs. • Algorithms in PM create varying results with regard to model accuracy, comprehensibility, justifiability and runtime. • The algorithm which is most suitable depends on the quality of the event log and the type of process. • Able to discover hand-over patterns from junior to senior operators. • Companies should consider which PM tool suits their organization.
Lee et al. (2013)	• Domain knowledge is essential in PM analysis. Process data in itself is diagnostic, the inclusion of domain knowledge provides insights regarding to the how and why the process is executed like that. • PM is well abled to answer questions with regard to time (e.g. how long does it take to move from activity a to activity b) and is able to identify bottlenecks in the process.
Theme 2: Risk management	
Caron et al. (2011)	• PM is a valuable tool to support a company’s risk management practices. • The impact and likelihood of certain risks can be assessed and simulated using PM. • PM is able to identify distorted relationships between employees. • PM is able to identify malfunctions in a company’s internal control environment.
Jans et al. (2011)	• PM has high relevance in companies internal control frameworks as it is able to detect violations of business rules. • PM is able to outperform traditional auditing techniques in certain settings. • PM is able to assess the effectivity internal control frameworks.
Wang et al. (2014)	• PM analysis is able to detect malfunction of internal controls. • The application of PM can create competitive advantages for companies through mitigation of operational and legal risks.

Theme 3: Importance of ontologies in process mining	
Jareevongpiboon & Janecek (2013)	• Enriching event logs with additional attributes improves the quality of PM analysis. • Event logs can be enriched with relatively little effort. • Adding extra attributes to the event log can improve trace clustering techniques (grouping of process traces).
Lee et al. (2014)	• Details added value of enhancing the logging infrastructure, in this case through RFID technologies. • Illustrates how the application of PM can discover how various configurations influence efficiency and quality. With this insight major improvements were made to the production process resulting in higher efficiency and quality.
Theme 4: Process improvement	
Samalikova et al. (2014)	• Show how PM support process improvement techniques through objective evaluation of processes and the achievement of specific goals (e.g. bottleneck analysis). • Provide guidelines for useful PM application (high frequent, non-automated, complex processes). This implies that organizations should carefully consider which processes are worth analyzing. • Illustrate possible resistance in organizations to accept PM findings.
Leyer & Moorman (2015)	• Illustrates how organizations can apply simulation to improve their throughput times. • Findings in the particular case study showed that the prioritization of longest processing time led to a 40% decrease in throughput time in the tested settings.
Huang et al. (2012)	• Illustrate how PM can be used to assist in resource allocation. • Four different allocation methods are detailed: preference, availability, competence and cooperation.
Theme 5: Healthcare	
Rebuge & Ferreira (2012)	• Develop a methodology that is a novel contribution on how to apply PM in highly dynamic, complex, ad-hoc, multi-disciplinary environments. • PM is able to identify bottlenecks in healthcare processes. • PM is able to check whether processes are being executed as they should. • Pm is able to visualize transfer of work.
Theme 6: Mining from alternative sources	
De Weerdt et al. (2013)	• PM supports the benchmarking of processes against each other. • PM is able to identify areas that warrant further research (e.g. in this case inefficient document handling). • PM is able to provide in-depth analysis of processes providing insights suitable for improving processes. • Imperfect logging infrastructures harm the quality of PM analysis.
Mahmood & Shaikh (2013)	• Mined data from adaptive teller machines to reduce servicing times. • Developed 5 adaptive interfaces depending on the customers' ATM card, the ATM location and intensity of usage at certain times.

Table 4: Set of analyzed case studies

2.6.2 General application in production and services

Van der Aalst et al. (2007) conducted a case study within the Dutch National Public Works Department responsible for construction and maintenance of road and water infrastructures. Their goal was to demonstrate the applicability of PM and the algorithms present in ProM. The process that is analyzed in the case study, using PM techniques, is the invoicing process. The event log contained 14,297 cases, 17 activity types, 147,579 activity executions and 487 employees participated in the execution of these events. Van der Aalst et al. (2007) assert that a good performance indicator regarding the invoicing process is the timeliness of payments. They state that this should take a maximum of 31 days. Norms within the department were that 90% of the invoices were paid within these 31 days, 5% within 62 days and 5% later than that. Reality, however, was that only 70% of the invoices were paid within 31 days, 22% within 62 days and 8% later than that. A clear discrepancy between the SOLL and the IST position. They discovered the control flow of the process which the Dutch National Public Works Department deemed as highly informative, is less complicated than their own process model and better aligned with reality. Mining the organizational perspective brought informative insights about how users within the process interact with each other. For example, highly involved users were mainly assistants, while barely involved users were usually project leaders and system administrators who respectively just have a couple invoices for their projects and deal with exceptions within the process. In general Van der Aalst et al. (2007) stated that the turnover of work mainly went from senior employees to junior employees. Interesting findings from mining the case perspective included that the higher the invoice is the more time it takes to be paid. Van der Aalst et al. (2007) assert this is because employees try to avoid the responsibility of approving invoices involving large sums of money. To conclude the organization highly valued the analysis and in turn the researchers valued the organizations input. The domain knowledge of the organization was critical in deriving useful insights from the process data.

A case study conducted within ASML by Rozinat et al. (2009) analyzed a less structured process. Namely, the test process of wafer scanners. The test process consists of three phases: calibration, testing and qualification. Wafer scanners were seen as state of the art equipment and were usually produced in small batches, each new batch containing new innovations and therefore being (slightly) different. This makes the process less structured. They analyzed 24 cases that went through all three phases. These cases contained 720 different activity types and 54,966 activity executions. They found that certain activity types were more prone to detect errors, causing the entire process to restart once these errors were fixed. Bringing forward these activity types in the process sequence would led to lower throughput times. They also found some activity types were followed by high idle times indicating there is room for speeding up the entire testing process. Rozinat et al. (2009) conclude by stating that their analysis, despite bringing many useful insights, is already dated by the time it was performed. Because the wafer scanners are produced in small batches the flaws in the process executions of this batch do not necessarily hold true for the next batch. Therefore Rozinat et al. (2009) suggest PM analysis in this kind of rapid-pace environments should be carried out in an iterative manner where a continuous flow of useful insights is extracted.

Goedertier et al. (2011) conducted a case study within customer service. They analyzed how incoming calls were dealt with within the customer service department. The event log consisted of 17,812 cases, containing 42 different activity types and 80,401 activity executions. The low amount of activity executions per case point towards relatively simple processes. Even though the process is fairly simple, it is also very human-centric, which can lead to high variation. Easy calls are dealt with by junior operators while more challenging calls are forwarded to senior operators with more decision making authority. They analyzed how various algorithms coped with practical situations and found that not all algorithms are able to cope equally well with these real-life event logs. Descriptive statistics were identified as the best performer but this technique is no longer applicable when processes are concurrent. Concurrent indicating the process contains an AND-split where 2 strings of activity sequences are performed or an OR-split where multiple events which can follow on the prior event. They deemed the heuristics miner as the best performer because it scored well on all quality dimensions: accuracy, comprehensibility, justifiability and runtime. Accuracy refers to replay fitness, comprehensibility to the degree to which the resulting process model is understandable, justifiability to how the process model fits existing domain knowledge and runtime indicates the time it takes to run the algorithm. Goedertier et al. (2011) conclude by saying two things. They state that this case study proves the scalability of PM algorithms to real-life logs and that although the heuristics miner was deemed as the best performer it might be outperformed in other settings. In this case study Goedertier et al. (2011) illustrated the significance of selecting the right PM tool and its applicability in human-centric processes.

Lee et al. (2013) investigated how PM techniques can generate insights with regard to shipbuilding. Construction of ships generally is done by creating multiple 'blocks' of the ship and later assembling them together. Lee et al. (2013, p. 83) state that domain experts within shipbuilding have the following questions: "Which tasks are bottlenecks?" and "How long do blocks remain in the shipyard?". Therefore they examined the process of transporting these 'blocks'. The event log contained 190 cases (blocks), which were necessary to form one ship. They found that, on average, blocks were transported 16 times. Trace clustering techniques were employed to group blocks by characteristics. The clustering was deemed appropriate by domain experts (Lee et al., 2013). Lee et al. found waiting times before each transportation and identified bottlenecks within the process. Domain experts were reasonably satisfied with the answers they were able to provide. This is because the analysis was not perfectly executed. Lee et al. (2013) operate under the assumption that each workshop (place where blocks get transported to for work) can only perform one activity. This may have decreased the reliability of the clustering process (Lee et al., 2013, p. 94). Moreover it was not taken into account that multiple blocks can concurrently be processed in these workshops. This case study once again indicates the need for in-depth domain knowledge in complex processes, indicating that PM practitioners need to have a high degree of awareness of what is going on in the process.

2.6.3 Risk management

Caron et al. (2011) investigate the contribution PM techniques and tools can have to enterprise risk management (ERM). ERM is defined through the COSO ERM framework (see COSO, 2004), a world-level template for best practices in ERM. Caron et al. (2011) state the following relevance for using PM in ERM (p. 466):

ERM Component	Process mining contribution
Internal environment	• Focus on analyzing the organizational structure and the roles. • Indirect improvement of the internal environment (through visibility of operations).
Objective setting	• Provide support by constructing an overview of high frequent process behavior and process performance.
Event identification	• Open-minded analysis of the full process reality. • Analysis of infrequent behavior. • Simulation and analysis of extreme situations.
Risk assessment	• Provide estimates for both the likelihood and the impact of risks based on historic data.
Risk response	• Position risk on a risk map to identify the possible risk responses (e.g. detective or preventive controls). • Identify multiple risk response options.
Control activities	• Implementation of detective controls.
Information and communication	• Clear, focused, honest, accurate and timely reports.
Monitoring	• Assessment of the effectiveness of preventive controls (for avoid and reduce responses). • Monitor the evolution in both the likelihood and the impact of risks (especially interesting for accept responses).

Table 5: Process mining's contribution to ERM, table adopted from Caron et al. (2011, p. 466).

In order to validate these claims and to show their practical relevance, Caron et al. (2011) illustrate the application in an insurance claim handling case. They used 2 event logs, both with 31 activity types and a combined total of 14,942 events and 1095 cases. The case company had identified 7 possible events that cause risk in the claim handling process. These 7 events either referred to the absence of an activity that should occur, bypassing internal controls, distorted employee relations, suboptimal task allocation and the timeliness of activities. PM analysis was able to identify occurrences of all of these events. This proves the relevance of PM in risk management processes. PM supports the risk management process with regard to the points mentioned in table 5.

Jans et al. (2011) investigated how PM techniques can be employed to detect internal corporate fraud. The process subject to analysis was the procurement process. They took a random set of 10,000 cases which contained 7 activity types, 62,531 events and 290 executing users. Despite the process containing only 7 activity types they found 161 variations of process executions, although more than 90% of the process executions followed the top 6 variations. The main part of the case study however is on the aspect of checking conformance. With regard to checking segregation of duties they found that a small number of persons are responsible for the majority of the violations. Additionally, they found that 2,6% of the cases did not follow internal rules regarding authorization. Whether there were actual instances of fraud committed remains unclear and is deemed the business of the case company. Despite the fact this case study does not specifically detect fraud using PM, it does detect violations which enable occurrences of fraud to take place. Similarly to this, Jans et al. (2014), in follow-up work, found comparable results and deem that the practice of conformance checking can be very useful for auditing, stating the following benefits:

1. Event logs of good quality are very rich in information. Therefore the analysis can be performed on multiple attributes. Through this, it is easier for PM techniques to detect any violations of the prescribed way of execution the process.
2. PM techniques are able to analyze the entire population whereas traditional auditing techniques employ analysis on a random sample.

Wang et al. (2014) performed a case study within a Chinese port specialized in bulk cargo. They state that because logistics processes are high human-centric, deviations are not uncommon and can lead to significant uncertainties. PM analysis is able to provide insight in the logistics process and can assist in mitigating risks within the processes creating strategic advantages. The event log subjected to analysis contains 223,414 events over a timeframe of almost 2.5 years. Findings indicated that 1% of the long-term contracts was not timely signed; that 57% out of 661 cases with a temporary loading certificate contained an activity predicting arrival after the actual arrival; and that there are relatively many violations concerning the cargo list, a serious operational and legal risk within port logistics. With regard to performance they found many ships remain inactive for long times before cargo is loaded. This indicates that if the port operates more efficiently, they could a) do the same amount of work with less ships or b) do more work with the same amount of ships. Also many trucks that offloaded cargo were not timely weighed, this seemed to be an issue mainly during various holidays. Furthermore, multiple violations of internal control measures were detected using conformance checking. These control measures were created to avoid operational and legal risks, thus are of serious importance. Wang et al. (2014) have shown the application of PM techniques to a highly complex environment. They developed a framework which other logistic organizations are able to use to analyze operations, employing PM techniques. The analysis for the case company was highly valuable as it detected serious malfunctions within its internal control framework.

2.6.4 Importance of ontologies in process mining

Jareevongpiboon & Janecek (2013) describe and illustrate the importance of high quality process data for PM analysis. They detail the following ontologies for PM and analysis (Jareevongpiboon & Janecek, 2013, p. 463):

Ontologies	Description
Task ontology	Concepts of activities performed in the process being analyzed
Originator ontology	Concepts related to actors performing activities which can be concepts about roles, departments or resources
Event ontology	Concepts of event for process executions (activities)
Time ontology	Concepts related to data and time which are universal in any domain. This ontology therefore can be reused from other sources
Data attributes ontology	Data attributes are additional info of tasks and they may identify business objects being updated or created in the process.

Table 6: Description of domain ontologies for process mining and analysis as defined by Jareevongpiboon & Janecek (2013, p. 463)

These ontologies play an important role in the quality of PM analysis. To reflect back on De Weerdt et al. (2013): if logging infrastructures are able to accurately record all these ontologies, the level of analysis can be drastically improved. Jareevongpiboon & Janecek (2013) performed a case study in the clothing industry where they analyze the restocking process. In their case study they illustrate how the event log can be enriched by adding extra ontologies. They state that adding these ontologies leads to a more comprehensible process model through better trace clustering. Trace clustering can be performed using these ontologies. Therefore, if more ontologies are added, the quality of trace clustering techniques employed is improved. Moreover, the level of analysis is deepened by the addition of these extra ontologies. Through this, they were able to provide insights in different ways the restocking process takes place, which business rules are followed for certain ontologies (e.g. brand or men's clothing), which tasks are related to the restocking process, and how brands are distributed among the various types of stores. Jareevongpiboon & Janecek (2013) add to the literature by describing an efficient way to add ontologies to event logs and by showing the value that can be derived from high quality process data. The inclusion of extra ontologies greatly increased the quality of PM analysis.

Lee et al. (2014) demonstrate the application of radio frequency identification-based recursive process mining systems (RFID-RPMS). Applying RFID-identification allowed the case company to log extra data attributes that can be analyzed. The combination of RFID-identification with the intelligence of PM techniques proved a successful match. The RFID-RPMS was designed to capture parameters from the production process to investigate their effect on the quality of finished products. The case study was conducted in a garment company in China. The case company faced two major problems: low visibility of operations and quality assurance relying on human inspection. Through the use of RFID technologies the case company was able to log the following process parameters: ply height of the fabric, speed of the cutting machine, sewing distance per garment, speed of sewing machine, number of trims for attachment per garment and washing time. They tested the influence of these parameters on the quality parameters embodied in the number of minor and major defects per garment. Using trial and error approach over six months they found two major decision rules (e.g. if product speed is high than ply height should be low) that greatly enhance the quality of the finished products. Production time was shortened by 26% after the 6 month period, the number of major defects were reduced by 7% after the 6 month period, and the enhanced logging infrastructure enabled continuous process improvement. Lee et al. (2014) illustrate how enhanced logging infrastructure allows companies to derive more value from PM techniques.

2.6.5 Process improvement

Samilkova et al. (2014) describe how PM can help organizations obtain objective data as a basis for process improvement. They state that current software process improvement methods such as Capability Maturity Model Integration (CMMI) rely on process information, gathered using interviews, focus groups and documentation (e.g. formal process model, procedure descriptions, et cetera). PM is able to enhance the quality of data gathering by providing more accurate process information in a shorter period of time. CMMI details 3 generic goals: achievement of specific goals, management of existing processes and management of newly developed processes. Samilkova et al. filter processes with regard to PM suitability on the following three elements:

1. Complexity: PM is deemed especially appropriate for processes using various resources and many different steps. For other processes traditional analysis is deemed sufficient.
2. Non-automated: PM is considered not particularly useful for automated processes. Automated processes are generally quite standard, namely because this enables their automatization.
3. Frequency: only processes that are frequently repeated will contain sufficient data to perform a thorough analysis.

From this Samilkova et al. (2014) assess that PM is useful in supporting the achievement of specific goals. Additionally the management of existing processes can be objectively evaluated using PM techniques. Other sub-goals are not deemed appropriate for their lack of complexity, frequency and suitability (e.g. training activities). To prove the application of these two points Samilkova et al. (2014) test their assumptions on a change management process. This change management process consists of: (1) initiating and recording change requests in a change request database; (2) analyzing the impact of changes and fixes proposed in change requests; (3) categorizing and prioritizing change requests; (4) reviewing change requests to be addressed in a next baseline with relevant stakeholders and obtaining their agreements; (5) and tracking the status of change requests to closures. Samilkova et al. (2014) used an event log containing 6,870 completed cases. Performing their analysis they found that only 30% of all cases fully complied with existing procedures. All findings refer to incorrect handling of the procedure. One of the major findings was that 70% of the cases skip the analysis step (step 2). Interestingly enough when the organization was confronted with these findings they first denied the significance and portrayed it as an exception. More analysis on similar projects finally convinced the organization that its formal procedures are not being executed. Concluding this paper implies that organizations should carefully consider which processes benefit enough from PM to put in the effort of analyzing them. However this should not be generalized too far. Namely because a fairly simple automated process that occurs very frequent may benefit greatly from techniques such as conformance checking, benchmarking and simulation, and operational support.

Leyer and Moorman (2015) show how simulation techniques can be applied to improve process throughput times, specifically by lowering idle time in the processes. Generally processes in service organizations contain a significant amount of idle time. The case study is conducted within the financial sector and concerns a loan processing process containing 391 completed cases. In their simulation they analyzed the following configurations in sequencing of activities: first in first out, shortest processing time, longest processing time, earliest due date and results analysis. These different configurations were tested in a normal (current) setting, increased demand (highest historical amount of cases a week), decreased demand (lowest historical amount of cases a week), vacation (lower amount of cases and employees), no vacation (higher amount of cases and employees), and flu season (normal amount of cases, lower amount of employees).

All simulation results were contrasted against the first in first out prioritization currently in use. Results indicate that the configuration prioritizing longest processing time increased throughput time by over 40% in all settings simulated. This is far better than any of the other prioritization configurations. All other configurations led to an increase in throughput time between 8% and 40%. Results however varied within the various settings tested. This paper illustrates how service-oriented organizations are able to apply simulation to improve their throughput times. The reason longest processing time proved superior was that any additional input needed from customers was able to be gathered in a timely manner, allowing the processes to be completed.

Huang et al. (2012) show how PM can help to organizations to efficiently allocate their resources. Resources refer to people, machines or other resources. There are four different measures on which to allocate resources:

1. Preference: based on preference of the resource itself.
2. Availability: the extent to which a resource is or is expected to become available.
3. Competence: the resource's suitability to perform a certain task.
4. Cooperation: combine resources to perform a task.

Huang et al. (2012) provide an approach to measure and apply resource behaviors in a business environment. For the measurement of these resources please see Huang et al. (2012). They test this approach in the radiology examination process in a Chinese hospital. The event log contains 1,000 cases, 14,000 events and has 17 participating resources. Huang et al. (2012) computed the preference, availability, competence, and cooperation measures for all resources involved in the process. This allowed the case organization to select resources based on the parameters they felt were important for the process. For example when they have multiple resources available they can allocate resources based on their own preference. The contribution of this case study is showing how PM can support the allocation of resources.

2.6.6 Healthcare

Rebuge and Ferreira (2012) developed a methodology for applying PM in healthcare. Applying PM in healthcare is particularly difficult due to the highly dynamic, complex, ad-hoc, and multi-disciplinary nature of healthcare (Rebuge & Ferreira, 2012). PM provides an objective idea of what is going on, where human perceptions of what is going on is generally very subjective. The methodology consist of log preparation (getting the data), inspecting the data (verifying the quality), repeated trace clustering (grouping similar traces together to increase comprehension until a satisfactory level of comprehension has been achieved), and selecting clusters to analyze. Once these steps are taken analysis of the control flow, performance analysis and organizational analysis can be conducted. Applying this methodology allowed Rebuge and Ferreira (2012 to understand the process and its variants, and to discover infrequent behavior as well. For example they found cases where physicians schedule exams, perform the exam, and request the exam only after they have performed it. Performance analysis identified bottlenecks in certain groups that led to doubled waiting times for patients. Lastly organizational analysis identified illegitimate handovers to colleagues. With this methodology Rebuge and Ferreira provide a novel contribution to how PM can be applied in very highly dynamic, complex, ad-hoc and multi-disciplinary environments.

2.6.7 Mining from alternative sources

De Weerdt et al. (2013) investigated the application of PM within an insurance company. The insurance company mainly offers life, non-life insurances and retirement savings, which are offered through a large network of brokers. The case company worked with a document management system which is not necessarily process aware. Despite this fact, the document management system contained well-defined steps, indicating which activities were undertaken as a result of the incoming document. The case company, however, had no idea what these actual process executions looked like. The event log examined consisted of 44,880 cases, containing 15 activity types, 189 document types and 59 teams involved in the execution of these processes.

Through their analysis they were able to find what the process model looked like and how teams interacted with each other. This brought to light several inefficiencies which included reiterated handovers. Because the company has a strong focus on throughput times this inefficiency was further examined. This showed that processes including reiterated handovers and wrong classification of document types, were executed significantly slower than average. This provided input to the case company to re-engineer their process. The results in the case study were considered remarkable by the case organization. Contributions include dealing with document management systems and the benchmarking of process variants against each other. Even though this was already possible there had been no case study that clearly benchmarked process variants against each other. De Weerdt et al. (2013) state that PM's greatest strength is also its greatest weakness: the reliance on real data. Real data provides information about actual process executions. However, this data is often not optimally logged because of imperfect logging infrastructures and activities performed outside these logging infrastructures (De Weerdt et al., 2013). A process analysis using PM deduces knowledge from the data that is subjected to this analysis. Therefore the quality of the data is an important determinant of the quality of the analysis. To conclude, they state that PM still faces significant challenges in highly complex processes, but that PM is maturing well towards dealing with these issues.

Mahmood and Shaikh (2013) show how PM can be applied to data originating from automated teller machines (ATMs). The purpose was to reduce the time customers spend at the ATM so one ATM can process more customers in the same amount of time. The event log contained 10 million transactions conducted by 5,000 customers. To minimize computational cost a random sample was selected resulting in 2 million transactions conducted by 676 customers. They extracted the following information from this event log:

1. Withdrawal of cash is the most frequent activity, followed by purchases* and balance inquiries.
2. Activities are often repeated, withdrawal of cash being the most frequently repeated activity.
3. These operations are often performed in a sequence. Sequences containing withdrawal have the highest frequency.
4. The most frequent sequence consists of cash withdrawal, balance inquiry and purchase collectively.
5. A majority of customers only withdraw cash and do not use any of the other options.
6. A majority of customers only withdraw specific amounts.
7. Withdrawal rates can be determined for the various ATM locations.

This led to the development of 5 different interfaces. Corresponding reasons are listed in brackets (see list above).

1. Only shows the most frequently used ATM operations to the customer (1).
2. Only shows the most frequently withdrawn amounts to the customer (4, 5, 6).
3. Asks whether the customer wants to make an additional withdrawal (after current withdrawal) (2).
4. Autonomously shows the customers bank balance on the various screens (3).
5. Asks the customer whether he wants to see his purchase history (1, 3).

Customers of banks where then surveyed and asked on, among others, their opinion regarding service times at peak moments. A large majority indicated the preference for adaptable interfaces allowing faster service times. The solution is currently being implemented in large Pakistani banks.

2.7 Conclusion

To summarize, in chapter 2.2 PM was introduced and some contextual information was given. Chapter 2.3 detailed the general PM applications: process discovery, conformance checking, process enhancement and operational support. Chapter 2.4 and chapter 2.5 respectively detailed the importance of satisfactory event log quality and process model quality. Lastly, in chapter 2.6 case studies were detailed, concerning themselves with the applicability of PM in practice. This chapter draws conclusions with regard to all the information gathered in this literature review and serves as a basis for the further direction of this thesis.

Since the introduction of PM, twenty years ago the discipline has come a long way. The application of PM nowadays is easier. This has caused it to gain popularity in other domains. Process improvement methodologies can use PM to gather data more objectively. Risk management processes benefit from PM through the detection and elimination of operational risks. Because it is able to detect deviations from the desired position, it can be also used for compliance purposes, to support organizations' compliance with, e.g., Sarbanes Oxley and Basel II/III. As long as the domain benefits from objective process-related data or intelligence, PM can be applied to benefit that domain.

Within PM four different techniques are distinguished: process discovery, visualizing process data using process models and statistics about the process; conformance checking, determining the conformance of process executions (IST position) with the SOLL position; process enhancement, providing organizations with simulation and benchmarking tools; and lastly, operational support, allowing organizations to benefit from detection, predictions, and recommendations to support process executions. The findings from chapter 2.3 are summarized in table 7.

Technique	**Purpose**
Process discovery	Process discovery visualizes process-related data in the form of process models and statistics. Through this they are able to analyze the control-flow perspective, the performance perspective, the role (user) perspective, and the case perspective. The control-flow perspective concerns itself with the execution order of activities; the performance perspective details time-related information with regard to the process executions; the role perspective details the specific role users/resources play in the process; and lastly the case perspective enables in-depth analysis of specific cases. Additionally, some environments may benefit from trace clustering techniques, grouping multiple similar traces together. This is especially useful for organizations with a very strong human-centric focus in complex and dynamic environments.
Conformance checking	Comparing actual process executions with desired process executions. This allows organizations to manage process-related operational risks. This is particularly useful for risk management, compliance, and auditing purposes. Applied in real-time this can even prevent problems from materializing by interfering before their occurrence (Seufert & Schiefer, 2005).
Process enhancement	There are two process enhancement techniques to distinguish between: benchmarking and simulation. Benchmarking allows organizations to compare processes to each other and identify best practices from similar processes. Simulation allows organizations to how specific parameters influence the outcome of the process. This enables organizations to optimize their processes using a trial-and-error based approach but without the negative effects of a trial-and-error approach.
Operational support	Operational support, supports ongoing processes. Three different forms of operational support should be distinguished between: • Prediction: prediction techniques can predict expected characteristics (e.g. time or next activity) of running processes. • Detection: detection techniques are able to monitor the process and report any violations of pre-determined rules (e.g. a maximum amount of process executions, violation of segregation of duties, et cetera). • Recommendation: recommendation techniques are able to recommend the user of the process on what to do next based on historic data.

Table 7: Summary of process mining techniques and their purposes

A very important element determining the value organizations can derive from PM techniques is the quality of their logged process data. Process data is generated within process aware information systems. However, the quality of logging is contingent upon how this information system is setup. Process data should be reliable and accurate. The basis is logging task, originator, event, and time ontologies. The quality of process data can be further enhanced by logging data ontologies (e.g. the price of a purchase, the speed of a machine, item type, brand, et cetera).

Another key element determining the value organizations derive from PM techniques, lies in process model quality. Process discovery is useful to extract information from the process data, from which organizations can deduce knowledge. However, this is under the precondition that the organization understands the process model. Some process models are very complex, making it extremely difficult to derive useful insights from the process model. Simplicity concerns itself with the extent organizations are able to understand the process model. Other factors affecting process model quality are: fitness, determining whether the whole event log can be replayed on the process model; precision, determining the amount of abundant paths in the process model; and generalization, describing how likely it is that future process executions can also be replayed on the discovered process model.

The examination of case studies was categorized by six major themes: general application in production and services, risk management, importance of ontologies, process improvement, healthcare and mining from alternative sources. The general application in production and services underlined the importance of domain knowledge and showed that process data contains valuable insights with regard to process executions. Several case studies in risk management showed the contribution of PM in risk management processes. Jans et al. (2014) note that PM is able to outperform traditional auditing techniques by analyzing the entire population and its high accuracy. The importance of data ontologies was underlined by Jareevongpiboon and Janecek (2013), and Lee et al. (2014), who respectively were able to derive valuable insights through manually adding extra data ontologies and the inclusion of RFID to enhance logging infrastructure. Especially Lee et al. (2014) were able to greatly improve the quality and throughput time of the process they analyzed, through the discovery of relations between various parameters in a production process.

Case studies on process improvement detailed how PM is able to support other process improvement techniques. Moreover, PM provides simulation techniques that are able to improve processes, using a trial-and-error approach. This allows organizations to experiment with the way their processes are executed without the possible negative implementation consequences. Lastly, various methods for resource allocation are detailed, allowing organizations to manage their resource allocation more effectively. The analysis in healthcare is somewhat problematic because of the complex environment. Extensive trace clustering is needed, but PM is steadily becoming more useful as the various techniques mature. Lastly, mining from alternative sources such as an ATM, show creative use of PM techniques. Additionally, it was discovered that although process aware information systems are preferred, other information systems may be viable as well, provided that relevant data is logged, referring to task, originator, time and event ontologies. De Weerdt et al. (2013) detailed the application of PM using data from a document management system.

To conclude the case analysis a note on the applicability of PM. Samilkova et al. (2014) propose that organizations should consider the suitability of processes for PM application. They propose to filter processes on their frequency (higher is better), complexity (higher is better) and automation (lower is better). While this may generally hold true for process discovery, this does not necessarily apply to other PM techniques. Moreover, analyzing relatively simple processes allows organizations to learn how to extract insight from their process data as the complexity will not be overwhelming. Take for example a fairly simple automated process that occurs very frequently. This process is one of the backbones for value creation in the specific organization. This process may greatly benefit from techniques such as conformance checking, to show deviations, benchmarking and simulation to improve process efficiency, and operational support to support its execution. Therefore, organizations should consider the impact processes have on their business. A relative high frequency is needed to infer the right conclusions. However, complexity and automation are not necessarily reasons for exclusion.

Thus, PM is clearly useful for analyzing and supporting business processes. PM yields great insight in business processes and ensures smoother executions through operational support. However, all the case studies identified in the literature review, were conducted by researchers and not by internal practitioners. This gives to wonder whether PM is being employed in practice by organizations and to which extent it is employed. However, for organizations to consider the adoption of PM one important element is missing.

Current literature does not provide organizations with a clear methodology to justify and implement PM. Organizations considering to invest in PM will generally want to develop a business case. However, the literature review did not identify a methodology organizations can use to do so. PM is a type of information technology (IT). Therefore it should be examined how investments in IT can generate economic benefits and how IT investments should be evaluated. The findings of this analysis can then be generalized and applied specifically to PM.

3. Information technology investments

The last chapter concluded stating that there is no method available to implement and justify PM. In order to develop a method, IT investment literature is examined. First, it is established whether IT investments create value. The effect of IT investments on productivity, profitability, productive or technical efficiency, quality, costs and customer surplus are categorized by positive, insignificant and negative effects. Next, the value creation process of IT investments is examined. Lastly, the development of business cases is addressed, so that later in chapter 4, a business case framework can be developed for PM.

3.1 Approach

The goal of this chapter is to provide a solid basis for building the PM business case framework. In order to do so, a systematic literature review was conducted. This paragraph details the approach for the literature review conducted in this chapter. The approach in schematic form can be found in figure 3. The textual description can be found below.

The following Boolean phrase was used to search: "TI ("IT investments" OR "Information technology investments") AND ("benefits" OR "Productivity" OR "Profitability" or "Consumer surplus" OR "operational efficiency" OR "Costs" OR "Quality" OR "Quantifying" OR "Quantification" OR "Case study")". The databases searched are Business Source Premier, Academic Search Premier and Library, Information Science & Technology with the criteria that the journal should be scholarly (peer reviewed), an academic journal, and in the English language. This initial search yielded 63 results.

The following step was downloading and documenting all available papers, unavailable papers and duplicate papers. The next step was reviewing the abstracts of all downloaded papers to assess their relevance for this paper. With the goal of the paper in mind the abstracts were reviewed using the following criteria:

1. IT investments context
2. Results of IT investments
3. Quantifying IT investments

These three criteria enforced the goal of the research within the context of IT investments. Context on IT investments was provided through the first criterion; results of IT investments enforced the collection of papers indicating to which results IT investments lead; and quantifying IT investments gave a way to calculate the expected benefits. All papers collected in the search were reviewed based on these three criteria. However, not all three criteria had to be applicable. As long as papers provided good input, in any of the three criteria, they were considered for further reviewing.

After all papers were subjected to a brief review, a detailed review took place, to further examine the papers and gather additional literature. The gathering of additional papers takes place trough backward searches. Backward searches were conducted to gather additional information, in support or addition to, the literature set from the original search. This yielded a large set of additional papers, the majority originating from table 8.

Additionally, several recommendations were made to enhance the quality of this thesis. Berghout & Tan (2013) was recommended to ensure the buildup of a thorough and rich business case. Furthermore backward searches in this paper yielded valuable references for the thorough development of the PM business case. Hevner et al. (2004) was recommended to ensure the systematic development of a methodology to justify an organization's PM investment. Lastly the Prince2 framework (Bentley, 2010) was recommended to provide further input for the business case framework.

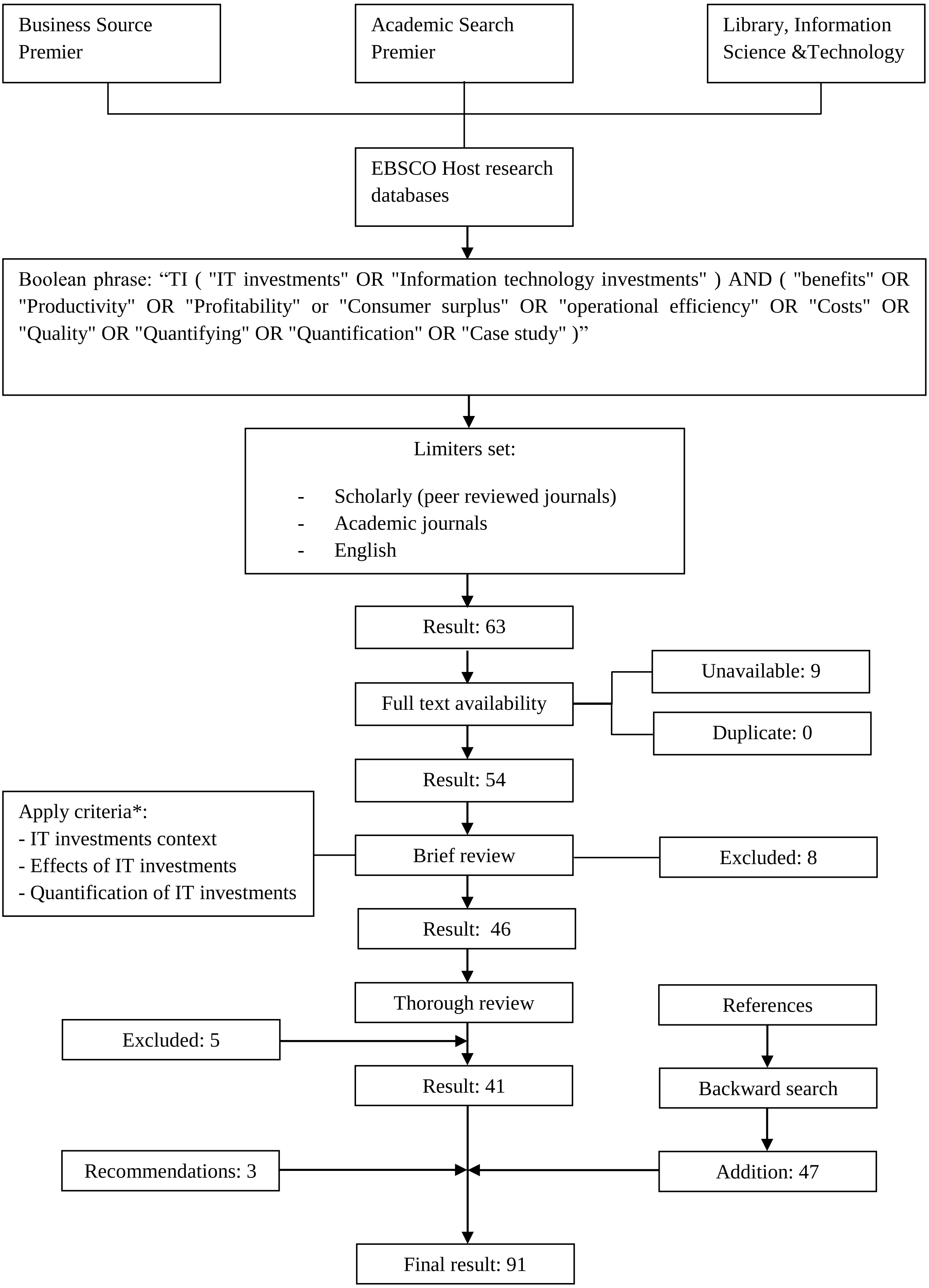

Figure 3: Schematic approach of the literature review on information technology

3.2 Economic benefits of IT investments

In this chapter the 'economic' benefits of IT investments are detailed to answer the question whether IT creates value. These findings are then put into perspective and serve as a starting point for the next chapter which details how this value is created. Below, in table 8, a categorization of the literature is made to show the effects of IT investments. Several authors (e.g. Weill, 1992; Alpar & Kim, 1990) are listed under several effect magnitudes due to their research design. This incorporated different time periods or different types of IT investments.

Measure	Positive effect	No significant effect	Negative effect
Productivity	• Baker et al. (2008) • Barua et al. (1995) • Brynjolfsson & Hitt (1993; 1995; 1996) • Dewan & Min (1997) • Hitt & Brynjolfsson (1996) • Ko & Osei-Bryson (2004; 2006) • Lee & Barua (1999) • Lichtenberg (1995) • Mahmood & Mann (2005) • Mukhopadhyay et al. (1997) • Osei-Bryson & Ko (2004) • Park et al. (2007) • Tambe & Hitt (2012) • Weill (1992)	• Ko & Osei-Bryson (2004) • Thatcher & Pingry (2004) • Weill (1992)	
Profitability	• Alpar and Kim (1990) • Dewan & Min (1997) • Lee & Barua (1999) • Mahmood & Mann (2005) • Sriram & Stump (2004) • Tambe & Hitt (2012) • Weill (1992) • Yao et al. (2009)	• Ahituv & Giladi (1993) • Alpar and Kim (1990) • Barua et al. (1995) • Osei-Bryson & Ko (2004) • Strassmann (1990) • Thatcher & Pingry (2004) • Weill (1992)	• Alpar and Kim (1990) • Hitt & Brynjolfsson (1996)
Productive or technical efficiency	• Chen & Lin (2009) • Lin (2009) • Lin & Shao (2000) • Shao & Shu (2004) • Shao & Lin (2000; 2001; 2002) • Shu & Lee (2003)		• Lin & Shao (2006)
Quality	• Chaudhry et al. (2006) • Mukhopadhyay et al. (1997)		
Costs	• Harris & Katz (1988) • Weill (1992)	• Weill (1992)	
Customer surplus	• Bresnahan (1986) • Brynjolfsson (1996) • Hitt & Brynjolfsson (1996)		

Table 8: Outline of the effects of IT investments

Higher productivity/operational efficiency is generally achieved through automation of tasks that were human-centric earlier. Quality improves through higher visibility of operations, or involving IT actively in the quality monitoring process. IT is likely to outperform humans as they are able to process all information, where humans generally only partly process all relevant information. The decreased costs lay in increased efficiency and lower search costs (see chapter 3.2). A customer surplus can be achieved by enhancing current value propositions or creating new value propositions. However, from table 8 it also becomes clear that although IT predominantly has positive effects on productivity, quality, costs and customer surplus, it does not necessarily have positive effects on profit. There are three main reasons for this:

1. The value IT generates can be competed away by competitors, captured by trading partners or captured by end customers in the form of lower prices and/or better quality (Bresnahan 1986; Hitt & Brynjolfsson 1996).
2. Diverse concepts of IT are being used to measure the effects of IT investments, such as the tool-view, proxy view, ensemble view and the nominal view (Melville et al., 2004). Furthermore the analysis takes place at differing levels (firm, industry, country), while using varying methodologies (Brynjolfsson 1993; Brynjolfsson & Yang, 1996; Dedrick et al., 2003; Wilson, 1995).
3. Synergies exist between IT investments and organizational investments. E.g. an IT investment is made for a certain application. Employees are then trained to learn how to make the best use of this IT application. Thus an organizational investment is made which is complementary to the IT investment. Organizational elements that influence this synergy are: organizational change, policies and rules, organizational structure, workplace routines and organizational culture (Brynjolfsson & Hitt, 2000; Brynjolfsson et al. 2002; Cooper et al., 2000).

These three factors concerning who captures the value of the IT investment, the use of varying concepts, levels of analysis and methodologies, and synergies between IT investments and other elements, have caused this discrepancy in the literature. Therefore Lin & Chuang (2013) and Khallaf (2012) state that literature concerning IT investments is inconclusive with regard to the value of IT investments and how to measure the value of IT investments.

Therefore literature is shifting from 'what is the value of IT investments' towards 'how is value being created by IT investments'. The inconclusiveness of current literature is no surprise, as there are many contingent variables that play a role in creating value from IT investments. One of the factors literature is looking into, is how IT investments enable strategy. 85% of respondents among big American corporations believed IT enables business strategies, while 62% even believed IT helps in shaping business strategies (Kappelman et al., 2014). Companies follow strategies with the aim to create and maintain a competitive advantage (Bridoux, 2004). This competitive advantage enables organizations to create durable financial results. Therefore IT investments play a strong role in enabling these durable financial results.

3.3 Enabling the value of IT

In the previous chapter it was established that IT investments, under the right conditions, generate value. This chapter takes a closer look at how this value is created and which factors influence the outcome of the desired value creation. This will aid the creation of a business case framework for PM in chapter 4. Firstly, it is examined how IT is able to generate value. Next, a general framework is detailed, detailing best practices with regard to how to enable IT value creation. Lastly, the technology acceptance model is examined. This model assesses the likelihood of users accepting the new technology. Mandate from users is critical for the success of IT investments.

ICAEW (2008) identified six broad ways in which IT creates value:

Value creator	Description
1. Higher efficiency	Doing more with the same amount of resources or doing the same with less resources.
2. Lower search costs	Search costs can be lowered through intelligent search algorithms. This contains two elements: finding and being found. When customers or users of your service are easier able to find you they will be more likely to do business with you. On the other hand, efficiently finding potential customers or suppliers in new markets will open up new markets which creates new opportunities for business (Anderson, 2006).
3. Reduction of business constraints	The reduction of business constraints in the form of physical assets and high transaction costs paves the way for new opportunities. Among others this creates opportunities to outsource, increase globalization, increase flexibility and to cooperate with other parties.
4. Greater visibility of operations	Greater visibility of operations are leading the way for improved governance and control measures. Increased data collection and the ever decreasing price results in more data from which relevant information with regard to governance and control measures can be derived.

5. Enhancement of current value proposition	Enhancement of current value propositions through better understanding the needs of customers and improving their customer experience (e.g. through customer journey mining).
6. Creation of new value propositions	The creation of new value propositions is partly enabled thanks to IT. New products and services are created, often information-based. Typical examples are developments such as Uber and Airbnb but also more solidified companies, such as Google (e.g. self-driving car, solar panel map, et cetera).

Table 9: Six ways IT creates value as defined by ICAEW (2008)

Now that a broad understanding of value creation through IT investments is developed, the way that this value is created is examined. Because without enabling the value creation the value is null. The process of value creation through IT investments is described using Ashurst et al.'s (2008) competence framework. This details the planning of benefits, delivery of benefits, review of benefits, and the exploitation of benefits. Complementary to this framework, the purpose of complementary organizational investments are detailed. Lastly, the acceptation of new technologies is detailed using Ventakesh & Davis' (2000) technology acceptance model.

Ashurst et al. (2008) define 4 competences that enhance an organization's capability to generate value from their IT investments, as shown in table 10, below.

Competence	**Description**
Planning of benefits	The ability to effectively identify and enumerate the planned outcomes of an IS development project and explicitly stipulate the means by which they will be achieved.
Delivery of benefits	The ability to design and execute the program of organizational change necessary to realize all of the benefits specified in the benefits realization plan.
Review of benefits	The ability to effectively assess the success of a project in terms of the potential benefits, the delivered benefits, and the identification of the ways and means by which further benefits might be realized.
Exploitation of benefits	The adoption of the portfolio practices required to realize the potential benefits from information, applications and IT services, over their operational life.

Table 10: 4 competences that enhance the value organizations can derive from their IT investments as defined by Ashurst et al. (2008, p. 8-9)

Systematically planning benefits, creating a plan of how to deliver these benefits and the review of benefits are all elements that should be covered in business cases. By developing a business case organizations systematically investigate the benefits, costs and risks associated with their intended IT investment. Additionally, organizations are forced to think about how they will measure whether their IT investment has the intended yield. Through examining technological factors, organizations set realistic expectations and avoid unpleasant surprises causing the project to fail or go over budget. Lastly, the planning of the project, governance and roles of all stakeholders should be defined.

In support of Ashurst et al. (2008), Melville et al. (2004) state that the business value of IT investments is significantly influenced by complementary organizational investments in training and business processes. Training helps users to understand the technology, the purpose behind it, and the possibilities this technology offers. Business processes may need to be adapted to increase the effectiveness of the technology. For example, when implementing an automated process the business process has to be redesigned in order to reach this automation. A more subtle example is the recording of extra data ontologies for the purpose of creating extra process intelligence.

The business value of IT investments is dependent upon the extent to which an application is used within the organization (Devaraj & Kohli, 2003). Therefore the acceptation of these new technologies is crucial for enabling the value of these IT investments. Obviously, technologies that are not accepted do not lead to any economic benefits. Technology acceptance can be examined on country, firm, and individual levels. For the development of business cases the individual level approach is most suitable. Country level is not appropriate to firms while firm level technology acceptation models indicate how likely it is that an organization will accept the technology. Because this paper develops a methodology for the justification and implementation of PM, the likelihood a firm will have a favorable attitude towards PM is beyond the scope of this paper. Therefore the technology acceptance model (TAM) is used. TAM was created by Davis (1986) for the purpose of explaining perceived usefulness and user intentions through social influence and cognitive instrumental processes (e.g. job relevance, output quality, perceived, ease of use). A key extension was made by Venkatesh & Davis (2000) who extended the model. This is also the model presented in figure 4.

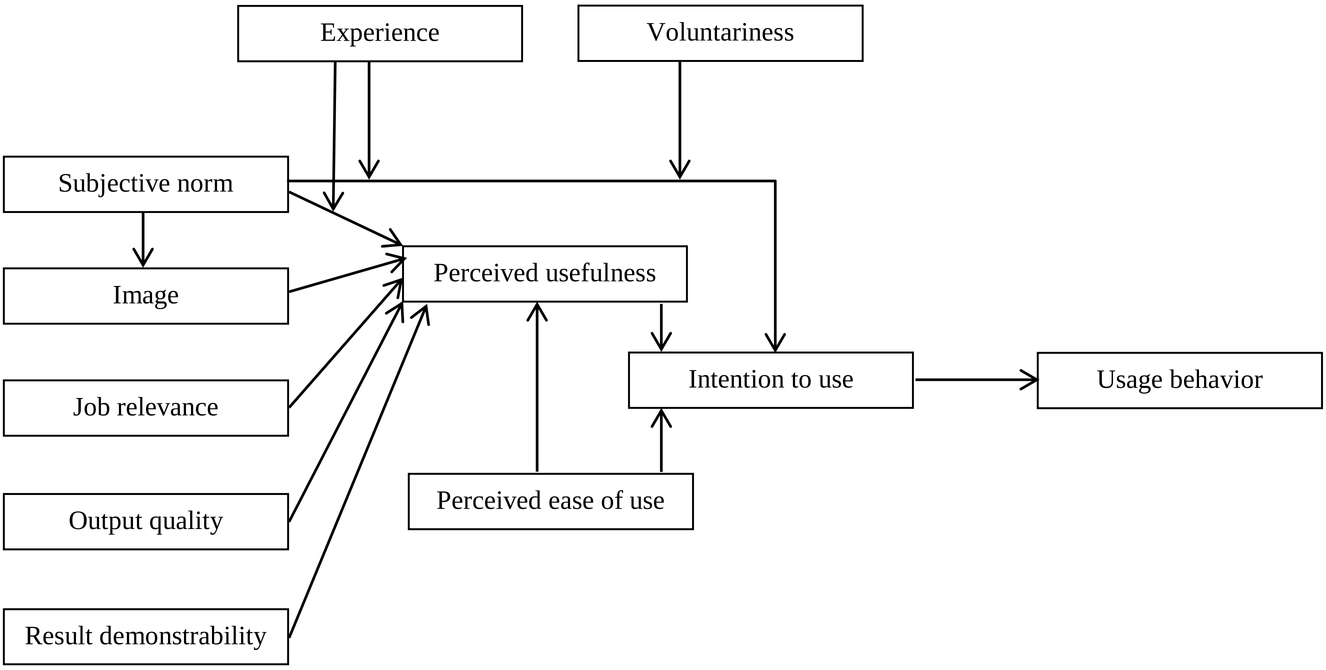

Figure 4: Extended technology acceptance model, adopted from Venkatesh & Davis (2000, p. 188)

The TAM-model states how various contextual factors lead to a certain usage behavior of new technologies. Usage behavior is a crucial determinant in determining the success of the IT investment. Technologies may offer all the possibilities to solve a specific problem, but when this technology is not used in the proper way, it will not create value. Venkatesh & Davis (2000) state that subjective norms, images, relevance to one's job, output quality of the technology, demonstrability of results, and ease of use determine the perceived usefulness of a new technology. Experience with the technology moderates the relationship between subjective norms and perceived usefulness. Subjective norms are defined as: "A person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein & Ajzen 1975, p. 302). Next, perceived usefulness and perceived ease of use influence one's intention to use the technology. This is moderated by experience and voluntariness. Experience will lead to a quicker intention to use, because it is less of a novel situation for the user and voluntariness refers to possible pressure from managers or colleagues. All these factors combined determine the usage behavior of new technologies. The practical implication of this is that investments in IT are not an exact science, such as physics or mathematics. Rather the success of IT investments are influenced by many contextual and contingent factors which cannot all be exactly defined before the IT investment takes place.

3.4 Business cases for IT investments

Business cases help organizations to make an informed decision regarding their investment, through (among others) detailing the benefits, costs, risks and the alignment with strategy. A richer business case will result in a more accurate idea of the costs and benefits the IT investment brings (Berghout & Tan, 2013). Therefore it is important, within boarders of efficiency, to set out a thorough business case underlying the investment decision. The business case is set out with the use of Bergout & Tan's (2013) literature review regarding business case constituents. This serves as a basis for developing a general business case framework for PM in chapter 4. Below, in table 11, an overview can be found of the business case constituents. However, first the purpose of constructing a business case is detailed.

Ward et al. (2008) state that developing business cases serves four different purposes:

1. Prioritizing different investment options.
2. Identification of how the proposed investment will generate benefits.
3. Ensuring commitment and mandate from senior management.
4. Creating a basis for review once the investment is made.

However, Ward et al. (2008) also point out that although 75% of the survey respondents agree with these purposes, the majority of respondents are dissatisfied with their approach. Business cases should therefore take a practical, not too complex scope, in order for organizations to benefit. Prioritizing different investment options is beyond the scope of this paper. The identification of how the investment will generate benefits, ensuring the commitment and mandate from senior management, and the creation of a basis for review, will be detailed later in chapter four.

Element	**Description**
Organizational	
Business case objectives	Overview of the business case through identifying and explaining the purpose of the intended IT investment, targeted business objectives, proposed course, issues, risks and timetables. Additionally, the expected costs and benefits should be forecasted.
Benefits appraisal	Valuation of the benefits of the IT investment, either qualitative, quantitative or a mix of those two methods. Quantification is done through listing the tangible financial benefits that can be realized by the intended IT investment. Qualitative benefits of the intended IT investments are assessed by describing the alignment of the intended IT investment with the targeted business objectives, a review of assumptions, and rationale behind critical issues that impact the organizations businesses.
Consolidation	Consolidation serves to bring everything together. It provides an overview of the business case by listing business targets, financial requirements, decisions regarding the execution of the project, and agreed-upon actions including the formal acceptance of stakeholders
Technological	
Technological requirements	The technological requirements concern itself with an analysis of the technical requirements which are needed to achieve the targeted business objectives. Additionally the demands of the end-users need to be identified and compiled. This provides clear input for an analysis of the supplier options.
Supplier options	Supplier options concern itself with the selection of eligible suppliers. A pre-selection is made and evaluated based on whether they can meet the technical requirements of the intended IT investment. Thereafter probable contractual risks and options for strategic collaboration should be assessed.
Project	
Project planning and governance	Project planning and governance is concerned with setting intended deadlines, schedules and milestones for the realization of the IT investment. Additionally the level of project coordination and governance need to be clarified and described.
Cost appraisal	Cost appraisal deals with accounting for cost data estimates for the intended IT investment, often separated by initial costs (e.g. hardware and legal fees), running costs (e.g. licensing and maintenance) and other organizational costs (e.g. personnel recruitment and training).
Risk assessment	A risk assessment is conducted to determine possible managerial and technical risks for the proposed IT investment (e.g. impact on the organization's employees) while including viable countermeasures (e.g. expected chance in management and training procedures to be enacted for affected employees) and exit points of resolutions are not available. The development of predictive models and alternative scenarios help to identify and cope with risks in advance whenever this is feasible to do.
Stakeholders	Stakeholders and beneficiaries for the intended IT investment should be identified, including particular emphasis on possible interaction problems, project responsibilities and collective contributions to project success.

Table 11: Elements of a business case as defined by Berghout & Tan (2013).

3.5 Conclusion

In this chapter it was established that IT investments generally have positive outcomes for organizations. However, there are many exceptions to this finding. Many organizations fail to deliver the intended benefits, due to poor planning. In chapter 3.3 it is examined how the value of IT investments can be enabled. There are six different ways in which IT can create value. In chapter 4, while setting out the business case objectives, all ways that apply to PM will be detailed. Another factor be found of great importance is the acceptance of new technologies, as this determines their usage.

Organizations therefore should have detailed plans of how the IT investment can yield the outcomes organizations are targeting and develop a systematic way to deliver, monitor and exploit these benefits. A systematic way to do this, is by developing a business case detailing the expected benefits, costs and risks of their intended IT investment. Additionally, organizations are forced to think about how they will measure whether their IT investment has the intended yield. Through examining technological factors organizations set realistic expectations and avoid possible surprises. Lastly, the planning of the project, governance and roles of all stakeholders should be defined. This chapter, in combination with chapter 2, has generated sufficient input to develop the PM business case framework.

4. Justifying and implementing process mining

Building upon the basis laid in chapter 3, this chapter provides a general business case framework specifically applied to PM. In order to develop the framework, all information from chapter 2 and 3, and the author's practical experience, using PM tools, are used. In the conclusion an eight phase methodology is detailed, guiding organizations in setting up their business case, testing their business case, implementing process mining and reviewing the benefits of process mining once the implementation has taken place.

4.1 Business case objectives

PM is used to gain insight in, and support process executions. The business case objectives are formulated using the various PM techniques, because the techniques determine the range of possibilities and therefore the range of possible business case objectives. There is a distinction to be made between the offline and real-time application of PM. The timeliness of information is a crucial element of an organizations' ability to act upon the discovered process knowledge. Therefore first the offline PM applications are detailed, thereafter the real-time PM applications are detailed.

Organizations should consider to which business processes they want to apply PM. The effort of analyzing may not be worth it for all processes. Samilkova et al. (2014) therefore propose to filter processes on their frequency, complexity and human origin (non-automated processes). These criteria may be suitable for process discovery but should not be generalized to other techniques. Organizations should first consider the impact processes have on their business. A relatively high frequency is necessary to infer the right conclusions from the process data. However, complexity and automation should not be seen as large decision making factors for conformance checking, process enhancement and operational support. While formulating business case objectives, organizations should also consider their maturity in the process intelligence discipline, to avoid setting unrealistic targets.

Offline PM applications
Process discovery
Process discovery techniques display actual process executions. This can be used for several purposes: • Internal and external reporting of process-related information. Internal reporting serves as a diagnostic tool to measure and signal any variances influencing the achievement of internal objectives. Externally, information regarding customer's processes can be communicated. This seems particularly useful for organizations that serve customers through service level agreements (enhancement of proposition). • The basis of any process improvement technique. Process improvement techniques traditionally gather data about the IST-position of process executions through interviews, focus groups, observations, review of external documents, et cetera. While this may provide useful contextual information it is not

optimal for determining the IST-position of how processes are being executed. Using a wrong starting point obviously hampers the quality of the process improvement project. PM is able to overcome this subjectivity by mining process data from the event log. • Monitoring the effects of changes in the process. Processes are constantly being changed and updated. However, for many organizations the changes made to processes are made on an intuitive basis and the results of these changes are not verified. PM enables organizations to verify whether changes made to processes have the intended effects. • Examination of bottlenecks within the processes. When time is a logged ontology process discovery tools are able to visualize bottlenecks within processes. When these results deviate from what is expected further investigation is warranted to determine the cause. • Identifying the interaction between various users/departments, and their role in the process.
Conformance checking
Conformance checking check whether the IST-position shows any deviations from the SOLL-position. This is particularly usefully for detecting violations of business rules. Thus it serves as diagnostic tool that supports internal auditors in their work. Jans et al. (2011; 2014) showed how conformance checking can be applied to identify internal control violations and noted the following: • Event logs of good quality are very rich in information. Therefore the analysis can be performed on multiple attributes. Through this it is easier for PM techniques to detect any violations of the prescribed way of execution the process. • PM techniques are able to analyze the entire population whereas traditional auditing techniques employ analysis on a random sample. The second point they bring forward is a clear advantage over traditional auditing techniques. Analyzing the entire population lowers the risk of internal control violations going unnoticed. However, as the first point states this is strongly contingent upon the quality of the event log. Luckily, data can be enhancement after the process has been executed as shown by Jareevongpiboon & Janecek (2013). This allows organizations to derive more value from the application of conformance checking. A pilot study should be conducted to confirm the possibility and feasibility of enhancing data for the purpose of conformance checking.
Process enhancement
Process enhancement techniques lean on two pillars: process simulation and benchmarking. Process simulation allows organizations to examine how proposed changes will affect the process. The major advantage of this is that any negative changes will not be implemented as simulation will have already revealed its detriment to the process executions. Moreover it allows organizations to perform a more objective scenario analysis. Benchmarking can be used to reveal best practices within organizations. Often organizations with many different departments/business units/locations use varying practices for the same processes. Benchmarking this data will reveal which practices are best suited to the organization.
Operational support
Offline operational support is limited to prediction. It can be employed to predict remaining case times. By knowing how much time it takes to finish the current amount of cases organizations are able to make their personnel planning more efficient.
Real-time PM applications
Process discovery
The real-time application of process discovery techniques allows organizations to monitor processes as they are being executed. Through this technique organizations are able to: signal trend breaks within their processes; signal build-up of work or lower workloads; and monitor operational performance. This insight allows them to take action in a timely manner, when deemed necessary.
Conformance checking
Real-time conformance checking allows organizations to intervene before problems materialize (Seufert & Schiefer, 2005). However, as Jans et al. (2011; 2014) illustrated the quality and possibilities of applying conformance checking techniques are strongly contingent upon the quality of the process data. Offline conformance checking allows for data enhancement after the processes have been executed. This is not a possibility when employing real-time conformance checking. Therefore organizations should identify processes and activities of which they want to check the conformance, determine how to conduct their conformance, and conduct a pilot study to verify whether the logging infrastructure generates process data of sufficient quality to conduct conformance checking without manual enhancement. When this is not the case organizations can choose to check conformance offline, or to enhance the logging infrastructure.
Process enhancement
Real-time process enhancement is currently not a functionality in PM applications. Currently, there is no real-time support for either simulation or benchmarking. Neither does the need seem to be there, as slightly older data will generally serve process simulations and benchmarking equally fine as data from ongoing processes.

Operational support
Operational support has three functionalities: detection, recommendation and prediction. • Detection, similar to conformance checking allows you to intervene before any problems materialize (Seufert & Schiefer, 2005). Unlike conformance checking, detection should be seen as a broader functionality. Where conformance checking compares the IST-position with the SOLL-position, detection, as part of operational support, is able to detect anything programmed base on process-related data. For example organizations can choose to generate an alert when the number of running processes exceed 100, when segregation of duties are violated, et cetera. • Recommendations can be given to users with regard to future steps to take. Based on historic data algorithms are able to compute a likely next step for process executions. As this technique is still in a novel stage this should only be applied to rater basic processes. • Prediction, similar to the offline application, is able to predict the remaining time of current cases. The major difference is that the application in real-time takes into account the development of the workload, as processes are being completed and new processes are started. This yields a more accurate and up-to-date analysis the workload that organizations face.

Table 12: Process mining business case objectives

Applying the six ways IT generates value, as defined by ICAEW (2008), to PM yields the following findings:

1. Higher efficiency: conformance checking allows for more effective and efficient internal auditing.
2. Greater visibility of operations: process discovery allows to visualize process executions. This provides process improvement initiatives, and control and governance measures with a more solid basis.
3. Enhancement of the current value proposition: organizations can enhance the quality of their products and services as detailed in chapter 2.6. Moreover organizations that are deeply involved with their customers (e.g. through service level agreements or organizations with very few, but major customers) are able to inform their customers on process progress. This may serve as a unique selling point to their customers. Additionally consulting firms focused on process improvement can enhance their value proposition by increasing the objectivity and speed of their data collection.
4. Creation of new value propositions: consulting firms might offer PM support as a new value proposition.

The extra benefit the real-time PM application has to offer lies in the timeliness of information. When organizations are able to effectively respond to relevant information in a timely manner, they will be able to leverage the benefits of the investment.

4.2 Benefits appraisal

The benefits appraisal serves to justify the investment in PM. The benefits appraisal identifies whether the business case objectives are able to generate the anticipated benefits. Before starting the PM project, organizations should identify which benefits PM can bring within their organization. As soon as a general business case for PM has been detailed, and mandate is given to this business case, organizations can start their pilot study. The pilot study is necessary to evaluate whether the perceived benefits are indeed achieved. Conducting the investment in PM this way prevents waste of organizational resources. Benefits can be appraised both in a qualitative and a quantitative way. A combination of the two methods is generally preferred to include both an objective and subjective basis. The Prince2 methodology prescribes the benefits appraisal should include (Bentley, 2010):

- All benefits of the business case;
- A measurable norm with a target;
- Points in time at which this norm will be measured, including the reason for that point in time;
- An identification of persons with the necessary skills to appraise these benefits;
- A consideration with regard to whether the time invested in appraising the benefits is reasonable in relation to the benefits anticipated form the investment.

Hevner et al. (2004) states that: *"A mathematical basis for design allows many types of quantitative evaluations of an IT artifact, including optimization proofs, analytical simulation, and quantitative comparisons with alternative designs"* (p. 77). Appraising the benefits of PM therefore can partly be conducted using quantitative measures. Once the pilot has been conducted any optimization proofs can be applied to other data sets using the simulation feature PM has to offer. However it is dangerous to wrongly apply optimization proofs. Processes should be comparable to each other with regard to the following elements:

1. Magnitude: number of process executions.
2. Complexity: average number of activities within the process.
3. Nature: the origin of the process (human centered vs automated).

Therefore, optimization proofs of large transaction processes cannot be generalized to small ones; optimization proofs of a simple purchasing process cannot be generalized to a complex purchasing process; and optimization proofs of a human-centered sales process cannot be generalized to an automated sales process. Therefore, when organizations appraise PM benefits in a quantitative way, they should take this into consideration for their pilot study design. A scope of different processes should be selected that best represents the different kind of processes the organization has, with regard to the above 3 elements.

However, quantitative benefits appraisal is not always possible as not all tools offer simulation features. Moreover, a combination quantitative and qualitative appraisal will detail the impact more clearly. The need for qualitative appraisal is illustrated by the following quote: *"The rich phenomena that emerge from the interaction of people, organizations, and technology may need to be qualitatively assessed…"* (Hevner et al., 2004, p. 77). Benefits of PM can be qualitatively appraised by looking at the suitability to the organization. Therefore, non-quantitative evaluation criteria are contingent upon the organizational setting in which PM is applied. With this respect it makes sense to evaluate to which extent the business case objectives have been achieved during the pilot study.

Literature is divided on qualitative benefits appraisal of IT investments. Gunasekaran et al. (2006) state that evaluation criteria to assess the benefits of the project should be based on organizational strategies, goals, and objectives. Literature is divided because the definition of a successful IT project is contingent upon organizational context.

Because strategy enables value creation, it makes sense to assess the strategic impact of investing in PM. There are many authors that make a case for appraising the benefits using strategic impact (e.g. Powell, 1993; Reich & Benbasat, 1996; Sarkis & Sundarraj, 2000). Sánchez et al. (2013) suggest to use a strategy map to evaluate this strategic impact. Kaplan and Norton (2004) argue that the strategy map can be used for aligning information capital to enterprise strategy. Reversing this, organizations can check whether their proposed IT investment is aligned with their strategy. Because IT is seen as an enabler of organizational strategy (Orlikowski & Barley 2001; Kappelman et al. 2014), it makes sense to appraise the benefits in this manner.

PM has many applications that are able to further enhance strategic objectives. Therefore organizations, looking to invest in PM, should construct a strategy map or use an existing strategy map to test strategic alignment of their business case objectives. The strategy map contains four perspectives: financial, customer, internal organization, and learning and growth. The financial perspective describes the financial targets the organization has (e.g. increase revenues, cut costs). The customer perspective describes how these financial targets are achieved (e.g. maintain customer base, provide excellent quality to customers, provide low cost products to customers, et cetera). The internal organization perspective consequently describes what is needed to achieve these goals. Referring to the quality aspect, organizations may want to reduce the number of defects in their products (see e.g. Lee et al., 2014). Lastly the learning and growth perspective describes developments the organization should make in order to be able to achieve the financial, customer and internal organization-related objectives. Generating visibility of operations or logging infrastructure enhancement are examples of objectives in this perspective.

Once organizations have constructed their strategy map, they should assess the impact of the business case objectives on their overall strategy. Too much complexity may make it difficult for organizations to properly assess the impact, and therefore, an ordinal scale is proposed ranging from negative impact to positive impact. Organizations should detail whether the impact of the business case objectives, on each strategy map objective, is either negative, somewhat negative, neutral, somewhat positive or positive. This allows them to justify their PM investment in the area where value is created (the strategy). Organizations that already have a balanced scorecard can quantify the result proofs from the pilot study to evaluate whether they want to implement PM.

4.3 Consolidation

Consolidation serves to bring everything together. It provides an overview of the business case by listing business targets, financial requirements, decisions regarding the execution of the project, and agreed-upon actions including the formal acceptance of stakeholders (Berghout & Tan, 2013).

Consolidation should occur in different stages of the project. First, to gain mandate for the general business case. Second, to gain mandate for the pilot study. Lastly, to gain mandate for the implementation. Mandate from relevant stakeholders is crucial for the success of IT projects.

The consolidation of the general business case should provide an overview of:

1. Business case objectives: which Pm techniques should be invested in and how are these techniques expected to generate value.
2. Benefits appraisal: alignment of business case objectives with strategy.
3. Technical requirements: preconditions given the targeted business case objectives.
4. Expected costs: costs to be taken into account while taking the decision.
5. Risks: risks associated with the PM project given the organizational context.
6. Stakeholders: identification of stakeholders and their possible roles in the PM project.

Once mandate has been gained for the general business case, the pilot study should be planned. The consolidation of the pilot study contains the same elements, but also includes project planning and governance, detailing specific agreements with regard to the pilot study. The same applies to the implementation plan, but in higher level of detail.

4.4 Technical requirements

Contingent upon the business case objectives, technical requirements have to be determined. Based on the technical requirements suppliers can be selected to enable the realization of PM. It makes sense to address the technical requirements per technique, as PM is not one exclusive technique. Rather it is a collection of techniques which share that they all use process data. Therefore the technical requirements are addressed, respectively for process discovery, conformance checking, process enhancement and operational support. This ensures that the functionality demands of end-users are achieved. Additionally, in order to pick a supplier, organizations should consider which users use the PM tool. Ease of use, through intuitive and visually attractive applications, can be crucial for the acceptation. Other organizations might not care so much about the ease of use but want to get to the absolute bottom of their process analysis. It is essential to think about this before selecting a supplier.

Technique	**Requirements**
Process discovery	The information system has to be process aware (PAIS). This enables PM tools to mine the event log holding all the process data. Furthermore, it is important to define which objects should be analyzed. Based on that list, organizations should verify whether their logging infrastructure is logging all the necessary data ontologies (see e.g. Jareevongpiboon & Janecek, 2013), and whether activities have clear names. When this is not the case (e.g. no time, originator or data ontologies recorded) organizations can either enhance their logging infrastructure or decide to analyze the process with the current process data. However, this would reduce the possible depth of the analysis. Alternatively, document streams can be mined from document management systems, provided that task, originator, event and time ontologies are also logged. This yields a different kind of analysis as the stream and modifications of the documents is leading, but can nonetheless yield very useful results as shown by De Weerdt et al. (2013).
Conformance checking	For conformance checking, the information system should be process aware. It is important that there is certainty that all elements subjected to conformance checking are correctly logged. For subjecting time, it is important that all processes operate in a universal timeframe. For subjecting users, to workload targets or segregation of duties, it is important that the logging of users takes place adequately. In practice, it is sometimes the case that logging is a-synchronized, e.g. logging the user of the previous process step, or that the system is defined as the user instead.

Process enhancement	Once again, it is important that the information system is process aware. Process enhancement is mainly done through benchmarking and simulating processes, to verify whether proposed changes have the desired results. In order to properly benchmark processes, it is essential that the process benchmarked has the relevant ontologies (e.g. same timeframe, same way of user logging, same categories, same currency, similar activity names et cetera) logged in the same way. For simulating processes the technical requirements of process discovery apply. Additionally all simulated parameters should also be logged within the process, to enable the simulation.
Operational support	Operational support is the most extensive form of PM. For ex-post operational support (e.g. daily prediction of workloads) the requirements from process discovery apply, assuming that timestamps are logged. The real-time application of this technique leaves no room for error, as there is no time to change any data as the techniques are applied in real-time. Therefore all of the requirements from process discovery, conformance checking and process enhancement apply. Additionally, real-time operational support requires a direct connection to the process data subjected to these techniques. Organizations should therefore look at whether relevant PM vendors support their data warehouse. If not, Organizations may choose to purchase a data integration tool or reconsider the business case objectives.

Table 13: Technical requirements for process mining techniques

In summary, organizations should verify whether the targeted business objectives can be achieved with their current logging infrastructure. If this is not the case, the logging infrastructure should be enhanced, provided that the costs of the enhancement outweigh the targeted benefits. This often involves redesign of the business processes. When the costs do not outweigh the benefits, organizations have two options. They can either choose to enhance the logging infrastructure regardless, operating under the assumption that data is increasingly more important in today’s business environments. Because not enhancing the logging infrastructure might be postponing what is inevitably needed to sustain their competitive advantage. The alternative is to modify the targeted business case objectives within the possibilities of the current logging infrastructure. The same story applies to the compatibility of the data warehouse for the purpose of real-time operational support. Organizations can either start using a different data warehouse if their data warehouse is not supported, select a different PM vendor that does support the data warehouse, rethink the targeted business objectives or opt for the purchase or licensing of a data integration tool.

4.5 Supplier options

Once the technical requirements have been determined, based on the business case objectives, it is time to examine supplier options. This focuses specifically on PM software. Data integration tools should be evaluated with respect to their costs, functionality and ease of use. Generally speaking, there are two options: buying the functionality, or developing the functionality by having internal or external IT staff program the application. Because this paper focuses on advancing the business practicality of PM, internal development is beyond the scope. Since it is unlikely that organizations without extensive PM experience, will be developing these tools themselves.

There are many suppliers that offer PM software. The list below has been limited to a selection of software vendors that offer stand-alone PM solutions. However, PM solutions part of a bigger package can be evaluated in similar fashion. The list is not exhaustive, but shows to illustrate how supplier options can be assessed. The first selection should be made on the relevant support needed. E.g. when an organization is looking for process discovery support, anything more than that will be a waste of its resources. Further selection should be made on specific criteria, defined by the organization itself.

In table 14 it is detailed to which extent, current (10/01/2016), PM software vendors support PM functionality. Ease of use is indicated on an ordinal scale, ranging from low to high. Namely, because this plays a big role in the acceptance and necessary training by and of users. Additionally, space for extra comments is created to enrich the supplier analysis. All information is gathered from online documentation and triangulated through inquiries with the suppliers (except ease of use as this cannot objectively determined by the relevant supplier).

Supplier	Process discovery	Conformance checking	Process enhancement	Operational support	Ease of use
Prom	V	V	V	V	Low
Easily the tool with the most applications, but also the most difficult tool, by distance. The tool is free and is developed to be the go-to tool for academics. Serious training is needed in order to harness the full promise this tool has to offer.					
Disco	V	X	X	X	High
Very intuitive and visually attractive tool that offers extensive filter possibilities. This makes it very suitable for answering questions with regard to business processes.					
MyInvenio	V	V	X*	X*	High
This tool seems very intuitive. Besides process discovery functionalities, this tool also offers conformance checking functionalities. * Furthermore, inquiry revealed process simulation and real-time operational support are scheduled to be added in the upcoming update.					
Cognizant ZDLC	V	X	V	X	Average
Various packages are offered: process discovery for apps, for process data and a user activity profiler. The scenario modeler enables modeling proposed changes into the process, allowing to check their effectiveness upfront. Process discovery techniques are advanced and include the automatic discovery of business rules.					
QPR Process Analyzer	V	X	X	X	Average
QPR Process Analyzer is an extensive discovery tool. There are many informative statistics with regard to the discovered process. However, the tool seems just a bit less intuitive than other PM tools limited to process discovery thanks to its detailed layout.					
Celonis Process Mining	V	X	X	X	High
Celonis is a very intuitive process discovery tool. Celonis has extensive export facilities allowing users to easily share their results with other people, namely through integration in PowerPoint presentations, Word or Excel documents. Sharing of results in other tools is often restricted to the tool itself.					
Perceptive Process Mining	V	V	V	X	Average
Perceptive offers a broad range of visually attractive PM applications. Process discovery, conformance checking and process improvement techniques are all supported. However, it does not offer these functionalities in real-time.					
Minit	V	X	X	X	High
Minit is a process discovery tool. It offers more or less the same functionalities as Disco with the addition that it also discovers social networks. This allows organizations to analyze the handover of work between people and departments.					
SNP Business Process Analysis	V	X	X	X	High
SNP Business Process analysis is a process discovery tool. It offers very extensive filter possibilities allowing users to answer any question they can come up with, provided the relevant process data is logged.					
Interstage Process Analytics	V	V	V	V	Average
Interstage Process Analytics offers the full range of PM functionalities in real-time. The interface and design are visually appealing. Real-time operational support is offered, allowing to check for conformance and monitor and support processes as they are being executed.					
ARIS	V	V	V	V	Average
ARIS offers a range of tools with PM functionalities. ARIS Process Performance Manager is purely a process discovery tool. ARIS Governance, Risk and Compliance Management offers real-time conformance checking functionalities, simulation of risks, notification thresholds, et cetera. Both tools are offered in the ARIS's Process Intelligence solution package.					

Table 14: Overview of process mining functionalities offered by stand-alone vendors

To conclude, PROM, ARIS and Interstage Process Analytics offer the most extensive PM functionalities, allowing to achieve any business case objective that can be achieved through PM. MyInvenio can soon be added to that list, once they release their update. PROM, however, is made for academics and relatively difficult to use. This is likely to create serious boundaries with regard to the acceptance and its perceived usefulness. Perceptive and Cognizant ZDLC offer all functionalities, but not in real-time. The remainder of the tools focus on process discovery: Disco, QPR Process Analyzer, Celonis Process Mining, Minit and SNP Business Process Analysis. All of these tools have few technical requirements as illustrated in the previous chapter and generally high ease of use.

4.6 Project planning and governance

Project planning and governance is crucial for the implementation success of PM. Deadlines should be set with regard to evaluation periods to check whether the targeted benefits are being achieved. Moreover, organizations have to appoint someone that has the final responsibility over the project. By doing so organizations avoid ineffective decision making, which increases the effectiveness and efficiency of the whole implementation. Organizations should consider eight different phases for their PM implementation, namely planning, evaluating the general plan, detailing the pilot study, conducting the pilot study, evaluating the pilot study, planning the implementation, implementation, and the continuous review once PM is implemented.

The first step is planning. Before taking action, organizations should decide on the purpose PM can serve within their organization. A first step is identifying the impact processes have on the business. Processes should be sufficiently frequent in order to infer the right conclusions from the process data. Planning in this stage includes detailing the business case objectives, targeted benefits, expected costs and risks, evaluation of technical requirements, and the identification of relevant stakeholders and their role.

The second step is evaluating the general plan. Once organizations have constructed a general business case, they should decide whether PM is expected to generate value. For the project success it is crucial to involve relevant stakeholders in this decision.

The third step is detailing the pilot study. Once an organization has a clear view of how PM can add value to their organization and has decided to further investigate this, more detailed plans should be developed. These plans should entail detailed deadlines of various stages of the pilot (e.g. process discovery, conformance checking, process enhancement and operational support), targeted results of the pilot and responsible stakeholders. Additionally organizations should determine which PM software they want to use to conduct the pilot. Generally, there are multiple software vendors that fit the requirements. Organizations may decide to conduct the pilot study using several different programs. Important to consider is the perceived ease of use. Depending on the users of the PM application organizations can choose specialist PM programs (e.g ProM) or more user-friendly programs. Many PM vendors offer a free period to test and evaluate their program

The fourth step is conducting the pilot study. Once the targets for the pilot study and the responsible stakeholders have been appointed, the pilot study can be conducted. During the pilot study organizations should test whether the assumptions they made in the business case hold true (e.g. expected benefits, technical requirements, costs).

The fifth step is evaluating the pilot study. Once the pilot study has been conducted, organizations should evaluate the results. They should verify whether all of the assumptions made in the business case hold true. Additionally, the optimization proofs from the pilot study can be applied to other similar processes to quantify the impact PM has on the organizations' business. If the pilot study is conducted using multiple software vendors, a decision should be made with regard to what vendor's PM services will be purchased. When the results of the pilot study are not satisfying organizations should investigate why and how the targeted business objectives were not achieved. Depending on that outcome organizations can choose to go back to the planning phase, implement PM with a different scope or not to implement PM at all.

The sixth step is planning the implementation of PM. Once organizations have decided to implement PM within their organization, detailed implementation plans should be constructed. First of all, these plans should define the extent of PM implementation (business units, departments, users, processes, et cetera). Additionally, plans should be developed to train all users of PM software. Additionally, users should be informed about the results of the pilot study. Referring back to the TAM-model (Venkatesh & Davis, 2000) users' acceptance is contingent upon result demonstrability and output quality. By demonstrating the results from the pilot study an organization increases its chances of successful adoption by its users. The training serves to increase users' experience and conception of how PM is relevant to their job. All of these factors will in turn influence the subjective norm and image they have of PM. All of this will determine their perception with regard to usefulness and ease of use, which will in turn, influence their usage behavior and therefore their acceptance.

The seventh is step is actually implementing PM. Once detailed plans have been developed, organizations can start implementing their PM solutions. Implementation should systematically happen, in accordance with the developed plans. This makes it possible to review the implementation later.

The eighth step is continuously reviewing the achievement of benefits. Once PM has been integrated in the organization, organizations should continuously or periodically monitor whether the implementation has the intended effects. The lack of achieving business objectives signals obstacles in the PM implementation that organizations should address in a timely manner. Through continuous reviewing organizations can monitor whether the application of PM is feasible on a continuous basis.

4.7 Cost appraisal

The value of any IT investment is determined by the benefits it bring minus the costs it brings to the organization. Insights in IT costs will lead to a richer business case and therefore a better investment decision. Van Maanen and Berghout (2002) state that total cost ownership (TCO) models force organizations to consider the costs of IT investments beyond their initial investment. Furthermore, cost categories are predefined which prevents neglecting non-obvious types of costs.

The TCO-model presented below is an adapted version of Mutschler et al.’s (2005) TCO model for business process intelligence. Some alterations were made to make it fitting to the PM business case. Additionally enhancement of logging infrastructure and data integration tools were added into the TCO-model. Optional costs that do not all apply to all business cases are in italic. Their optionality depends on the choices made regarding the business case objectives and existing conditions within the respective organization.

Direct costs				Indirect costs
PM Software	**PM hardware**	**PM support**	**PM customizing**	**End user costs**
PM licensing costs	PM server	PM user training	*Customizing of PM solution*	User self-support
Process warehouse	Database server	PM user helpdesk	*Maintenance of PM solution*	Informal learning
Data integration tools	*Enhancement of logging infrastructure*	*Solution administration*		*Personal customization*

Table 15: TCO-model for process mining costs

With regard to the PM software costs, the obvious cost are the licensing costs for the tool. Licensing costs vary per software vendor, but largely depend on the purpose (e.g. evaluation, a project, continuous use) and the scope of application (e.g. number of users). The storage of process data takes space. If organizations choose to start logging data, or decide to enhance the logging of the data, this will generate extra logging costs. For this purpose extra storage costs for the process warehouse should be taken into account. Lastly, when data has to be extracted from multiple different databases, a data integration tool to create an integrated data warehouse may serve as an efficient and effective solution.

Continuing with PM hardware, there are three elements driving costs. First is the need for a PM server. Any application of PM, beyond the pilot phase will consume resources from the server. In order for organizations’ servers to continue running at their current speed, new servers should be allocated and dedicated to PM applications. Second, the storage of all PM data (e.g. modelled scenarios, process models, et cetera.) takes space. For this purpose extra storage database server warehouse should be taken into account. Lastly, companies should take into account the costs of enhancing their logging infrastructure when they choose to do so. An example is the use of RFID in Lee et al.’s (2014) case were RFID was used to assure the quality of garments. However, time spend on manually enhancing data, as shown by Jareevongpiboon and Janecek (2013), should also be taken into account.

PM support serves to support users make effective and efficient use of PM solutions. Costs that should be taken into account are the training of users and time spend on supporting PM users with questions. Additionally, depending on the tool, solution administration costs may apply to keep the tool up to date and compatible with an organizations' data infrastructure. This largely depends on the magnitude of integration. E.g. most process discovery tools will have no difficulty updating. Fully-fledged real-time integrated PM solutions however, should first be tested on functionality to warrant their continuous functionality. Once ongoing functionality is guaranteed, IT support can update the PM tool to its latest version.

The last category of direct PM costs is the customizing and maintenance of the PM solution. Despite that this is optional, it is highly advised in order to make efficient and effective use of the PM solution. Organizations should formulate and evaluate performance indicators that will serve as an objective standard for taking action on discovered metrics. Additionally, organizations should decide on which processes should be checked for conformance and using what metrics. Scenarios should be developed before they are simulated and organizations have to consider whether benchmarking certain processes against each other is a viable practice. Lastly, real-time operational support requires careful planning. What metrics should the PM application detect, predict and which recommendations should it generate, if any. All these costs fall under customization costs of the PM solution. Another element to consider are the maintenance costs. New databases should be integrated to ensure their compliance with the PM tool, policies and standards should be kept up to date, et cetera.

All of the cost categories above cover the direct costs to be considered. There are, however, also indirect costs affecting the cost of PM. These are user self-support costs, referring to the time users spend trying to figure out the PM tool by themselves. Extensive training is able to lower these costs. Additionally, informal learning costs should be considered. Especially in the beginning, users will want to experiment with the tool to get a feel for its capabilities. This will cost time and thus lower the time they can spend on other activities. Lastly, some tools offer personal customization features, setting those up will cost time and therefore should be taken into account as well.

Unfortunately, there is no clean-cut model to accurately quantify all of these costs. Without exception, all cost drivers are contingent upon the magnitude of the organization, complexity of the processes, complexity of the logging infrastructure, complexity of data warehouses, pre-existing knowledge of users and most of all the business case objectives. Generally speaking process discovery can be applied without incurring any significant costs. Applying the full scope of possibilities PM has to offer will be much more expensive. When developing a business case, it is important to estimate realistic figures that are suitable for the scope of the project.

4.8 Risk assessment

There are risks involved in undertaking any project. A good risk assessment will prevent organizations from being too optimistic about the project. In this chapter, risks will be identified and measures will be provided on how to mitigate these risks. Not all the risks mentioned in this chapter may apply to all organizations. Nor are the risks provided exhaustive. They should, however, provide an idea of general risks to consider before investing in PM. The first five risks are derived from Cresswell et al. (2002):

Risk	**Mitigation**
Unrealistic expectations	Develop a thorough business case detailing how benefits are created, which costs and risks to factor in.
Lack of organizational support	Involve relevant stakeholders early in developing the business case. They are more likely to accept the technology when they understand its purpose and have contributed to its implementation.
Failure to meet technical requirements	Perform an analysis contrasting the technical requirements needed to achieve the formulated business case objective with the current logging infrastructure. Any deviations should be discussed and mitigated prior to starting the project. Any unforeseen failure to meet technical requirements should become apparent during the pilot study.
Lack of strategic alignment	Develop a strategy map and check the alignment of the formulated business case objectives with this strategy map.
Lack of understanding of PM technology	Involve personnel and/or consultants with sufficient knowledge on PM in the development of the business case.

Lack of responsibility of relevant stakeholders	Identify relevant stakeholders and their role in the project. Assign responsibility of achieving certain business case objectives to the relevant stakeholders.
Non-effective use of PM solution	Provide adequate training to users to show how users can leverage PM techniques and derive valuable insights from it.

Table 16: General risks in PM projects

4.9 Stakeholders

Relevant stakeholders with regard to the PM project should be identified to identify possible interaction problems, project responsibilities and collective contributions to project success. Responsibilities should be assigned to relevant stakeholders, describing their contribution to the PM project. Possible interaction problems should be solved, prior to starting the project, to ensure a smooth implementation. In order to gain stakeholder mandate, specific benefits for the various groups of stakeholders should be identified. Key stakeholders include customers, the board, project managers, senior management, specialist IT jobs, operational management, (internal) reporting related jobs, process-related jobs (e.g. process developer), process-improvement related jobs (e.g. lean six sigma black belts). Other relevant stakeholders may include the parent company, consultants and sales representatives. Organizations should clearly detail what is expected from the various stakeholder groups, how they should contribute to the project, and what benefits does PM bring to their jobs.

4.10 Conclusion

In this chapter a business case framework for justifying investments in PM has been detailed. This provides support to organizations in building there PM business case. Organizations should first consider the impact of their processes on their business. Next, organizations should consider their maturity level with regard to process intelligence. From there, organizations can start formulating the business case objectives. These objectives provide the basis for the benefits appraisal. It is recommended that organizations evaluate their benefits in both a quantitative and a qualitative way. This will create a solid basis for evaluating the pilot and the continuous review of PM benefits, once PM has been implemented. The technical requirements for the proposed business case objectives should be detailed to understand the scope of the project. Additionally, relevant stakeholders should be identified to gain mandate and assess possible risks within the PM project. Lastly, in order to evaluate the general plan organizations should have an indication of the costs associated with PM.

Once a general plan has been approved by relevant stakeholders, it is time to start planning in more detail. The first step is the selection of a relevant supplier to perform the pilot study. This should be based on the technical requirements formulated earlier and user preferences with regard to ease of use, visual appeal, et cetera. The general business case should be increased in detail, to get a more accurate picture on how to measure the benefits, risks and their mitigation, and applicable costs. It should also set specific points in time at which the pilot study is evaluated, using pre-determined evaluation criteria. The pilot study serves as an execution plan. Representative process to the organization should be identified which can be used to generalize results.

Once the detailed plan has been approved by relevant stakeholders, organizations can start conducting their pilot study. The pilot study serves to test all the assumptions made in the business case. During the pilot study, support should be provided to users, so they are able to effectively leverage the possibilities PM has to offer. In accordance with the plan, the evaluation of business case objectives should take place at specific points of time, using pre-determined measures. At the end of the pilot study the whole project should be evaluated. Organizations can then choose to implement PM in line with the original business case, adapt the scope of implementation, restart the pilot in case the results were inconclusive or choose not to implement PM at all. For the first two options organizations should develop detailed plans describing the scope of implementation (e.g. processes, departments, user groups, et cetera), training and support of users, and implementation details.

Once mandate has been given to the implementation plan, organizations can start the execution of this plan. Continuous support is important to avoid a lack of acceptance or non-effective use of the PM tools. The implementation should occur in accordance with the earlier detailed plan. Once the implementation is completed, organizations should continuously monitor the effects to check whether the intended results are being achieved.

In summary, the following steps should be followed:

Phase 1: Planning
• Determine the impact processes have on the business. • Consider maturity level of process intelligence in the organization. • Formulate business case objectives and determine the scope of PM. • Determine the alignment of the business case objectives with the strategy, using a strategy map. • Formulate target benefits regarding the business case objectives. • Identify technical requirements, costs, risks and stakeholders. • Make a general plan detailing the basic concept of the PM pilot study. • Consolidate all information in a briefing with supporting documents to gain stakeholder mandate.
Phase 2: Evaluation of general plan
• Evaluate the general plan with a representative set of stakeholders. • Make changes to the general plan to better suit the needs of stakeholders.
Phase 3: Detailing the pilot study
• Once stakeholder mandate is given, the pilot study should be planned in further detail. • Perform a supplier analysis and select a supplier. • Set a time-frame for the pilot study. • Identify representative processes (with regard to magnitude, complexity and automation) to test the assumptions made in the business case. • Determine specific points in time to evaluate the pilot study, using pre-determined measures. • Identify the roles and contributions of various groups of stakeholders to the pilot study. • Assign responsibility to stakeholders for measuring the achievement of targeted benefits.
Phase 4: Conducting the pilot study
• Provide training to users involved in the pilot study. • Provide support to users involved in the pilot study. • Measure the achievement of targeted benefits, using pre-determined measures, at specific points in time.
Phase 5: Evaluation of pilot study
• Apply optimization proofs to similar processes using simulation. • Shortly after the pilot study, qualitatively evaluate the usability, relevance and impact of PM to support business processes with regard to the formulated business case objectives. • Evaluate, together with the earlier set of stakeholders, the entire pilot study. Discuss both the qualitative and quantitative findings. • Decide on making the investment in PM. Organizations can choose to either not implement PM, implement PM with a changed scope, implement PM with the earlier determined scope or re-evaluate the business case objectives (return to phase 1).
Phase 6: Pre-implementation
• If mandate has been given for implementation, detailed implementation plans should be developed. • Scope of implementation should be clearly described. • A timetable for implementation should be developed (e.g. describing enhancement of logging infrastructure, period of database integration, actual implementation, et cetera). • A training program should be developed to train the various user groups in effectively leveraging the possibilities PM offers. • Support personnel should be trained to support other users with questions, once the implementation starts.
Phase 7: Implementation
• Implement PM using the plans developed in phase 6. • Report on progress of implementation. • Provide training in accordance with the developed training programs.
Phase 8: Continuous review
• Periodically review the benefits using the pre-determined measures. • Assess the adequacy of the logging infrastructure for modern business needs.

Table 17: eight phase implementation plan for process mining

5. Conclusion and discussion

To conclude, the significance, relevance, and practical and academic uses of this paper are detailed. This is followed up by the discussion, which puts the business case framework design into perspective, using Hevner et al.'s (2004) 7 guidelines for design-science. Lastly, directions for further research are presented to help further advance PM research, particularly with regard to its business applicability.

5.1 Conclusion

This paper was intended to further the business applicability of PM. After conducting a literature review, detailing the current business applicability of PM, it became apparent that organizations may have a hard time justifying their PM investments. Prior to this paper, there was no business case framework available, tailored to the specifics of PM. This paper fills the gap by providing a PM business case framework that organizations can use to justify PM investments.

The broad literature review on PM ensures sufficient knowledge regarding the current state of research of PM. An additional literature review on IT investments served to put the findings of the PM literature review into context. Incorporating the knowledge from these two literature reviews together led to the development of the specific PM business case framework presented in chapter 4. An eight phase methodology was constructed covering the entire implementation process, from general planning up until continuous review, once PM is implemented.

The developed PM business case framework will support organizations in justifying their PM investments, by using the systematic methodology developed in this paper. Organizations should start with creating a general business case framework, detailing business case objectives, targeted benefits, expected risks and costs, technical requirements, and relevant stakeholders. This is used to gain mandate from the relevant stakeholders. Once mandate has been given, organizations should start planning the specifics of a pilot study to confirm whether the assumptions made in the business case hold true. The pilot study should be evaluated using pre-determined evaluation criteria. This paper suggests to apply the optimization proofs found in the pilot study to other similar processes using PM simulation techniques. Additionally, alignment of the business case objectives should be checked using a strategy map. Lastly, the pilot study itself should be qualitatively evaluated with respect to functionality and suitability to the organization. This ensures a thorough evaluation of the pilot study.

Organizations can then choose to implement PM in line with the original business case, adapt the scope of implementation, restart the pilot, in case the results were inconclusive, or choose not to implement PM at all. For the first two options, organizations should develop detailed plans, describing the scope of implementation (e.g. processes, departments, user groups, et cetera), training and support of users, and implementation details.

The last step of implementation is the continuous review of targeted benefits. Monitoring the targeted benefits allows organizations to keep its IT portfolio relevant. When targeted benefits are not being achieved, organizations should take corrective action. Complementary investments in training may be needed when users do not effectively leverage the possibilities of PM. Alternatively, monitoring may indicate that the expected benefits are not as big as previously expected, despite properly implementing PM.

5.2 Discussion

In order to systematically review the contribution and limitations of this paper, it is evaluated on Hevner et al's (2004) 7 guidelines of design-science research. Each guideline will be covered in its own indention.

Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation. In this paper, a business case framework was developed to help organizations to justify their (possible) investment in PM. An eight phase methodology was developed to guide organizations through the process of planning, testing, implementing and reviewing PM solutions.

The objective of design-science research is to develop technology-based solutions to important and relevant business problems. Literature currently does not provide organizations with a systematic method to evaluate and justify their possible investment in PM. Despite that further refinement of the framework is needed, Hevner et al. (2004) state: *"Problem solving can be defined as a search process (see guideline 6) using actions to reduce or eliminate the differences (Simon, 1996)"* (p. 85). This paper, at the least, reduces the problems organizations face in justifying their (possible) PM investments.

The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods. Hevner et al. (2004) state that: *"… design is inherently an iterative and incremental activity, the evaluation phase provides essential feedback to the construction phase as to the quality of the design process and the design product under development. A design artifact is complete and effective when it satisfies the requirements and constraints of the problem it was meant to solve"* (p. 85). The evaluation of the business case framework is most suitable through conducting a case study. However, because of pragmatic reasons this has not happened. The paper does however put forward some form of evaluation in the form of an informed argument. Despite this, it is clearly in need of a thorough evaluation in business settings (see also directions for further research).

Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies. This paper provides a novel contribution to research, by providing a methodology that can be used to justify and implement PM. Practical business experience ensured an accurate understanding of business and technology environments in organizations. This makes the developed business case framework more useful as it is better aligned with modern business and technology environments.

Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact. Research rigor was, to some extent, achieved through systematic literature reviews that served to access the knowledge bases of PM and IT investments. However, some recommendations were made in order to increase the quality of the developed business case framework. These recommendations were made to complement the literature review on IT investments. This literature review is therefore deemed as partially insufficient with regard to accessing the relevant knowledge base needed. Backward searches in the recommendations alleviated most of this limitation. Moreover, Lee (1999) states that overemphasis on rigor often results in lower relevance. The relevance of this paper has thus not been impacted by this limitation.

The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment. *"Effective design requires knowledge of both the application domain (e.g., requirements and constraints) and the solution domain (e.g., technical and organizational).* The application domain refers to PM where the solution domain refers to organizations. Knowledge of the application domain was developed systematically, through an extensive literature review and practical experience with PM tools. Knowledge of the solution domain was developed by applying PM in practice. However, the extent to which PM was applied was process discovery, and the application to one organization does not warrant enough generalizability to other organizations. Additionally, the fact that the researcher was not a part of the PM research domain prior to the research has possibly led to neglected areas in the business case framework. Therefore, evaluation is crucial to confirm the validity of this paper. Moreover, there may have been other methods available for organizations to justify their PM investments, but the solution provided is at least deemed as satisficing.

Design-science research must be presented effectively, both to technology-oriented as well as management-oriented audiences. In order for researchers and practitioners to take advantage of the developed framework, its presentation is kept fairly simple. This ensures anyone interested in PM has the ability to understand the framework. This is particularly important because organizations considering to invest in PM are likely to have no prior experience with PM.

Thus, a major limitation of this paper is that, although it provides a framework through which organizations can justify their investments in PM, it does not provide supportive proof. Therefore, this framework is in need of testing. This will prove the validity and will ensure further refinement of the business case framework and its corresponding methodology. Because, as Hevner et al. (2004) note, design is an iterative process.

5.3 Directions for further research

In this chapter directions for further research are provided. There are various research directions that will further increase the business applicability of PM. Directions for further research include: evaluation criteria to justify PM; case studies with regard to how companies employ process mining; case studies with regard to the value companies derive from process mining; surveying various process mining user groups on their perceptions towards process mining; and testing of the PM business case framework and its corresponding methodology. All of these suggestions are beneficial for the further development of the PM business case framework and its corresponding methodology.

Quantitative and qualitative evaluation criteria have been proposed to appraise the benefits of PM projects. The simulation techniques PM possesses provide an excellent opportunity to apply the optimization proofs found in the pilot study to other relevant business processes. For qualitative assessment, it is suggested to check the alignment of the business case objectives with a strategy map. Further research should test the relevance of this suggestion for PM projects and possibly extent the qualitative assessment, or come up with other qualitative evaluation criteria.

The use of case studies is very popular in the PM discipline. Many case studies focus on technical application of PM in different business environments. However, there are also many case studies on the business applicability of PM. What is lacking, however, is a case study with regard to how organizations apply PM in practice. All case studies identified in this paper detailed a problem that was solved by researchers. It will be interesting to see how organizations apply PM in practice. This will provide further input on the application areas of PM and the obstacles organizations face while implementing and using PM.

Additionally, case studies can be conducted that study the value of PM in more detail. What is the effect of applying PM in organizations? Currently, literature does not provide insight in the value organizations are able to derive from PM. Creating this knowledge will provide more clarity for organizations with regard to various aspects. First, whether companies are able to derive value from PM; second, in which way this value is derived; and third which PM techniques generate value.

To further increase the business applicability of PM, it is essential to create more insight in the user groups using PM. A survey is an efficient and effective research methods to gather these insights. The survey should be send to: process improvement specialists, project managers, researchers, consultants, external auditors, internal auditors, risk managers, operational managers, tactical management and strategic management. The insights from these user groups and the perception they have with regard to the purpose and value of PM, is likely to create new venues for PM research.

Last but not least, the PM business case framework and its corresponding methodology are in need of testing and further refinement. The validity of the proposed business case framework for justifying PM in practice should be tested in various case studies. *"Because design is inherently an iterative and incremental activity, the evaluation phase provides essential feedback to the construction phase as to the quality of the design process and the design product under development"* (Hevner et al., 2004, p. 85). This paper serves as a basis for further research on the justification and implementation of PM. The PM business case framework is coarse-grained and should be refined to better suit various sectors (e.g. healthcare, production, trade and services). The development of sector-specific PM business case frameworks will further support companies in the justification of their PM investments.

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