



Graduate Program
Department of Applied Informatics

Thesis

A Systematic Investigation of Risk Management and Process Mining Ontologies

by

Dimitrios S. Karamitros

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Dedicated to Elijah and Chryssa

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Abstract

This study proposes and examines the “Risk – Process” ontology with respect to and in comparison with the Process mining methodology. The ontology consists of Process elements (Process Mining, Business Process Management and Business Process Intelligence) and Risk elements (Governance, Risk Management & Compliance, Internal Audit and Enterprise Risk Management). A two-fold literature review is executed, focusing firstly on the six key elements of the “Risk - Process” ontology, and secondly at the “Risk” components of the ontology. Moving on, as an original contribution, the popularity and the coherence of the aforementioned elements in internet searches from 2004 to 2018 is presented and forecasted with the use of the Google Trends tool. As a last step, a statistical analysis of the time series obtained through Google Trends is performed, in order to find relation, correlations, statistical significance and predictors with respect to Process mining.

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Chapter 1

Introduction

Nowadays, is all about data. Everybody talks about big data, data science, data mining, data analysis, and the list goes on. These newly established doctrines examine and try to explain what is hiding behind raw data. Vast amounts of data waiting to be subjected to statistical analysis, taxinomised, rated, correlated, in order for the researcher to come to a conclusion. But in the past, not everybody wondered or worried, how these data were being generated and whether the processes that lead to the accumulation of all that data were articulate and foul proof. There was a little -or no consideration at all- about the solidness of the processes provided these data. And that, was simply not intelligent enough for this particular group of strategies and methodologies operating under the name of business intelligence.

1.1 The birth of process mining methodology

With the previous reflection in mind and sparked by the related work of prof. Will van der Aalst (the godfather of process mining), a group of researchers in the last decade developed an exciting new doctrine that arose as a data science methodology and still struggles to cement its place in the competitive field of enterprise process intelligence related tools. The aforementioned methodology was most suitably baptized Process Mining and the principle behind it, is very simple, yet elaborate. The basic idea is to diagnose processes by mining event logs for knowledge (van der Aalst and De Madeiros, 2005).

According to van der Aalst et al. (2003), the process mining methodology has become a vivid research area. Until recently, the information in event logs of information systems were rarely used to analyze the underlying processes. Process mining aims at

improving this by providing techniques and tools for discovering process, control, data, organizational, and social structures from event or transaction logs.

Process mining is a family of approaches which looks at data from event logs to see what people are doing. From looking at the steps someone takes to complete a task, a process can be automatically constructed. By continuing to gather this data over time a researcher is able to distinguish where bottlenecks occur or where inefficiencies lie within the process. Aalst (2016), also states that process mining can be viewed as the missing link between data science and process science. In practice, process mining is used as a useful tool for ERM professionals and auditors to gain more knowledge about the actual business processes and enables a better risk assessment.

1.2 Aim & objectives of the thesis

This thesis aims to provide a systematic Investigation of Risk Management and Process Mining Ontologies through a series of steps assembled in a framework, that detail, analyze and respond appropriately to the continuous challenges of the Enterprise Risk Management perspective. The primary question imposed in this body of work was if there are sufficient evidence - in both academia and business - to claim an imprint, an important contribution of Process Mining methodology to Risk Management. In order to approach an answer to this question we formed an ontology, a skeletal framework, within it we performed and executed an academic-oriented and a business-oriented research.

As long as the academic approach is considered, a two-fold literature review is conducted and presented. At the first stage, we examine the element of Process mining with respect to the remaining elements of the ontology. This co-examination and cross-examination of the elements is executed in order to specify the most relevant articles from a process mining scope of research. The main consideration in this stage is to highlight the importance and the imprint of the process mining methodology to our examined ontology. At the second stage, the author focuses on the "Risk" triangle and

the aim of the searches executed is to discover the existing imprint, as well as the future implications of the process mining methodology to Risk Management concept. As a challenge in this latter stage of the review, is the disclosure of the ultimate article; the Holy Grail of the related literature, that combines and unites all the properties and advantages of the best practices.

As long as the business research is considered, there is no doubt that Process mining and Risk methodology are industrial applications (Aalst et al., 2007). No matter how detailed an academic literature review will be, it is only indicative of the trends and the needs of the business world. In order to research and measure in a quantitative manner the imprint of process mining to the needs of the business world, we need a tool which encapsulates and depicts the various relations and contemporary trends in an ever-changing reality. The most suitable tool is no other than Google Trends, a tool that measures the internet searches conducted on the Google search engine. It does not just measure the sheer volume of them, but also measures the contextual ingredients of the search topic and records the geographical location of the search. The aforementioned tool provides an actual depiction of the needs of the researchers and to put it in simple words, it incorporates what the world is looking for.

The quantitative findings from the Google Trends tool are depicted as time series of popularity scores. The statistical behavior, patterns and underlying logic of these scores is analyzed with the use of IBM SPSS tool, a well-known and widely used statistical package. With the statistical analysis of the data obtained, we search to find the existence of any relation and common ground in terms of pattern-based behaviour between the elements examined. As a last step to our analysis, we built a model in order to find which element resembles the most to process mining in terms of behavior.

1.3 The key elements of the proposed “Risk-Process” (R-P) ontology

According to Merriam Webster online dictionary (www.merriam-webster.com), the definition of framework is among others: i) a basic conceptual structure (as of ideas), and ii) a frame of reference.

In practice, the implementation of a risk management framework in an enterprise consists of, and employs, several forms, the two main ones being: a) Governance, Risk Management & Compliance and b) Internal Audit. On the other hand, the process mining methodology is integrally related to: a) Business Process Intelligence, and b) Business Process Management.

The skeletal framework formulated, addressed and discussed in the thesis, is schematically and ontologically depicted as two intrallaping triangles:

- i) The first triangle consists of: a) Process Mining, b) Business Process Management and c) Business Process Intelligence. That triangle is named as the "Process" triangle.
- ii) The second triangle consists of: a) Governance, Risk Management and Compliance, b) Internal Audit and c) Enterprise Risk Management. That triangle is named as the "Risk" triangle.

For ease of reference we will be name the above conceptual framework as the "Risk – Process" ontology, or for short the "R-P" ontology. The "R-P" ontology is depicted in Figure 1.1.

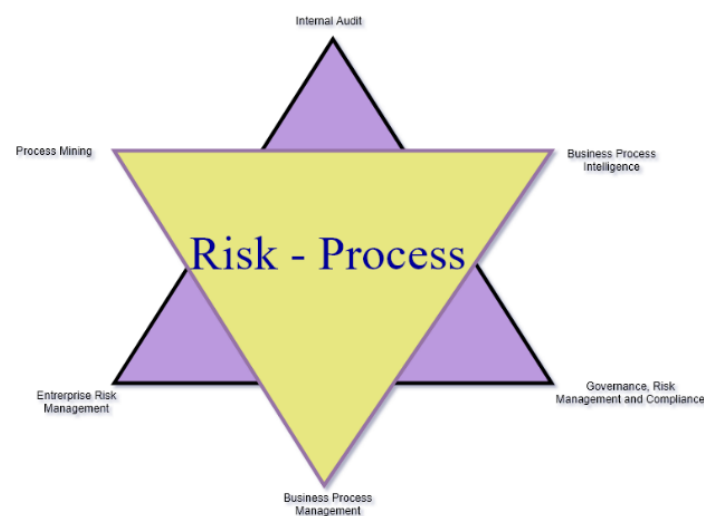


Figure 1.1. The two triangles of the "R – P" ontology

1.4 A presentation of the core elements of the ontology

The ontology of the framework was created having in mind the problems faced by modern organizations and big firms. A tool that can be used as a point of reference in the business world. The six elements that serve as the reference points to the “R-P” ontology are briefly presented below.

1.5 Process Mining

The basic idea of process mining is to diagnose processes by mining event logs for knowledge (van der Aalst and De Madeiros, 2005). Process mining could be a useful tool for auditors to gain more knowledge about the actual business processes and enables a better risk assessment (Hakvoort and Sluiter, 2008).

Furthermore, according to Process Mining Manifesto (W. M. P. Aalst et al., 2011), - which is a collective body of work and thought by members and supporters of the IEEE Task Force on Process Mining (and seeks to promote the research, development, education, implementation, evolution, and understanding of this the relatively new methodology), “Process mining is a relatively young research discipline that sits between computational intelligence and data mining on the one hand, and process modeling and analysis on the other hand. The idea of process mining is to *discover, monitor and improve real processes* (i.e., not assumed processes) *by extracting knowledge from event logs* readily available in today's (information) systems. Process mining includes (automated) process discovery (i.e., extracting process models from an event log), conformance checking (i.e., monitoring deviations by comparing model and log), social network/organizational mining, automated construction of simulation models, model extension, model repair, case prediction, and history-based recommendations”.

In practice, according to the dedicated site <http://www.processmining.org/>, "Process Mining techniques allow for extracting information from event logs. For example, the audit trails of a workflow management system or the transaction logs of an enterprise resource planning system can be used to discover models describing processes, organizations, and products. Moreover, it is possible to use process mining to monitor deviations (e.g., comparing the observed events with predefined models or business rules in the context of SOX). Process mining is closely related to BAM (Business Activity Monitoring), BOM (Business Operations Management), BPI (Business Process Intelligence), and data/workflow mining. Unlike classical data mining techniques the focus is on processes and questions that transcend the simple performance-related queries supported by tools such as Business Objects, Cognos BI, and Hyperion."

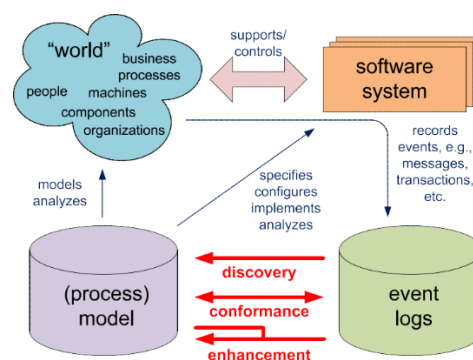


Figure 1. 2 Positioning of the three main types of process mining: discovery, conformance and enhancement

According to van der Aalst et al. (2003), the process mining concept has become a vivid research area. Until recently, the information in event logs of information systems was rarely used to analyze the underlying processes.

Process mining aims at improving this by providing techniques and tools for discovering process, control, data, organizational, and social structures from event or transaction logs. The basic idea of process mining is to diagnose processes by mining event logs for knowledge (van der Aalst and De Madeiros, 2005). Process mining could be a useful tool for auditors to gain more knowledge about the actual business processes and enables a better risk assessment.

1.6 Enterprise Risk Management

ISO 31000:2009 defines risk as the effect of uncertainty on objectives, and notes the following:

1. An effect is a deviation from the expected — positive and/or negative.
2. Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).
3. Risk is often characterized by reference to potential events and consequences, or a combination of these.
4. Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.
5. Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequence, or likelihood.

Also, ISO 31000:2009 defines risk management as the coordinated activities to direct and control an organization with regard to risk. Adding to this, ISO 31000:209 defines the risk management framework as set of components that provide the foundations and organizational arrangements for designing, implementing, monitoring, reviewing and continually improving risk management throughout the organization, under the following notes:

1. The foundations include the policy, objectives, mandate and commitment to manage risk.
2. The organizational arrangements include plans, relationships, accountabilities, resources, processes and activities.
3. The risk management framework is embedded within the organization's overall strategic and operational policies and practices.

1.7 Enterprise Risk Management & Internal Audit

The elements of Internal Audit and Enterprise Risk Management are key success factors for the profitability and the longevity of any given firm or organization. In practice, both Internal Audit and Enterprise Risk Management functions, focus on an organization's risk profile and areas of great risk importance and exposure, but the two often take different approaches.

From the one hand, Internal Audit serves as the assurance arm of risk management, answering the question: Are you doing what you said you were going to do to manage risk? This function maintains independence to be objective in review and analysis of risk.

From the other hand, Enterprise Risk Management proactively works with the business to understand, assess, and report on risk. This function seeks to understand potential areas of risk focus and work with the business to develop and implement an adequate risk response, if needed. In every institution, firm or organization, in order to create stronger risk practices and build a strategic relationship between Enterprise Risk Management and Internal Audit, it's crucial to increase collaboration between the two. The constant monitoring and reporting of risks is especially important to ensuring there is a constant feedback between risk management and audit. Problems will arise if approaches between Enterprise Risk Management and Internal Audit teams are not coordinated. It can lead to inconsistency in priorities, burdens on the stakeholders, and increased reporting needs, which consequently means that out enterprise is less responsive to risk factors and more time and more money consuming.

1.8 Business Process Management

According to the dedicated site <http://bpmcenter.org/>, the Business Process Management lifecycle is following the flow depicted in Figure 1.3

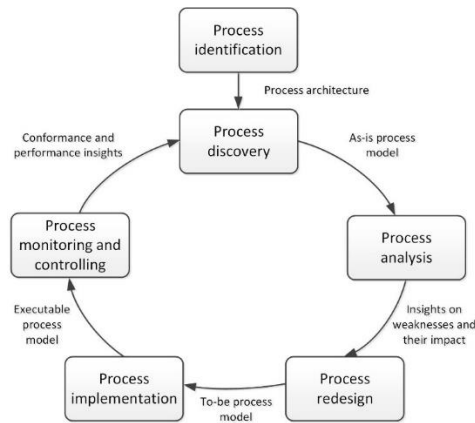


Figure 1. 3 The BPM lifecycle

The BPM Center is a collaborative virtual research center in the area of Business Process Management which was founded in 2004 by the Information Systems groups (IS@CS and IS@IEIS) at Eindhoven University of Technology (Eindhoven, The Netherlands) and the Business Process Management Discipline at the Information Systems School, Science and Engineering Faculty of Queensland University of Technology (Brisbane, Australia). The aforementioned institutes are among the world’s leading academic institutions in the area of Business Process Management.

1.9 Business Process Intelligence

According to (Castellanos et al., 2009), Business Process Intelligence refers to the application of Business Intelligence techniques to business processes (Grigori et al., 2004). In this context, Business Intelligence refers to technologies, applications, and practices for the collection, integration, analysis, and presentation of business information and also sometimes to the information itself. The purpose of Business Intelligence is to support better business decision making (Power 2007). The data source for Business Intelligence is a so-called data warehouse, i.e., a special data base where an organization stores important historical data. Most of the time the data is collected from different information systems as used in an organization. Data analysis and data mining can be performed using this data. The goal is to translate the data to

useful business information that can support the decision making process of the organization. If the data warehouse also contains information about the processes within an organization it is called a process data warehouse (Casati et al., 2007) and can be used as source for Business Process Intelligence analysis. Business Process Intelligence is an emerging area, that is quickly gaining interest due to the increasing pressure companies are facing to improve the efficiency of their business processes and to quickly react to market changes in order to be competitive in this highly dynamic Internet era. In addition, the need to meet regulatory compliance has recently strengthened this trend (e.g., the Sarbanes-Oxley Act of 2002).

BPI often triggers process improvement or reengineering efforts. BPI not only serves as a tool for improving business processes performance, but also fosters changes by facilitating decision-making. In addition, BPI is used to monitor the alignment of operational business processes with strategic business goals and to give the visibility that regulatory compliance requires. Furthermore, BPI is not restricted to the analysis of historical data, but can also be used to optimize future efforts (e.g., through predicting future problems).

1.10 Governance, Risk Management and Compliance

Corporate or enterprise governance is the set of processes, customs, policies, laws, and institutions affecting the way an enterprise or corporation is directed, administered and controlled. Corporate governance includes the manner of the relationships among the stakeholders (like the board of directors, employees, customers, creditors, suppliers, and the community at large) involved in the enterprise and the goals for which the enterprise is governed. According to (Moeller, 2011), effective enterprise risk management, good enterprise governance processes, and the need for effective enterprise-wide compliance programs.

There has been renewed interest in the corporate or enterprise governance practices in modern corporations since 2001, particularly due to the high-profile collapses of a

number of large international firms such as Enron Corporation at that time and the failure of many financial institutions in the years starting about 2008 and without a sign of an imminent stop. For it was only when Enron failed, that the U.S. federal government finally passed the Sarbanes-Oxley Act in 2002 with an objective to restore public confidence in corporate or enterprise governance. The collapse of the banks and other financial institutions in 2008 and beyond worldwide (and especially in Greece), led to massive taxpayer bailouts and increased legal rules.

Today it is essential for an enterprise not only establish policies to effectively handle its governance issues but also to build a risk culture which will allow to establish an effective system of governance. After governance, risk issues, and management, the third key component of GRC is enterprise compliance. Compliance is either a state of being in accordance with some established guidelines, specifications, or legislation or the process of becoming so. Internal audits, for example, should be developed in compliance with the International Standards for the Professional Practice of Internal Auditing. An enterprise has also to develop systems in order to monitor and manage their levels of compliance conformance with the rules and regulations imposed as well as to take appropriate actions to detect and act on any violations of these regulations.

1.11 Research methodology

The starting point of the analysis will be to break these two triangles into their components and examine the effect to process mining in each component, as shown in Figure 1.4

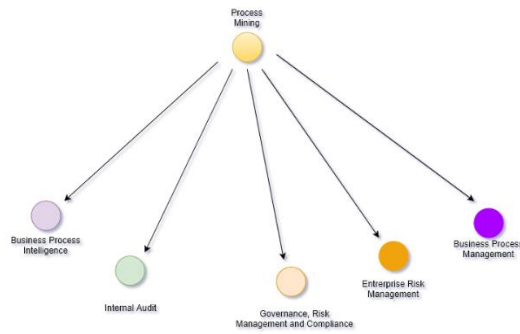


Figure 1. 4 The imprint of process mining to business components

In practical terms, the aim of the research is to:

- Broadly discuss the basic notion behind the convention and collaboration among these six elements with respect to the Process Mining methodology, Enterprise Risk Management and Internal Auditing
- Depict the impact of process mining as a topic to internet searches, in comparison with Enterprise Risk Management, Governance, Risk Management & Compliance, Internal Audit and other relevant topics
- Investigate the related literature, in the context of the imposed question,
- Rate the related articles by a point system based on their place on the obtained results, their frequency and their ratio.

1.4. Structure of the Thesis

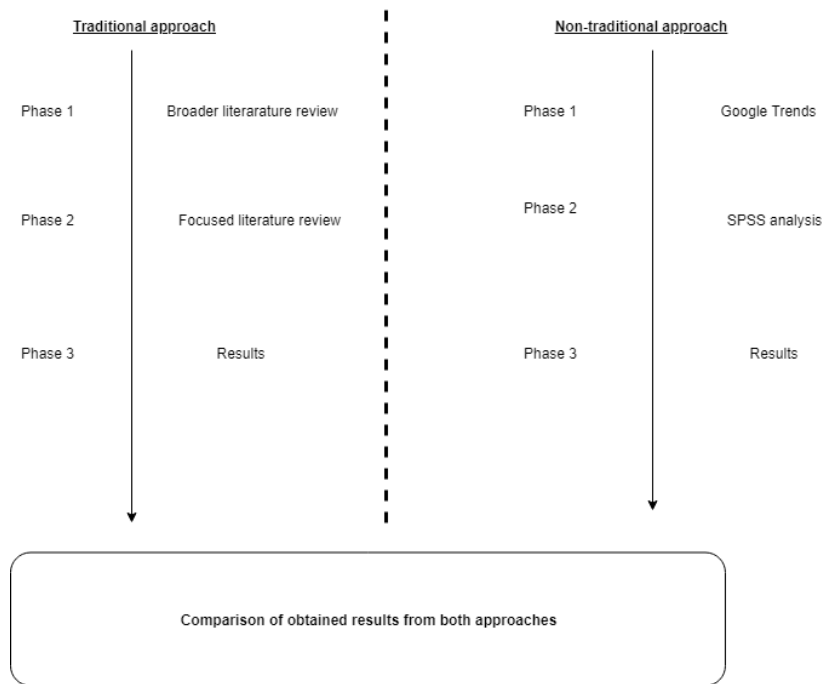


Figure 1. 5 Structure of the thesis

In Chapter 2 we conduct the literature review of the thesis, focusing: a) at first stage on the six key elements of the “Risk - Process” ontology, as discussed in Chapter 1 of the study and b) at a second stage at the “Risk” components of the ontology.

Following in Chapter 3, with the help of the Google Trends tool, we depict the popularity of the six aforementioned topics (Process mining, Enterprise Risk Management, Internal Audit, Governance, Risk Management and Compliance, Business Process Intelligence, Business Process Management), in internet searches from 2004 to December 2018. (This type of investigation, to our knowledge, is original, as it has not yet been committed in the corresponding literature for systematic reviews and synopses. This chapter is using as a hook, a link between the theoretical and the practical framework of the analysis).

In Chapter 5, (with the use of IBM SPSS), we analyze statistically the Google trends time series of the six elements of the study, in order to find relation, correlations, statistical significance and predictors with respect to process mining.

Finally in Chapter 6 we present the conclusions of the study, as well the implications for future research.

Chapter 2

2. Literature Review

A two-fold approach is selected concerning the approach and analysis of the relevant literature. The first section provides a broader systematic literature review on the relationship among process mining and the aforementioned areas of: i) Business Intelligence, ii) Enterprise Risk Management, iii) Internal Audit, iv) Business Process Management, and v) Governance, Risk Management & Compliance. In the second section of the review we conduct a more focused search for the element concerning the “Risk” triangle of the model. The rationale behind this two-fold approach is that to compare of the results produced by each search and to discuss the findings.

2.1 Review methodology

To gain insight on how the process mining implemented in the business domain a literature review has been conducted according to the general systematic review steps proposed by (Kelemen, 2017). The most common reasons for undertaking a systematic review are:

- 1) To summarize the existing evidence concerning the interaction of process mining methodology with the other five elements of the “R – P” ontology.
- 2) To identify any gaps in current research in order to suggest areas for further investigation,
- 3) To provide a framework/background in order to appropriately position new research activities.

2.2 Literature review

The first step in literature review was to define the keywords which will be used in the search. The second step was to define the relevant databases to perform search. The database of choice was Google Scholar, as trial searches conducted on other database (Web of Science, Computer Science Bibliography – DBLP, Science Direct, IEEE Computer Society, ACM, Springer), showed that Google Scholar is by far the fullest and broadest medium of research.

The inclusion and exclusion criteria for article selection are presented in Table 2.1. Based on these criteria all the articles have been selected. The whole research has been conducted in three phases. The first phase objective has been to rise queries in databases with defined keywords and titles and keywords analysis. The articles matching the criteria have been selected. The second phase has taken into consideration the abstracts and duplicates. If the paper has matched criteria, the third phase has been performed – the full text analysis. The papers that have not matched the criteria have also been excluded from the research.

	Phase 1	Phase 2	Phase 3
Inclusion criteria	<p>Title indicates that the paper is concerning the “R-P ” ontology</p> <p>Keywords indicate that the paper is concerning the “R-P ” ontology</p> <p>Book or Book Chapter concerning the “R-P ” ontology</p> <p>PhD or Master Thesis concerning the “R-P ” ontology</p> <p>Patent concerning the “R-P” ontology</p>	<p>The body of article indicates that the paper is about the “R-P ” ontology</p>	<p>Topics on the process mining usage in “R-P ” ontology</p> <p>The main challenges of process mining usage in “R-P ” ontology</p> <p>The main possibilities of future work or identified research areas</p>

Exclusion criteria	Title indicates that the paper is about another topic, it can include process mining but without any relation with the "R-P " ontology	Abstract of articles indicates that the paper is not related to the "R-P " ontology	There are process mining techniques not related to "R-P " ontology
	Keywords indicate that the paper is about a topic irrelevant with the "R-P " ontology	Duplicates excluded	There are no "R-P " ontology issues covered

Table 2. 1 Inclusion and exclusion criteria for article selection

Google scholar provides a simple way to broadly search for scholarly literature. From one place, we can search across many disciplines and sources: articles, theses, books, abstracts and court opinions from academic publishers, online repositories, universities and other web site. As mentioned on the google scholar webpage, Google Scholar aims to rank documents the way researchers do, weighting the full text of each document, where it was published, who it was written by, as well as how often and how recently it has been cited in other scholarly literature.

2.3 The literature review concerning the elements of "Risk - Process" ontology

In Table 2.2, there are presented the search terms and hits (results) obtained:

#	Term	Number of hits	% of decrease
	"process mining"	19.800	-
1	"process mining" AND "business process management"	7.100	64%
2	"process mining" AND "business process intelligence"	1.230	83%
3	"process mining" AND "internal audit"	200	84%
4	"process mining" AND "enterprise risk management"	140	30%
5	"process mining" AND "governance, risk management and compliance"	41	71%

Table 2. 2 Search terms and hits (results) obtained

For the sole purpose of comparison and functioning as a reference point, a search was also conducted for the term *process mining* alone, which came up with 19.800 results, a quite satisfactory number. Concerning the results of the main searches, the most popular search term was *Process mining AND Business process management*, that coined about 7.100 results (and a 64% decrease from the number of results *process mining* obtained). The second most popular search was for *Process mining AND Business process intelligence*, that came up with 1.230 results (and an 83% decrease from the top result, which is of course considered quite a sizable decrease). On the bottom side of the results, the least popular search was for *Process mining AND Governance, risk management & compliance*, which generated only 41 instances. In Figure 2.1 the number of results obtained are presented graphically:

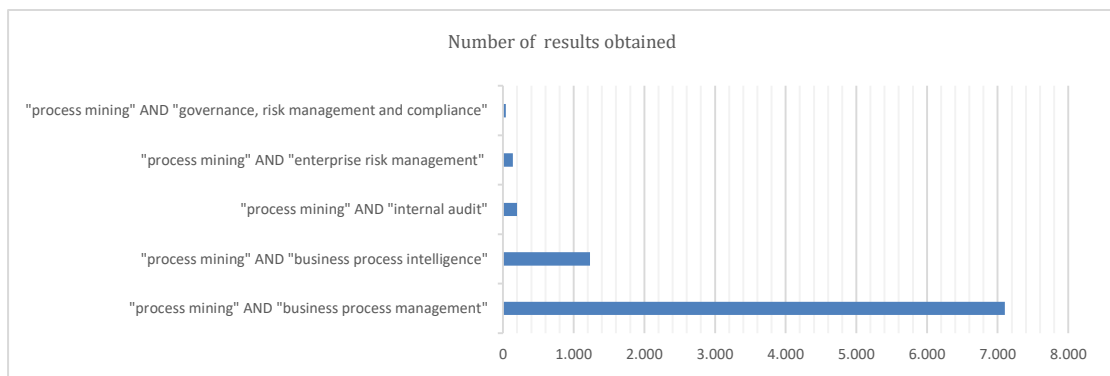


Figure 2. 1 Number of results obtained for the searches

2.4 Process Mining & Business Process Management

In Table 3.3 are depicted the top 20 (out of 7.100) articles in order of appearance in Google Scholar, their corresponding authors, their year of publication and their medium of publication:

#	Article	Authors	Year published	Referenced as	Published in
1	Business process management: A survey	Wil M. P. van der Aalst, Arthur H. M. ter Hofstede, Mathias Weske	2003	(Aalst, 2013)	International Conference on Business Process Management, BPM 2003: Business Process Management, Lecture Notes in Computer Science (LNCS)

2	Business process mining: An industrial application	W.M.P. van der Aalst, H.A. Reijers, A.J.M.M. Weijters, B.F. van Dongen, A.K. Alves de Medeiros, M. Song, H.M.W. Verbeek	2007	(Aalst et al., 2007)	Information Systems
3	Process-aware information systems: bridging people and software through process technology [BOOK]	Marlon Dumas, Wil van der Aalst, Arthur H. M. ter Hofstede	2005	(Dumas et al., 2005)	John Wiley & Sons
4	Handbook on business process management 2 [BOOK]	Jan vom Brocke, Michael Rosemann	2015	(Vom Brocke and Rosemann, 2010)	International Handbooks on Information Systems (INFOSYS)
5	The six core elements of business process management	Michael Rosemann, Jan vom Brocke	2014	(Rosemann and vom Brocke, 2015)	Handbook on Business Process Management 1, International Handbooks on Information Systems (INFOSYS)
6	Genetic process mining	W.M.P. van der Aalst, A.K. Alves de Medeiros, and A.J.M.M. Weijters	2005	(Aalst et al., 2005b)	International Conference on Application and Theory of Petri Nets, ICATPN 2005: Applications and Theory of Petri Nets 2005, Part of the Lecture Notes in Computer Science book series (LNCS, volume 3536)
7	An ontology framework for semantic business process management	Martin Hepp, Dumitru Roman	2007	(Hepp and Roman, 2007)	Proceedings of Wirtschaftsinformatik 2007
8	The ProM framework: A new era in process mining tool support	B.F. van Dongen, A.K.A. de Medeiros, H.M.W. Verbeek, A.J.M.M. Weijters, W.M.P. van der Aalst	2005	(van Dongen et al., 2005)	International Conference on Application and Theory of Petri Nets - Lecture Notes in Computer Science
9	Advances in business process management	M. Weske, W.M.P. van der Aalst, H.M.W. Verbeek	2004	(Weske et al., 2004)	Data & Knowledge Engineering
10	Business Process Management: a rigorous approach [BOOK]	Martyn A. Ould	2005	(Ould, 2006)	British Computer Society
11	Business process management (BPM) standards: a survey	Ryan K.L. Ko, Stephen S.G. Lee, Eng Wah Lee	2009	(Ko et al., 2009)	Business Process Management Journal
12	A review of business process mining: state-of-the-art and future trends	A. Tiwari, C.J. Turner, B. Majeed	2008	(Tiwari et al., 2008)	Business Process Management Journal
13	Business process analysis in healthcare environments: A methodology based on process mining	Alvaro Rebuge, Diogo R. Ferreira	2012	(Rebuge and Ferreira, 2012)	Information Systems
14	Process mining manifesto	Wil van der Aalst, Arya Adriansyah, Ana Karla Alves de Medeiros, Franco Arcieri, ThomasBaier, Tobias Blickle, Jagadeesh Chandra Bose, Peter van den Brand, Ronald Brandtjen, Joos Buijs, Andrea Burattin, Josep Carmona, Malu Castellanos, Jan Claes, Jonathan Cook, Nicola	2011	(W. M. P. Aalst et al., 2011)	International Conference on Business Process Management, Business Process Management Workshops, Lecture Notes in Business Information Processing

		Costantini, Francisco Curbera, Ernesto Damiani, Massimiliano de Leoni, Pavlos Delias, Boudewijn F. van Dongen, Marlon Dumas, Schahram Dustdar, Dirk Fahland, Diogo R. Ferreira, Walid Gaaloul, Frank van Geffen, Sukriti Goel, Christian Gunther, Antonella Guzzo, Paul Harmon, Arthur ter Hofstede, John Hoogland, Jon Espen Ingvaldsen, Koki Kato, Rudolf Kuhn, Akhil Kumar, Marcello La Rosa, Fabrizio Maggi, Donato Malerba, Ronny S. Mans, Alberto Manuel, Martin McCreesh, Paola Mello, Jan Mendling, Marco Montali, Hamid R. Motahari-Nezhad, Michael zur Muehlen, Jorge Munoz-Gama, Luigi Pontieri, Joel Ribeiro, Anne Rozinat, Hugo Seguel Perez, Ricardo Seguel Perez, Marcos Sepulveda, Jim Sinur, Prina Soffer, Minseok Song, Alessandro Sperduti, Giovanni Stilo, Casper Stoel, Keith Swenson, Maurizio Talamo, WeiTan, Chris Turner, Jan Vanthienen, George Varvaressos, Eric Verbeek, Marc Verdonk, Roberto Vigo, Jianmin Wang, Barbara Weber, Matthias Weidlich, Ton Weijters, Lijie Wen, Michael Westergaard, Moe Wyn			
15	Process mining: a research agenda	W.M.P. van der Aalst, A.J.M.M. Weijters	2004	(Aalst and Weijters, 2004)	Computers in Industry
16	Business process management: A personal view	W.M.P. van der Aalst	2004	(Aalst, 2004)	Business Process Management Journal
17	Business process management: a comprehensive survey	W.M.P. van der Aalst	2014	(Aalst, 2013)	ISRN Software Engineering
18	Semantic Business Process Management: A Lifecycle Based Requirements Analysis.	Branimir Wetzstein, Zhilei Ma, Agata Filipowska, Monika Kaczmarek, Sami Bhiri, Silvestre Losada, Jose-Manuel Lopez-Cobo, Laurent Cicurel	2007	(Wetzstein et al., 2007)	CEUR WorkShops Proceedings, Proceedings of the Workshop on Semantic Business Process and Product Lifecycle Management (SBPM)
19	An integration architecture for knowledge management systems and business process management systems	Jisoo Jung, Injun Choi, Minseok Song	2007	(Jung et al., 2007)	Computers in Industry
20	Business process intelligence	Daniela Grigori, Fabio Casati, Malu Castellanos, Umeshwar Dayal, Mehmet Sayal, Ming-Chien Shan	2004	(Grigori et al., 2004)	Computers in Industry

Table 2. 3 Top 20 articles of the Google Scholar search for “Process Mining” & “Business Process Management”

In the search conducted in Google scholar in December 2nd 2018, for the terms: “Process Mining” and “Business Process Management”, they search engine came up with 7.100 results.

In the first 20 articles (by order of appearance), there are unique 107 authors involved (once again, this large number of authors is biased, as the article “Process Mining Manifesto” is accounted with 77 authors/contributors).

As table 2.4 indicates, there is a hard core of authors that are contributing to the most relevant subsequent literature:

Times of Appearance	Authors	Contribution
10	1	50%
4	2	20%
3	4	15%
2	7	10%
1	93	5%

107

Table 2. 4 Core of authors in the search for “Process Mining” & “Business Process Management”

The fact that an author wrote or contributed in 10 out of the top 20 results (50%), indicates that, without a doubt, there is a hard core of authors that dominate the subsequent academic literature. Namely, the authors contributing in more than one article in the top 20 results of the search are shown in the table 2.5 whilst graphically, contributing authors are visualized in the pie chart 2.2

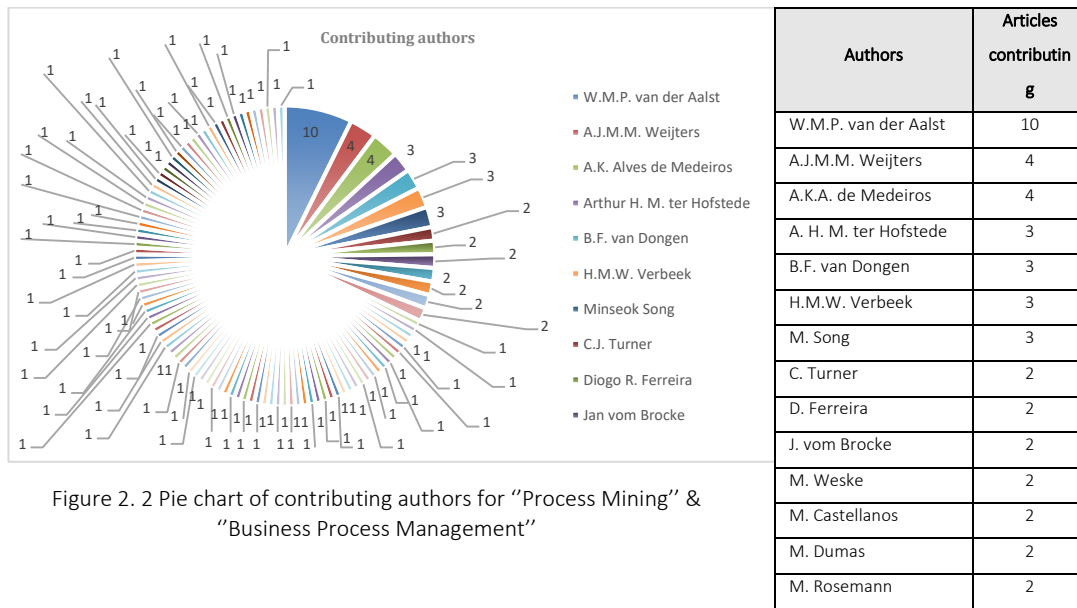


Figure 2.2 Pie chart of contributing authors for "Process Mining" & "Business Process Management"

Table 2.5 List of contributing authors for "Process Mining" & "Business Process Management"

As a next step, we present a chronological table of the top 20 articles. Starting from the year of the oldest top 20 result and moving forward, the aim is to depict the busiest years in the top 20 results.



Figure 2.3 Publications per year for 'Process Mining' & "Business Process Management"

Table 2.6 List of publications per year for 'Process Mining' & "Business Process Management"

From the table above, the most reputed publications in the field of process mining and business process intelligence happened between 2004 – 2005 and 2007 and ever since follows a declining tendency. A line chart of the table above is also presented.

In Table 2.7 are presented the media of publication for the top 20 results of the search.

Medium of publication	Times appeared	Type of publication
Business Process Management Journal	3	Journal
Computers in Industry	3	Journal
Handbook on Business Process Management, International Handbooks on Information Systems (INFOSYS)	2	Journal
Information Systems	2	Journal
CEUR WorkShops Proceedings, Proceedings of the Workshop on Semantic Business Process and Product Lifecycle Management (SBPM)	1	Conference
International Conference on Business Process Management, BPM 2003: Business Process Management, Lecture Notes in Computer Science (LNCS)	1	Conference
British Computer Society	1	Journal
Data & Knowledge Engineering	1	Journal
International Conference on Application and Theory of Petri Nets - Lecture Notes in Computer Science	1	Conference
International Conference on Application and Theory of Petri Nets, ICATPN 2005: Applications and Theory of Petri Nets 2005, Part of the Lecture Notes in Computer Science book series (LNCS, volume 3536)	1	Conference
International Conference on Business Process Management, Business Process Management Workshops, Lecture Notes in Business Information Processing	1	Conference
ISRN Software Engineering	1	Journal
John Wiley & Sons (Book)	1	Book
Proceedings of Wirtschaftsinformatik 2007	1	Conference

Table 2. 7 Media of publication for the top 20 results of the search for ‘Process Mining’ & ‘Business Process Management’

We notice that the most popular media are journals and specifically: a) Business Process Management Journal, b) Computers in Industry, c) Handbook on Business Process Management, d) International Handbooks on Information Systems (INFOSYS) and e) Information Systems journals.

2.5 Process Mining & Business Process Intelligence

In the following table are depicted the top 20 (out of 1.230) articles in order of appearance in Google Scholar, their corresponding authors, their year of publication and their medium of publication:

#	Articles	Authors	Year published	Referenced as	Published in
1	Business process intelligence	Daniela Grigori, Fabio Casati, Malu Castellanos, Umeshwar Dayal, Mehmet Sayal, Ming-Chien Shan	2004	(Grigori et al., 2004)	Computers in Industry
2	Business process mining: An industrial application	W.M.P. van der Aalst, H.A. Reijers, A.J.M.M. Weijters, B.F. van Dongen, A.K. Alves de Medeiros, M. Song, H.M.W. Verbeek	2007	(Aalst et al., 2007)	Information Systems
3	The ProM framework: A new era in process mining tool support	B.F. van Dongen, A.K.A. de Medeiros, H.M.W. Verbeek, A.J.M.M. Weijters, W.M.P. van der Aalst	2005	(van Dongen et al., 2005)	International Conference on Application and Theory of Petri Nets - Lecture Notes in Computer Science
4	Process mining manifesto	Wil van der Aalst, Arya Adriansyah, Ana Karla Alves de Medeiros, Franco Arcieri, ThomasBaier, Tobias Blickle, Jagadeesh Chandra Bose, Peter van den Brand, Ronald Brandtjen, Joos Buijs, Andrea Burattin, Josep Carmona, Malu Castellanos, Jan Claes, Jonathan Cook, Nicola Costantini, Francisco Curbera, Ernesto Damiani, Massimiliano de Leoni, Pavlos Delias, Boudewijn F. van Dongen, Marlon Dumas, Schahram Dustdar, Dirk Fahland, Diogo R. Ferreira, Walid Gaaloul, Frank van Geffen, Sukriti Goel, Christian Gunther, Antonella Guzzo, Paul Harmon, Arthur ter Hofstede, John Hoogland, Jon Espen Ingvaldsen, Koki Kato, Rudolf Kuhn, Akhil Kumar, Marcello La Rosa, Fabrizio Maggi, Donato Malerba, Ronny S. Mans, Alberto Manuel, Martin McCreesh, Paola Mello, Jan Mendling, Marco Montali, Hamid R. Motahari-Nezhad, Michael zur Muehlen, Jorge Munoz-Gama, Luigi Pontieri, Joel Ribeiro, Anne Rozinat, Hugo Seguel Perez, Ricardo Seguel Perez, Marcos Sepulveda, Jim Sinur, Pnina Soffer, Minseok Song, Alessandro Sperduti, Giovanni Stilo, Casper Stoel, Keith Swenson, Maurizio Talamo, WeiTan, Chris Turner, Jan Vanthienen, George Varvaessos, Eric Verbeek, Marc Verdonk, Roberto Vigo, Jianmin Wang, Barbara Weber, Matthias Weidlich, Ton Weijters, Lijie Wen, Michael Westergaard, Moe Wyn	2011	(W. M. P. Aalst et al., 2011)	International Conference on Business Process Management, Business Process Management Workshops, Lecture Notes in Business Information Processing
5	Business process intelligence (book chapter)	M. Castellanos, A. K. Alves de Medeiros, J. Mendling, B. Weber, A. J. M. M. Weijters	2009	(Castellanos et al., 2009)	Handbook of Research on Business Process Modeling [book] - Jorge Cardoso, Wil van der Aalst (Eds.)
6	Process mining: a research agenda	W.M.P. van der Aalst, A.J.M.M. Weijters	2004	(Aalst and Weijters, 2004)	Computers in Industry
7	Decision mining in ProM	A. Rozinat, W.M.P. van der Aalst	2006	(Rozinat and van der Aalst, 2006)	International Conference on Business Process Management, BPM 2006:

					Business Process Management, Lecture Notes in Computer Science book series
8	An outlook on semantic business process mining and monitoring	A. K. Alves de Medeiros, C. Pedrinaci, W. M. P. van der Aalst, J. Domingue, M. Song, A. Rozinat, B. Norton, L. Cabral	2007	(De Medeiros et al., 2007)	OTM Confederated International Conferences "On the Move to Meaningful Internet Systems", OTM 2007: On the Move to Meaningful Internet Systems 2007: OTM 2007 Workshops
9	Business process analysis in healthcare environments: A methodology based on process mining	Alvaro Rebugue, Diogo R. Ferreira	2012	(Rebugue and Ferreira, 2012)	Information Systems
10	Prom 6: The process mining toolkit	H.M.W. Verbeek, J.C.A.M. Buijs, B.F. van Dongen, W.M.P. van der Aalst	2010	(Verbeek et al., 2010)	Proceedings of the Business Process Management 2010 Demonstration Track
11	Process mining and verification of properties: An approach based on temporal logic	W.M.P. van der Aalst, H.T. de Beer, B.F. van Dongen	2005	(Aalst et al., 2005a)	OTM (OnTheMove) Confederated International Conferences "On the Move to Meaningful Internet Systems" 2005: CoopIS, DOA, and ODBASE - Lecture Notes in Computer Science book series
12	Workflow mining: Discovering process models from event logs	W.M.P. van der Aalst, A.J.M.M. Weijters, L. Maruster	2004	(Aalst et al., 2004)	IEEE Transactions on Knowledge and Data Engineering
13	Conformance testing: Measuring the fit and appropriateness of event logs and process models	A. Rozinat, W. M. P. van der Aalst	2005	(Rozinat and Van der Aalst, 2005)	International Conference on Business Process Management, BPM 2005: Business Process Management Workshops, Lecture Notes in Computer Science (LNCS)
14	The need for a process mining evaluation framework in research and practice	Anne Rozinat, Ana Karla Alves de Medeiros, Christian W. Günther, A. J. M. M. Weijters, Wil M. P. van der Aalst	2007	(Rozinat et al., 2007)	International Conference on Business Process Management, BPM 2007: Business Process Management Workshops, Lecture Notes in Computer Science (LNCS)
15	Business process analytics	Michael zur Mühlen, Robert Shapiro	2010	(zur Muehlen and Shapiro, 2010)	Handbook on Business Process Management 2, International Handbooks on Information Systems (INFOSYS)
16	Semantic process mining tools: Core building blocks	A.K. Alves de Medeiros, W.M.P. van der Aalst, Carlos Pedrinaci	2008	(de Medeiros et al., 2008)	European Conference on Information Systems (ECIS) Proceedings
17	A Meta Model for Process Mining Data	B.F. van Dongen, W.M.P. van der Aalst	2005	(van Dongen and Van der Aalst, 2005)	EMOI - INTEROP, Enterprise Modelling and Ontologies for

					Interoperability, Proceedings of the Open Interop Workshop on Enterprise Modelling and Ontologies for Interoperability, Co-located with CAISE Conference (Proceedings of the CAISE - CEUR WORKSHOPS)
18	Process Mining for the multi-faceted analysis of business processes—A case study in a financial services organization	Jochen De Weerd, Annelies Schupp, An Vanderloock, Bart Baesens	2013	(De Weerd et al., 2013)	Computers in Industry
19	Model-based business process mining	Jon Espen Ingvaldsen, Jon Atle Gulla	2006	(Bringsv\la erd, 2006)	Information Systems Management
20	Dimensions of business process intelligence	Markus Linden, Carsten Felden, Peter Chamoni	2010	(Linden et al., 2010)	International Conference on Business Process Management, BPM 2010: Business Process Management Workshops, Lecture Notes in Computer Science (LNCS)

Table 2. 8 Top 20 articles of the Google Scholar search for “Process Mining” & “Business Process Intelligence”

In the search conducted in Google scholar in December 2nd 2018, for the terms: “Process Mining” and “Business Process Intelligence”, they search engine came up with 1.230 results.

In the first 20 articles (by order of appearance), there are unique 103 authors involved (although this number of authors is biased, as the article “Process Mining Manifesto” is accounted with 77 authors/contributors). As the next table indicates, there is a hard core of authors that are contributing to the most relevant subsequent literature:

Times of Appearance	Number of Authors	Contribution
13	1	65%
7	1	35%
6	1	30%
5	2	25%
3	3	15%
2	6	10%
1	89	5%
Total	103	

Table 2. 9 Core of authors in the search for “Process Mining” & “Business Process Intelligence”

The fact that an author is contributing to 13 out of the top 20 results (65%), indicates that, in accordance with the previous search, there is also present a hard core of authors in the subsequent academic literature. Namely, the authors contributing in more than one article in the top 20 results of the search are shown in the following table:

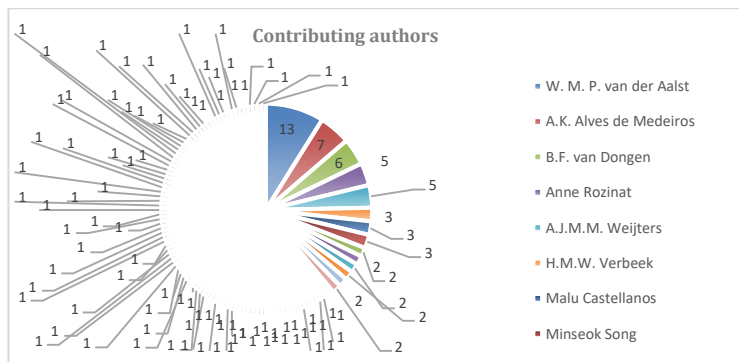


Figure 2. 4 Pie chart of contributing authors for "Process Mining" & "Business Process Intelligence"

Authors	Articles contributing
W. M. P. van der Aalst	13
A.K.A. de Medeiros	7
B.F. van Dongen	6
A. Rozinat	5
A.J.M.M. Weijters	5
H.M.W. Verbeek	3
M. Castellanos	3
M. Song	3
B. Weber	2
C. Pedrinaci	2
C. Gunther	2
D. Ferreira	2
J. Ingvaldsen	2
M. zur Muehlen	2

Table 2. 10 List of contributing authors for "Process Mining" & "Business Process Intelligence"

Next, the chronological table of the top 20 articles is presented. Starting from the year of the oldest top 20 result and moving forward, the aim is to depict the busiest years in the top 20 results.

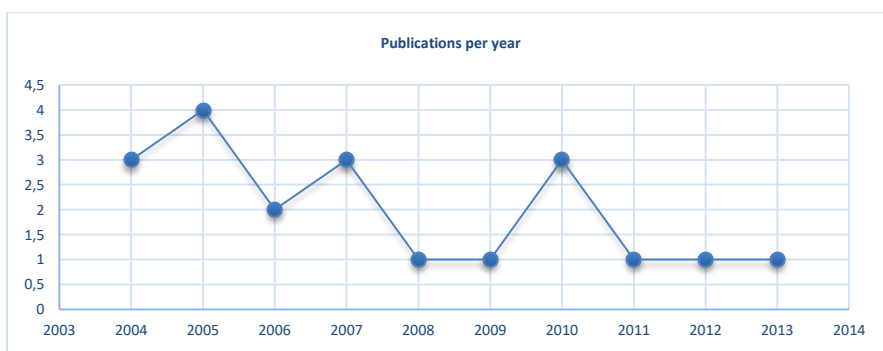


Figure 2. 5 Publications per year for 'Process Mining' & 'Business Process Intelligence'

Year	Publications
2004	3
2005	4
2006	2
2007	3
2008	1
2009	1
2010	3
2011	1
2012	1
2013	1

Table 2. 11 List of publications per year for 'Process Mining' & 'Business Process Intelligence'

From the table above, the most reputed publications in the field of process mining and business process intelligence happened between 2004 – 2007 and ever since follows a declining tendency. A line chart of the table above is also presented.

In Table 2.12 are presented the media of publication for the top 20 results of the search.

Medium of publication	Times appeared	Type of publication
International Conference on Business Process Management, Business Process Management Workshops	5	Conference
Computers in Industry	3	Journal
Information Systems	2	Journal
OTM (OnTheMove Confederated International Conferences "On the Move to Meaningful Internet Systems"	2	Conference
EMOI - INTEROP, Enterprise Modelling and Ontologies for Interoperability, Proceedings	1	Conference
European Conference on Information Systems (ECIS) Proceedings	1	Conference
Information Science Reference (Book)	1	Journal
Handbook on Business Process Management, International Handbooks on Information Systems (INFOSYS)	1	Journal
IEEE Transactions on Knowledge and Data Engineering	1	Journal
Information Systems Management	1	Journal
International Conference on Application and Theory of Petri Nets - Lecture Notes in Computer Science	1	Conference
Proceedings of the Business Process Management Demonstration Track	1	Conference

20

Table 2. 12 Media of publication for the top 20 results of the search for 'Process Mining' & 'Business Process Intelligence'

We notice that the most popular medium is the International Conference on Business Process Management, Business Process Management Workshops, followed by the a) Computers in Industry and b) Information Systems journals.

2.6 Process Mining & Internal Audit

In the following table are depicted the top 20 (out of 200) articles in order of appearance in Google Scholar, their corresponding authors, their year of publication and their medium of publication:

#	Article	Authors	Year published	Referenced as	Published in
1	On the exploitation of process mining for security audits: the conformance checking case	Rafael Accorsi, Thomas Stocker	2012	(Accorsi and Stocker, 2012)	Proceedings of the 27th Annual ACM Symposium on Applied Computing
2	Business process mining for internal fraud risk reduction: results of a case study	Mieke Jans, Nadine Lybaert, Koen Vanhoof	2010	(Jans et al., n.d.)	Hasselt University Research Paper
3	Process mining of event logs in internal auditing: a case study	Mieke Jans, Michael Alles, Miklos Vasarhelyi	2012	(Jans et al., 2012)	European Accounting Association - 35th Annual Congress
4	The case for process mining in auditing: Sources of value added and areas of application	Mieke Jans, Michael Alles, Miklos Vasarhelyi	2013	(Jans et al., 2013)	International Journal of Accounting Information Systems
5	A field study on the use of process mining of event logs as an analytical procedure in auditing	Mieke Jans, Michael G. Alles, Miklos A. Vasarhelyi	2014	(Jans et al., 2014)	The Accounting Review
6	Comprehensive rule-based compliance checking and risk management with process mining	Filip Caron, Jan Vanthienen, Bart Baesens	2013	(Caron et al., 2013a)	Decision Support Systems
7	Does process mining add to internal auditing? an experience report	Mieke Jans, Benoit Depaire, Koen Vanhoof	2011	(Jans et al., 2011a)	Lecture Notes in Business Information Processing book series (LNBIIP), International Workshop on Business Process Modeling, Development and Support, International Conference on Exploring Modeling Methods for Systems Analysis and Design, BPMDS 2011, EMMSAD 2011: Enterprise, Business-Process and Information Systems Modeling
8	Method of identifying and analyzing business processes from workflow audit logs (Hewlett-Packard Development Co LP patent)	Fabio Casati, Ming-Chien Shan, Li-Jie Jin, Umeshwar Dayal, Daniela Grigori, Angela Bonifati	2002	(Casati et al., 2002)	United States, Patent Application Publication

9	Business compliance governance in service-oriented architectures	Florian Daniel, Fabio Casati, Vincenzo D'Andrea, Emmanuel Mulo, Uwe Zdun, Schahram Dustdar, Steve Strauch, David Schumm, Frank Leymann, Samir Sebahi, Fabien de Marchi, Mohand-Said Hacid	2009	(Daniel et al., 2009)	International Conference on Advanced Information Networking and Applications
10	The remote audit	Ryan A. Teeter, Michael G. Alles, Miklos A. Vasarhelyi	2010	(Teeter et al., 2010)	Journal of Emerging Technologies in Accounting
11	AIS in an age of Big Data	Kevin C. Moffitt, Miklos A. Vasarhelyi	2013	(Moffitt and Vasarhelyi, 2013)	Journal of Information Systems
12	A framework for internal fraud risk reduction at IT integrating business processes: the IFR ² framework	Mieke Jans, Nadine Lybaert, Koen Vanhoof	2009	(M. Jans et al., 2010)	The International Journal of Digital Accounting Research
13	Accounting information systems: Tradition and future directions	Fernando Belfo, António Trigo	2013	(Belfo and Trigo, 2013)	Procedia Technology (CENTERIS 2013 - Conference on ENTERprise Information Systems / PROJMAN 2013 - International Conference on Project MANagement / HCIST 2013 - International Conference on Health and Social Care Information Systems and Technologies)
14	Data mining for fraud detection: Toward an improvement on internal control systems?	Mieke Julie Jans, Nadine Lybaert, Koen Vanhoof	2007	(Jans et al., 2007)	European Accounting Association - Annual Congress
15	The reliance of external auditors on internal audit's use of continuous audit	Irina Malaescu, Steve G. Sutton	2014	(Malaescu and Sutton, 2014)	Journal of Information Systems
16	Conceptual model for online auditing	Wil van der Aalst, Kees van Hee, Jan Martijn van der Werf, Akhil Kumar, Marc Verdonk	2011	(W. M. P. van der Aalst et al., 2011)	Decision Support Systems
17	Exploring features of a full-coverage integrated solution for business process compliance	Cristina Cabanillas, Manuel Resinas, Antonio Ruiz-Cortes	2011	(Cabanillas et al., 2011)	Lecture Notes in Business Information Processing (LNBIP), International Conference on Advanced Information Systems Engineering, CAISE 2011: Advanced Information Systems Engineering Workshops
18	Continuous auditing and continuous monitoring in ERP environments: Case studies of application implementations	Kishore Singh, Peter J. Best, Mario Bojilov, Catherine Blunt	2014	(Singh et al., 2013)	Journal of Information Systems
19	Trust is good, control is better: Creating secure clouds by continuous auditing	Sebastian Lins, Stephan Schneider, Ali Sunyaev	2018	(Lins et al., 2018)	IEEE Transactions on Cloud Computing
20	Key Information Requirements for Process Audits-an Expert Perspective.	M. Schultz, N. Mueller-Wickop, M. Nuettgens	2012	(Schultz et al., 2012)	EMISA – Der Mensch im Zentrum der Modellierung

Table 2. 13 Top 20 articles of the Google Scholar search for “Process Mining” & ‘Internal Audit’

In the search conducted in Google scholar in December 2nd 2018, for the terms: “Process Mining” and “Internal Audit”, they search engine came up with 200 results. In the first 20 articles (by order of appearance), there are unique 52 authors involved.

As the next table indicates, there is a hard core of authors that are contributing to the most relevant subsequent literature:

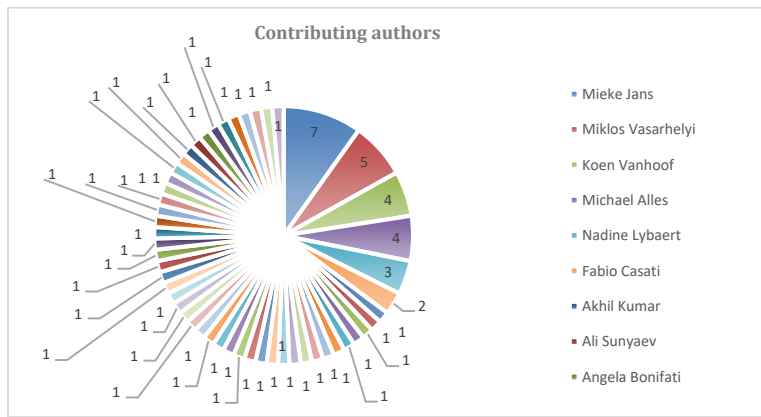
Times of Appearance	Authors	Contribution
7	1	35%
5	1	25%
4	2	20%
3	1	15%
2	1	10%
1	46	5%

52

Table 2. 14 Core of authors in the search for “Process Mining” & ‘Internal Audit’

In comparison with the findings of the first searches, it is safe to say that the previously seen hard core of authors is diminishing.

Namely, the authors contributing in more than one article in the top 20 results of the search are shown in the following table 2.15 and graphically, contributing authors are visualized in pie chart 2.6



Authors	Articles contributing
M. Jans	7
M. Vasarhelyi	5
K. Vanhoof	4
M. Alles	4
N. Lybaert	3
F. Casati	2

Table 2. 15 List of contributing authors for "Process Mining" & "Internal Audit"

Figure 2. 6 Pie chart of contributing authors for "Process Mining" & "Internal Audit"

Next, the chronological table of the top 20 articles is presented. Starting from the year of the oldest top 20 result and moving forward, the aim is to depict the busiest years in the top 20 results.



Year	Publications
2002	1
2003	0
2004	0
2005	0
2006	0
2007	1
2008	0
2009	2
2010	2
2011	3
2012	3
2013	4
2014	3
2015	0
2016	0
2017	0
2018	1

Figure 2. 7 Publications per year for "Process Mining" & "Internal Audit"

Table 2. 16 List of publications per year for "Process Mining" & "Internal Audit"

From the table above, the most reputed publications in the field of process mining and business process intelligence happened between 2009 – 2014, and ever since follows a declining tendency.

In Table 2.17 are presented the media of publication for the top 20 results of the search.

Medium of publication	Times appeared	Type of publication
Journal of Information Systems	3	Journal
Decision Support Systems	2	Journal
European Accounting Association - Annual Congress	2	Conference
EMISA – Der Mensch im Zentrum der Modellierung	1	Journal
IEEE Transactions on Cloud Computing	1	Journal
International Conference on Advanced Information Networking and Applications	1	Conference
International Journal of Accounting Information Systems	1	Journal
Journal of Emerging Technologies in Accounting	1	Journal
International Conference on Advanced Information Systems Engineering, CAISE	1	Conference
International Workshop on Business Process Modeling, Development and Support, International Conference on Exploring Modeling Methods for Systems Analysis and Design	1	Conference
CENTERIS - Conference on ENTERprise Information Systems	1	Conference
Proceedings of the 27th Annual ACM Symposium on Applied Computing	1	Conference
The Accounting Review	1	Journal
The International Journal of Digital Accounting Research	1	Journal
United States, Patent Application Publication	1	Patent Application Publication
Hasselt University Research Paper	1	University Research Paper

Table 2. 17 Media of publication for the top 20 results of the search for ‘Process Mining’ & ‘Internal Audit’

We notice that the most popular medium is the Journal of Information Systems, followed by the a) Decision Support Systems journal and b) the proceedings of the Annual Congress of the European Accounting Association.

2.7 Process Mining & Enterprise Risk Management

In the following table are depicted the top 20 (out of 140) articles in order of appearance in Google Scholar, their corresponding authors, their year of publication and their medium of publication:

#	Article	Authors	Year published	Referenced as	Published in
1	A comprehensive investigation of the applicability of process mining techniques for enterprise risk management	Filip Caron, Jan Vanthienen, Bart Baesens	2013	(Caron et al., 2013b)	Computers in Industry
2	Decision making in enterprise risk management: A review and introduction to special issue	Desheng Wu, David L. Olson, Alexandre Dolgui	2015	(Wu et al., 2015)	Omega

3	Enterprise risk management [BOOK]	David L. Olson, Desheng Dash Wu	2015	(Olson and Wu, 2015)	World Scientific Publishing Company
4	Comprehensive rule-based compliance checking and risk management with process mining	Filip Caron, Jan Vanthienen, Bart Baesens	2013	(Caron et al., 2013a)	Decision Support Systems
5	Basic Principles of Financial Process Mining A Journey through Financial Data in Accounting Information Systems.	Nick Gherkin, Niels Mueller-Wickop	2010	(Gehrke and Mueller-Wickop, 2010)	Americas Conference on Information Systems (Proceedings)
6	Business process mining for internal fraud risk reduction: results of a case study	Mieke Jans, Nadine Lybaert, Koen Vanhoof	2010	(Jans et al., n.d.)	working paper
7	Accounting information systems: Tradition and future directions	Fernando Belfo, António Trigo	2013	(Belfo and Trigo, 2013)	Procedia Technology (CENTERIS 2013 - Conference on ENTERprise Information Systems / PROJMAN 2013 - International Conference on Project MANagement / HCIST 2013 - International Conference on Health and Social Care Information Systems and Technologies)
8	Current research in risk-aware business process management: overview, comparison, and gap analysis	Suriadi Suriadi, Burkhard Weiß, Axel Winkelmann, Arthur H.M. ter Hofstede, Michael Adams, Raffaele Conforti, Colin Fidge, Marcello La Rosa, Chun Ouyang, Anastasiia Pika, Michael Rosemann, Moe Wynn	2014	(Suriadi et al., 2014)	Communications of the Association for Information Systems
9	Integrated enterprise risk management: From process to best practice	Kathryn Cormican	2014	(Cormican, 2014)	Modern Economy
10	Data mining models and enterprise risk management	David L. Olson, Desheng Dash Wu	2017	(Olson and Wu, 2017)	Enterprise Risk Management Models - Springer Texts in Business and Economics
11	Enforcing compliance on business processes through the use of patterns	Oktay Turetken, Amal Elgammal, Willem-Jan van den Heuvel, Mike Papazoglou	2011	(Turetken et al., 2011)	European Conference on Information Systems (Proceedings)
12	IT risk management framework and methods (ORACLE INC. AMERICA PATEND)	Jefre Futch, Andrew Gonczi, Roberta Mason, Ingrid Stuckenberg	2007	(Futch et al., 2007)	United States, Patent Application Publication
13	Profiling event logs to configure risk indicators for process delays	Anastasiia Pika, Wil M. P. van der Aalst, Colin J. Fidge, Arthur H. M. ter Hofstede, Moe T. Wynn	2013	(Pika et al., 2013)	25th International Conference on Advanced Information Systems Engineering (proceedings)
14	Accounting information systems: The challenge of the real-time reporting	António Trigo, Fernando Belfo, Raquel Pérez Estébanez	2013	(Trigo et al., 2014)	Procedia Technology (CENTERIS 2013 - Conference on ENTERprise Information Systems / PROJMAN 2013 - International Conference on Project MANagement / HCIST 2013 - International Conference on Health and

					Social Care Information Systems and Technologies)
15	Aggregating risk in an enterprise strategy and performance management system (SAP SE PATENT)	Karol Bliznak	2009	(Bliznak, 2009)	United States, Patent Application Publication
16	Integrated and personalized risk management in the sensing enterprise	-not relevant -			
17	Rule-based business process mining: Applications for management	Filip Caron, Jan Vanthienen, Bart Baesens	2012	(Caron et al., 2012a)	Management Intelligent Systems - Advances in Intelligent Systems and Computing Series
18	Method and apparatus for enterprise risk management (Core Systems Group LLC Patent)	Andrew M. Tait, Daniel E. Garlewicz	2012	(Tait and Garlewicz, 2012)	United States, Patent Application Publication
19	System and method for operational risk assessment and control (Bank of America Corp Patent)	Jennifer B. Owens, Jacob Firestone, Edward T. Hawthorne, Joseph L Valasquez, David Hadd, Bradley A. Yee	2009	(Owens et al., 2009)	United States, Patent Application Publication
20	Risk Management in Manufacturing SMEs in South Africa	-not relevant-			

Table 2. 18 Top 20 articles of the Google Scholar search for “Process Mining” & ‘Enterprise Risk Management’

In the search conducted in Google scholar in December 2nd 2018, for the terms: “Process Mining” and “Enterprise Risk Management”, the search engine came up with 140 results.

Two of the articles are classified as irrelevant, and in the remaining 18 articles (by order of appearance), there are unique 45 authors involved. As the next table indicates, there is a hard core of authors that are contributing to the most relevant subsequent literature:

Times of Appearance	Authors	Contribution
3	5	17%
2	6	11%
1	34	6%

45

Table 2. 19 Core of authors in the search for “Process Mining” & ‘Enterprise Risk Management’

In comparison with the findings of the first searches, it is safe to say that a hard core of popular authors no longer exists, as the five most popular authors contribute to 3 articles.

Namely, the authors contributing in more than one article in the top 18 results of the search are shown in the table 2.20 and graphically, contributing authors are visualized in pie chart 2.8.

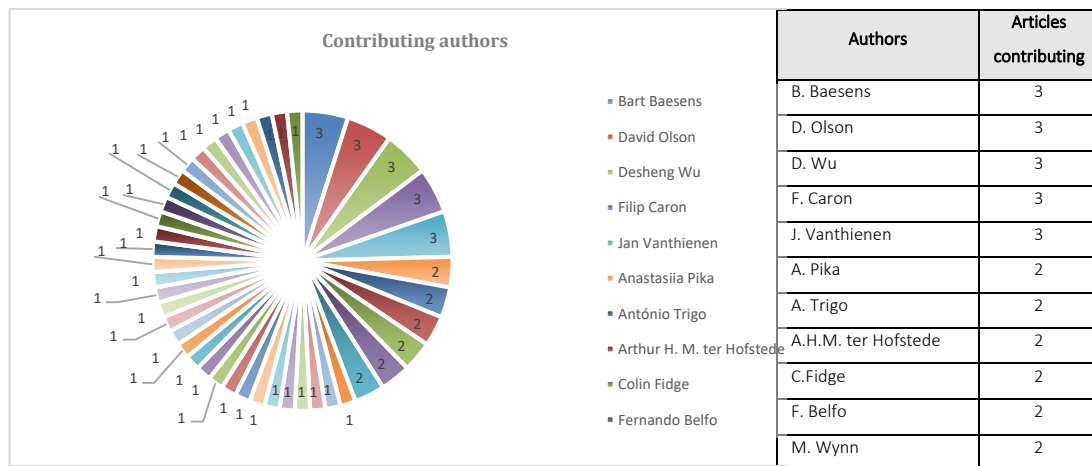


Figure 2. 8 Pie chart of contributing authors for “Process Mining” & “Enterprise Risk Management”

Table 2. 20 List of contributing authors for “Process Mining” & “Enterprise Risk Management”

Next, the chronological table of the top 20 articles is presented. Starting from the year of the oldest top 20 result and moving forward, the aim is to depict the busiest years in the top 20 results. As table 2.21 indicates, the most reputed publications in the field of process mining and business process intelligence happened between 2009 – 2015, and ever since follows a declining tendency. A line chart of the table above is presented below:

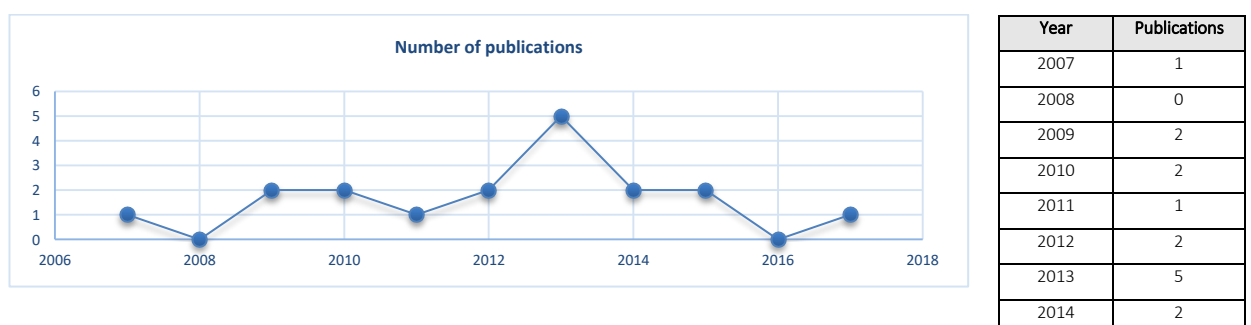


Figure 2. 9 Publications per year for 'Process Mining' & "Enterprise Risk Management"

2015	2
2016	0
2017	1

Table 2. 21 List of publications per year for 'Process Mining' & "Enterprise Risk Management"

In Table 2.22 are presented the media of publication for the top 20 results of the search.

Medium of publication	Times appeared	Type of publication
United States, Patent Application Publication	4	Patent Application Publication
CENTERIS - Conference on ENTERprise Information Systems	2	Conference
International Conference on Advanced Information Systems Engineering (proceedings)	1	Conference
Americas Conference on Information Systems (Proceedings)	1	Conference
Communications of the Association for Information Systems	1	Journal
Computers in Industry	1	Journal
Decision Support Systems	1	Journal
Enterprise Risk Management Models - Springer Texts in Business and Economics	1	Book
European Conference on Information Systems (Proceedings)	1	Conference
Management Intelligent Systems - Advances in Intelligent Systems and Computing Series	1	Journal
Modern Economy	1	Journal
Omega	1	Journal
Hasselt University Research Paper	1	University Research Paper
World Scientific Publishing Company	1	Book

18

Table 2. 22 Media of publication for the top 20 results of the search for 'Process Mining' & "Enterprise Risk Management"

We notice that the most popular medium is the United States, Patent Application Publication. That fact alone is of great importance as it depicts the impact of process mining to Enterprise Risk Management in an industrial level, as the patents are held by corporations such as SAP SE, Oracle Inc., Core Systems Group and Bank of America Corp.

2.8 Process Mining & Governance, Risk Management and Compliance

In the following table are depicted the top 20 (out of 41) articles in order of appearance in Google Scholar, their corresponding authors, their year of publication and their medium of publication:

#	Article	Authors	Year published	Referenced as	Published in
1	Managing regulatory compliance in business processes	Shazia Sadiq, Guido Governatori	2010	(Sadiq and Governatori, 2015)	Handbook on Business Process Management 2, Strategic Alignment, Governance, People and Culture - International Handbooks on Information Systems
2	A methodological framework for aligning business processes and regulatory compliance	Shazia Sadiq, Guido Governatori	2010	(Sadiq and Governatori, 2009)	Handbook on Business Process Management 2, Strategic Alignment, Governance, People and Culture - International Handbooks on Information Systems
3	Managing regulatory compliance in business processes	Shazia Sadiq, Guido Governatori	2010	(Sadiq and Governatori, 2015)	Handbook on Business Process Management 2, Strategic Alignment, Governance, People and Culture - International Handbooks on Information Systems
4	Formalizing and applying compliance patterns for business process compliance	Amal Elgammal, Oktay Turetken, Willem-Jan van den Heuvel, Mike Papazoglou	2016	(Elgammal et al., 2016)	Software & Systems Modeling
5	System and Method for Governance, Risk, and Compliance Management (CA Inc. - Computer Associates Think Inc. PATENT)	Mark L. Moerdler, Christopher S. Boswell, Galina Datskovsky, Murali Swaminathan, Bryan R. Diebold, Ying Ding, John D. Benton, Thomas J. McHale, Michael W. Stricklen	2009	(Moerdler et al., 2009)	United States, Patent Application Publication
6	Process mining: data science in action [BOOK]	W. M. P. van der Aalst	2016	(Aalst, 2016)	Springer
7	System and method for operational risk assessment and control (Bank of America Corp Patent)	Jennifer B. Owens, Jacob Firestone, Edward T. Hawthorne, Joseph L. Valasquez, David Hadd, Bradley A. Yee	2009	(Owens et al., 2009)	United States, Patent Application Publication
8	System and Method for Governance, Risk, and Compliance Management (CA Inc. - Computer Associates Think Inc. PATENT)	Mark L. Moerdler, Christopher S. Boswell, Galina Datskovsky, Murali Swaminathan, Bryan R. Diebold, Ying Ding, John D. Benton,	2009	(Moerdler et al., 2009)	United States, Patent Application Publication

		Thomas J. McHale, Michael W. Stricklen			
9	Enterprise operational analysis using DEMO and the enterprise operating system	Emmy Dudok, Sérgio Guerreiro, Eduard Babkin, Robert Pergl, Steven J.H. van Kervel	2015	(Dudok et al., 2015)	Enterprise Engineering Working Conference - Advances in Enterprise Engineering IX
10	System and method for operational risk assessment and control (Bank of America Corp Patent)	Jennifer B. Owens, Jacob Firestone, Edward T. Hawthorne, Joseph L Valasquez, David Hadd, Bradley A. Yee	2009	(Owens et al., 2009) (Zeng et al., 2012)	United States, Patent Application Publication
11	Automatic event management for regulation compliance (SAP AG Patent)	Ying Zeng, Atul Sudhalkar, Petr Stastny, Prathap Sakala	2012	(Zeng et al., 2012)	United States, Patent Application Publication
12	A comprehensive framework for the application of process mining in risk management and compliance checking	Filip Caron, Jan Vanthienen, Bart Baesens	2012	(Caron et al., 2012b)	SSRN Electronic Journal - KU Leuven Faculty of Business and Economics KBI 1226
13	From Detecting Deviations to Preventing Shocks: The Value of IT for Management Controls	Manuel Wiesche, Michael Schermann, Helmut Krcmar	2013	(Wiesche et al., 2013)	JMAR (Journal of Management Accounting Research) Research Conference in conjunction with 2012 Management Accounting Section Research and Case Conference - Proceedings
14	Complexity is dead, long live complexity! How software can help service providers manage security and compliance	Stefan Thalmann, Daniel Bachlechner, Lukas Demetz, Markus Manhart	2014	(Thalmann et al., 2014)	Computers & Security
15	Auditing service providers: supporting auditors in cross-organizational settings	Daniel Bachlechner, Stefan Thalmann, Markus Manhart	2014	(Bachlechner et al., 2014)	Managerial Auditing Journal
16	BIM-based approach to Building Operating Management: a Strategic Lever to achieve Efficiency, Risk-shifting, Innovation and Sustainability.	Vittorio Cesarotti, Miriam Benedetti, Federico Dibisceglia, Daniele Di Fausto, Vito Introna, Giovanni La Bella, Nicola Martinelli, Monica Ricci, Caterina Spada, Massimo Varani	2014	(Cesarotti et al., 2014)	XVIII INTERNATIONAL RESEARCH SOCIETY FOR PUBLIC MANAGEMENT (IRSPM) CONFERENCE 2014
17	Process mining: The missing link	W.M.P. van der Aalst	2016	(Aalst, 2016)	Book chapter of process Mining: Data Science in Action
18	IT Auditing for Modern Technology Management	Charles H. Le Grand	2013	(Le Grand, 2013)	EDPACS - The EDP Audit, Control, and Security Newsletter
19	Addressing the C-Level Question: How Effectively are Assurance Functions Contributing and Using Automated Analytics?	Michael P. Cangemi	2017	(Cangemi, 2017)	EDPACS - The EDP Audit, Control, and Security Newsletter
20	A tool for mining and checking processes	L. Canensi	2014	(Canensi, n.d.)	The ICCBR 2014 Doctoral Consortium

Table 2. 23 Top 20 articles of the Google Scholar search for “Process Mining” & ‘Governance, Risk Management and Compliance’

In the search conducted in Google scholar in December 2nd 2018, for the terms: “Process Mining” and “Governance, Risk Management and Compliance”, the search engine came up with 41 results. In the top 20 articles there are unique 54 authors involved. As the next table indicates, there is an absence of a hard core of authors, as the most popular authors contribute in just 15% of the top 20 articles:

Times of Appearance	Authors	Contribution
3	2	15%
2	19	10%
1	33	5%
54		

Table 2. 24 Core of authors in the search for “Process Mining” & ‘Governance, Risk Management and Compliance’

In comparison with the findings of the first searches, it is safe to say that a hard core of popular authors no longer exists, since the two most popular authors contribute to 3 articles each. Continuing, 19 authors contribute to 2 articles each, and 33 authors are contributing to only 1 article.

Namely, the authors contributing in more than one article in the top 18 results of the search are shown in the following table. Also graphically, contributing authors are visualized in the following pie chart.

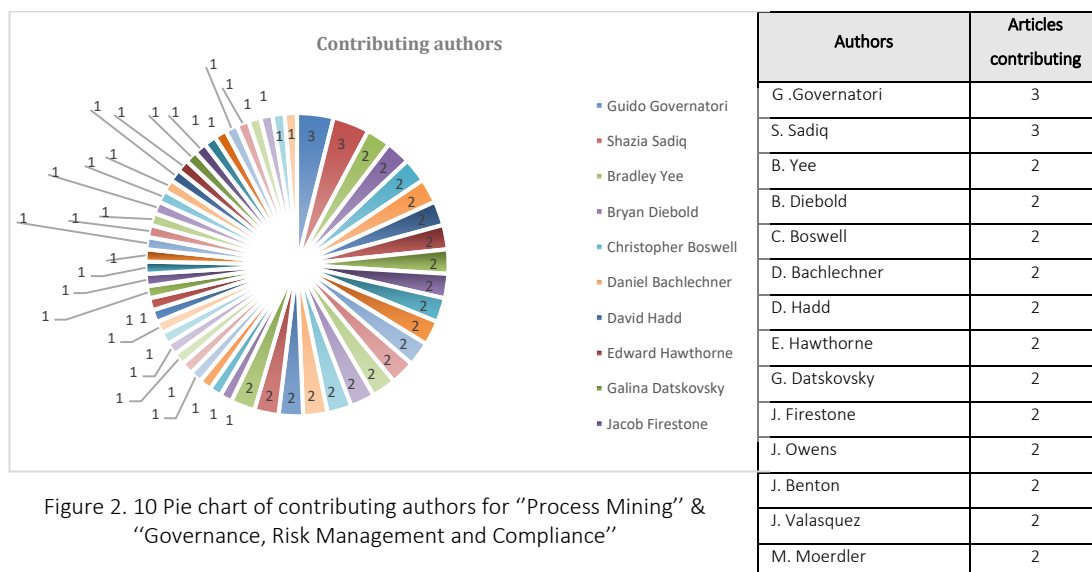


Figure 2. 10 Pie chart of contributing authors for “Process Mining” & “Governance, Risk Management and Compliance”

M. Manhart	2
M. Stricklen	2
M. Swaminathan	2
S. Thalmann	2
T. McHale	2
W.M.P. van der Aalst	2
Y. Ding	2

Table 2. 25 List of contributing authors for “Process Mining” & ‘Governance, Risk Management and Compliance’

Next, the chronological table of the top 20 articles is presented. Starting from the year of the oldest top 20 result and moving forward, the aim is to depict the busiest years in the top 20 results.



Figure 2. 11 Publications per year for ‘Process Mining’ & “Governance, Risk Management and Compliance”

Table 2. 26 List of publications per year for ‘Process Mining’ & “Governance, Risk Management and Compliance”

From the table 2.26 above, the most reputed publications in the field of process mining and Governance, Risk Management and Compliance happened between 2009 – 2010, and 2013 – 2016. A line chart of the table above is also presented.

In Table 2.27 are presented the media of publication for the top 20 results of the search.

Medium of publication	Times appeared	Type of publication
United States, Patent Application Publication	5	Patent Application Publication
Handbook on Business Process Management	3	Journal
EDPACS - The EDP Audit, Control, and Security Newsletter	2	Newsletter
Springer - Book Process Mining: Data Science in Action	2	Book
Enterprise Engineering Working Conference	1	Conference
KU Leuven Faculty of Business and Economics KBI 1226	1	University Research Paper

Computers & Security	1	Journal
JMAR (Journal of Management Accounting Research) Research Conference	1	Conference
Managerial Auditing Journal	1	Journal
Software & Systems Modeling	1	Journal
The ICCBR 2014 Doctoral Consortium	1	Consortium
XVIII International Research Society For Public Management (Irsprm) Conference	1	Conference

20

Table 2. 27 Media of publication for the top 20 results of the search for 'Process Mining' & "Governance, Risk Management and Compliance"

We notice that once again (like Enterprise Risk Management) the most popular medium is the United States, Patent Application Publication. That fact alone is of great importance as it depicts the impact of process mining to Governance, Risk Management and Compliance in an industrial level, as the patents are held by corporations such as SAP AG, Computers Associates Inc. and Bank of America Corp.

2.9 Crossover articles in the "R-P" Ontology literature review

In these five searches conducted we came up with 98 relevant articles. In these 98 articles there were 85 unique articles. There has not been an occurrence of an article that appears in more than two searches and only a handful of them (99) appear in two searches. These 9 articles, which crossover between the top 20 results of the search in 2 categories are presented in the table 2.28 below.

(PM & BPI) 1 & (PM & BPM) 20	Business process intelligence	Daniela Grigori, Fabio Casati, Malu Castellanos, Umeshwar Dayal, Mehmet Sayal, Ming-Chien Shan
(PM & BPI) 2 & (PM & BPM) 2	Business process mining: An industrial application	W.M.P. van der Aalst, H.A. Reijers, A.J.M.M. Weijters, B.F. van Dongen, A.K. Alves de Medeiros, M. Song, H.M.W. Verbeek
(PM & BPI) 3 & (PM & BPM) 8	The ProM framework: A new era in process mining tool support	B.F. van Dongen, A.K.A. de Medeiros, H.M.W. Verbeek, A.J.M.M. Weijters, W.M.P. van der Aalst
(PM & IA) 6 & (PM & ERM) 4	Comprehensive rule-based compliance checking and risk management with process mining	Filip Caron, Jan Vanthienen, Bart Baesens
(PM & BPI) 4 & (PM & BPM) 14	Process mining manifesto	Wil van der Aalst, Arya Adriansyah, Ana Karla Alves de Medeiros, Franco Arcieri, ThomasBaier, Tobias Blickle, Jagadeesh Chandra Bose, Peter van den Brand, Ronald Brandtjen, Joos Buijs, Andrea Burattin, Josep Carmona, Malu Castellanos, Jan Claes, Jonathan Cook, Nicola Costantini, Francisco Curbera, Ernesto Damiani, Massimiliano de Leoni,

		Pavlos Delias, Boudewijn F. van Dongen, Marlon Dumas, Schahram Dustdar, Dirk Fahland, Diogo R. Ferreira, Walid Gaaloul, Frank van Geffen, Sukriti Goel, Christian Gunther, Antonella Guzzo, Paul Harmon, Arthur ter Hofstede, John Hoogland, Jon Espen Ingvaldsen, Koki Kato, Rudolf Kuhn, Akhil Kumar, Marcello La Rosa, Fabrizio Maggi, Donato Malerba, Ronny S. Mans, Alberto Manuel, Martin McCreesh, Paola Mello, Jan Mendling, Marco Montali, Hamid R. Motahari-Nezhad, Michael zur Muehlen, Jorge Munoz-Gama, Luigi Pontieri, Joel Ribeiro, Anne Rozinat, Hugo Seguel Perez, Ricardo Seguel Perez, Marcos Sepulveda, Jim Sinur, Pnina Soffer, Minseok Song, Alessandro Sperduti, Giovanni Stilo, Casper Stoel, Keith Swenson, Maurizio Talamo, WeiTan, Chris Turner, Jan Vanthienen, George Varvaessos, Eric Verbeek, Marc Verdonk, Roberto Vigo, Jianmin Wang, Barbara Weber, Matthias Weidlich, Ton Weijters, Lijie Wen, Michael Westergaard, Moe Wyn
(PM & ERM) 19 & (PM & GRC) 7 & (PM & GRC) 10	System and method for operational risk assessment and control (Bank of America Corp Patent)	Jennifer B. Owens, Jacob Firestone, Edward T. Hawthorne, Joseph L. Valasquez, David Hadd, Bradley A. Yee
(PM & BPI) 6 & (PM & BPM) 15	Process mining: a research agenda	W.M.P. van der Aalst, A.J.M.M. Weijters
(PM & IA) 13 & (PM & ERM) 7	Accounting information systems: Tradition and future directions	Fernando Belfo, António Trigo
(PM & BPI) 9 & (PM & BPM) 13	Business process analysis in healthcare environments: A methodology based on process mining	Alvaro Rebuge, Diogo R. Ferreira

Table 2. 28 The 9 crossover articles of the “R-P” ontology

Year	Process Mining & Business Process Intelligence		Process Mining & Business Process Management		Process Mining & Internal Audit		Process Mining & Enterprise Risk Management		Process Mining & Governance, Risk Management and Compliance	
	Number of publications per year	%	Number of publication per year	%	Number of publications per year	%	Number of publications per year	%	Number of publications per year	%
2002	0	0%	0	0%	1	5%	0	0%	0	0%
2003	0	0%	1	5%	0	0%	0	0%	0	0%
2004	3	15%	4	20%	0	0%	0	0%	0	0%
2005	4	20%	4	20%	0	0%	0	0%	0	0%
2006	2	10%	0	0%	0	0%	0	0%	0	0%

2007	3	15%	4	20%	1	5%	1	6%	0	0%
2008	1	5%	1	5%	0	0%	0	0%	0	0%
2009	1	5%	1	5%	2	10%	2	11%	4	20%
2010	3	15%	0	0%	2	10%	2	11%	3	15%
2011	1	5%	1	5%	3	15%	1	6%	0	0%
2012	1	5%	1	5%	3	15%	2	11%	2	10%
2013	1	5%	0	0%	4	20%	5	28%	2	10%
2014	0	0%	2	10%	3	15%	2	11%	4	20%
2015	0	0%	1	5%	0	0%	2	11%	1	5%
2016	0	0%	0	0%	0	0%	0	0%	3	15%
2017	0	0%	0	0%	0	0%	1	6%	1	5%
2018	0	0%	0	0%	1	5%	0	0%	0	0%
	20	100%	20	100%	20	100%	18	100%	20	100%

Table 2. 29 The timetable of publications for the “R-P” elements

The majority of the articles concerning a) *Process Mining AND Business Process Intelligence* and b) *Process Mining AND Business Process Management*, were published between 2004 and 2007. On the other hand, the majority of the articles concerning c) *Process Mining AND Internal Audit*, d) *Process Mining AND Enterprise Risk Management*, and e) *Process Mining AND Governance, Risk Management and Compliance*, were published between 2009 and 2016.

2.10 A narrower literature review focused of the “Risk” elements of the study

In the second part of the literature review we conducted a search more focused on “Risk” triangle of the study. In total we conducted 13 searches on Google Scholar, blending the following seven relevant terms which included the following components of risk management and process mining:

1. Process mining
2. Audit
3. Enterprise risk management
4. COSO
5. ISO
6. Governance, risk management and conformance
7. Business process risk

The outcome of the searches is presented in Table 2.29, in descending order by the number of hits (results obtained).

#	Terms	Number of results
1	"process mining" AND audit	3.470
2	"process mining" AND "enterprise risk management"	3.430
3	"process mining" AND "governance, risk management and conformance "	113
4	"process mining" AND "enterprise risk management" AND "coso"	112
5	"process mining" AND "enterprise risk management" AND audit	97
6	"process mining" AND "enterprise risk management" AND "governance, risk management and conformance "	82
7	"process mining" AND "enterprise risk management" AND coso	67
8	"process mining" AND "enterprise risk management" AND coso AND iso	60
9	"process mining" AND "enterprise risk management" AND audit AND coso	59
10	"process mining" AND "enterprise risk management" AND iso	55
11	"process mining" AND "enterprise risk management" AND audit AND iso	42
12	"process mining" AND "enterprise risk management" AND audit AND iso AND coso	34
13	"process mining" AND "enterprise risk management" AND "business process risk"	7

Table 2. 30 Search results by number of hits

In Figure 2.12 a visualization of the results is presented.

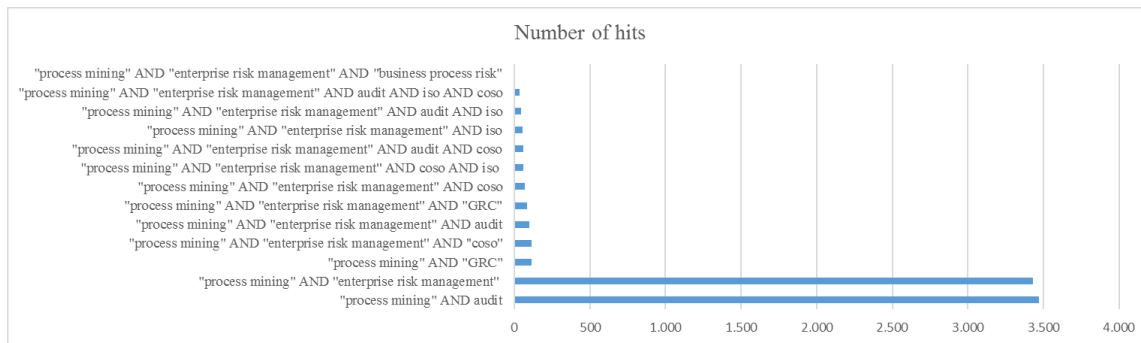


Figure 2. 12 Search results by number of hits

As a primary conclusion from the number of the obtained results is that process mining has not yet found the appropriate adoption from the academic community. The obtained results vary from 3.470 hits, which were obtained by the search terms: "*process mining*" AND *audit*, to a mere number of just 7 hits, which were obtained by the search terms: "*process mining*" AND "*enterprise risk management*" AND "*business process risk*".

As a cut-off point for the relevance of the articles participating in the analysis, we selected the first 20 results appeared in the Google Scholar for each search we conducted. From the 13 searches we conducted we came upon with 109 unique articles in a total of 247 articles $[(12 * 20) + 7]$, as the most relevant articles appeared in multiple instances on these searches. The synoptic grid of the first 20 results for each of the searches is presented in Table 2.30

2.11 The rationale behind the construction of metrics

In order to measure the impact, the popularity and the imprint of the related articles, four metrics were constructed:

- i) The article frequency metric
- ii) The article points metric
- iii) The Points/Frequency metric
- iv) The average rating of Frequency, Points & Points/Frequency metric.

The rating of the top 20 articles based on each metric is presented in the sections below.

2.13 Article Frequency metric

The frequency table of the articles (i.e. the sum of the times the same article appears in the search results) is presented on Table 2.31

Frequency	Number of articles
13	1
10	1
9	3
6	3
5	6
4	7
3	11
2	11
1	66
	109

Table 2. 32 Article Frequency

As it is depicted, there is one article appearing in all (13) searches, one article appearing in 10 searches, three articles appearing in 9 searches, etc. The 20 more frequent articles in descending order are presented on table 2.32

#	Articles	Authors	Frequency
1	Current research in risk-aware business process management: overview, comparison, and gap analysis	(Suriadi et al., 2014)	13
2	A comprehensive investigation of the applicability of process mining techniques for enterprise risk management	(Caron et al., 2013b)	10

3	Enterprise risk management [Book]	(Olson and Wu, 2015)	9
4	Enforcing compliance on business processes through the use of patterns	(Türetken et al., 2011)	9
5	IT risk management framework and methods	(Futch et al., 2007)	9
6	Basic Principles of Financial Process Mining A Journey through Financial Data in Accounting Information Systems	(Gehrke and Mueller-Wickop, 2010)	6
7	Managing regulatory compliance in business processes	(Sadiq and Governatori, 2015)	6
8	Computer readable medium for accelerating Sarbanes-Oxley (SOX) compliance process for management of a company	(Gutierrez and Sellers, 2008)	6
9	Comprehensive rule-based compliance checking and risk management with process mining	(Caron et al., 2013a)	5
10	Business process mining for internal fraud risk reduction: results of a case study	(Jans et al., n.d.)	5
11	Open source workflow management systems for the internal audit process	(de Almeida and Trigo, 2012)	5
12	Information system risk auditing model based on process mining	(Huang et al., 2012)	5
13	Rule-based business process mining: Applications for management	(Caron et al., 2012a)	5
14	A comprehensive framework for the application of process mining in risk management and compliance checking	(Caron et al., 2012b)	5
15	Profiling event logs to configure risk indicators for process delays	(Pika et al., 2013)	4
16	Accounting information systems: Tradition and future directions	(Belfo and Trigo, 2013)	4
17	Capturing compliance requirements: A pattern-based approach	(Turetken et al., 2012)	4
18	Integrated enterprise risk management: From process to best practice	(Cormican, 2014)	4
19	Managing Enterprise IT Risks through Automated Security Metrics	(Chatzipoulidis et al., 2016)	4
20	A proposed enterprise risk management model for health organizations	(Etges et al., 2018)	4

Table 2. 33 Top 20 of frequent articles

Nevertheless, the frequency alone is not to be considered as a solid and trustworthy sign of importance and relativity.

2.14 Article Points metrics

In order to sort the articles appearing in terms of significance / relativity we appointed a rating, a point system that grants a certain amount of points to each result, depending to how close it is to the top result. Under these rationale, the following tables of points were constructed:

Place in search results	Points
1	20,00
2	10,00
3	6,67
4	5,00
5	4,00
6	3,33
7	2,86
8	2,50
9	2,22

Place in search results	Points
1	7,00
2	3,50
3	2,33
4	1,75
5	1,40
6	1,17
7	1,00

10	2,00
11	1,82
12	1,67
13	1,54
14	1,43
15	1,33
16	1,25
17	1,18
18	1,11
19	1,05
20	1,00

Table 2. 35 Article points for the 13th search (7 results)

Table 2. 34 Article points for the 12 first searches (20+ results)

The 20 articles that gather the most points are presented on the Table 2.35.

#	Articles	Authors	Points
1	A comprehensive investigation of the applicability of process mining techniques for enterprise risk management	(Caron et al., 2013b)	167
2	Enterprise risk management [BOOK]	(Olson and Wu, 2015)	81,66
3	Current research in risk-aware business process management: overview, comparison, and gap analysis	(Suriadi et al., 2014)	48,52
4	Comprehensive rule-based compliance checking and risk management with process mining	(Caron et al., 2013a)	43,33
5	Enforcing compliance on business processes through the use of patterns	(Türetken et al., 2011)	32,51
6	Modeling control objectives for business process compliance	(Sadiq et al., 2007)	30
7	Process mining: data science in action [BOOK]	(Aalst, 2016)	27,84
8	IT risk management framework and methods	(Futch et al., 2007)	26,16
9	Auditing 2.0: Using process mining to support tomorrow's auditor	(Aalst et al., 2010)	24
10	Basic Principles of Financial Process Mining A Journey through Financial Data in Accounting Information Systems	(Gehrke and Mueller-Wickop, 2010)	22,55
11	Data Mining Models and Enterprise Risk Management	(Olson and Wu, 2017)	20
12	Managing regulatory compliance in business processes	(Sadiq and Governatori, 2015)	18,8
13	Business process mining for internal fraud risk reduction: results of a case study	(Jans et al., n.d.)	16,87
14	Profiling event logs to configure risk indicators for process delays	(Pika et al., 2013)	12,53
15	Accounting information systems: Tradition and future directions	(Belfo and Trigo, 2013)	11,52
16	Computer readable medium for accelerating Sarbanes-Oxley (SOX) compliance process for management of a company	(Gutierrez and Sellers, 2008)	11,32
17	Capturing compliance requirements: A pattern-based approach	(Türetken et al., 2012)	10,92
18	Generation of business process models for object life cycle compliance	(Küster et al., 2007)	10
19	Process mining and security: Detecting anomalous process executions and checking process conformance	(Aalst and de Medeiros, 2005)	10
20	Open source workflow management systems for the internal audit process	(de Almeida and Trigo, 2012)	9,67

Table 2. 36 Top 20 articles by points obtained

2.15 Points/Frequency metric

Another metric constructed is the Points/Frequency, which captures both a) the points obtained by each article with b) the dynamic of its frequency. In the Table 2.36 are presented (in descending order) the top 20 articles, based on the Point/Frequency metric.

#	Articles	Authors	<u>Points Frequency</u>
1	Data Mining Models and Enterprise Risk Management	(Olson and Wu, 2017)	20,00
2	A comprehensive investigation of the applicability of process mining techniques for enterprise risk management	(Caron et al., 2013b)	16,70
3	Auditing 2.0: Using process mining to support tomorrow's auditor	(Aalst et al., 2010)	12,00
4	Modeling control objectives for business process compliance	(Sadiq et al., 2007)	10,00
5	Generation of business process models for object life cycle compliance	(Küster et al., 2007)	10,00
6	Process mining and security: Detecting anomalous process executions and checking process conformance	(Aalst and de Medeiros, 2005)	10,00
7	Process mining: data science in action [BOOK]	(Aalst, 2016)	9,28
8	Enterprise risk management [BOOK]	(Olson and Wu, 2015)	9,07
9	Comprehensive rule-based compliance checking and risk management with process mining	(Caron et al., 2013a)	8,67
10	Decision making in enterprise risk management: A review and introduction to special issue	(Wu et al., 2015)	6,67
11	Peculiarity oriented mining and its application for knowledge discovery in amino-acid data	(not relevant)	6,67
12	The ProM framework: A new era in process mining tool support	(van Dongen et al., 2005)	6,67
13	On the exploitation of process mining for security audits: the conformance checking case	(Accorsi and Stocker, 2012)	5,00
14	A Meta Model for Process Mining Data	(van Dongen and Van der Aalst, 2005)	4,00
15	Basic Principles of Financial Process Mining A Journey through Financial Data in Accounting Information Systems	(Gehrke and Mueller-Wickop, 2010)	3,76
16	Current research in risk-aware business process management: overview, comparison, and gap analysis	(Suriadi et al., 2014)	3,73
17	Enforcing compliance on business processes through the use of patterns	(Türetken et al., 2011)	3,61
18	Business process mining for internal fraud risk reduction: results of a case study	(Jans et al., n.d.)	3,37
19	A business process mining application for internal transaction fraud mitigation	(Jans et al., 2011b)	3,33
20	Overview of workflow mining technology	(Gu et al., 2007)	3,33

Table 2. 37 Top 20 articles, based on Point/Frequency metric.

2.16 Average rating of Frequency, Points and Points/Frequency metric

The final metric constructed if the Average rating of: a) Frequency, b) Points and c) Points/Frequency, that captures both the points obtained by each article with the dynamic of its frequency. In the Table 2.36 are presented the top 20 articles, based in Point/Frequency metric.

#	Article	Authors	Average rating of [Frequency, Points, (Points/Frequency)]
1	A comprehensive investigation of the applicability of process mining techniques for enterprise risk management	(Caron et al., 2013b)	1,67
2	Enterprise risk management [Book]	(Olson and Wu, 2015)	4,33
3	Current research in risk-aware business process management: overview, comparison, and gap analysis	(Suriadi et al., 2014)	6,67
4	Comprehensive rule-based compliance checking and risk management with process mining	(Caron et al., 2013a)	7,33
5	Enforcing compliance on business processes through the use of patterns	(Türetken et al., 2011)	8,67
6	Basic Principles of Financial Process Mining A Journey through Financial Data in Accounting Information Systems	(Gehrke and Mueller-Wickop, 2010)	10,33
7	Modeling control objectives for business process compliance	(Sadiq et al., 2007)	10,67
8	IT risk management framework and methods	(Futch et al., 2007)	12,00
9	Process mining: data science in action [Book]	(Aalst, 2016)	12,33
10	Managing regulatory compliance in business processes	(Sadiq and Governatori, 2015)	13,33
11	Business process mining for internal fraud risk reduction: results of a case study	(Jans et al., 2008)	13,67
12	Auditing 2.0: Using process mining to support tomorrow's auditor	(Aalst et al., 2010)	15,00
13	Profiling event logs to configure risk indicators for process delays	(Pika et al., 2013)	17,00
14	Accounting information systems: Tradition and future directions	(Belfo and Trigo, 2013)	18,33
15	Data Mining Models and Enterprise Risk Management	(Olson and Wu, 2017)	18,67
16	Capturing compliance requirements: A pattern-based approach	(Turetken et al., 2012)	20,67
17	Generation of business process models for object life cycle compliance	(Küster et al., 2007)	22,67
18	Computer readable medium for accelerating Sarbanes-Oxley (SOX) compliance process for management of a company	(Gutierrez and Sellers, 2008)	23,33
19	Process mining and security: Detecting anomalous process executions and checking process conformance	(Aalst and de Medeiros, 2005)	23,67
20	Open source workflow management systems for the internal audit process	(de Almeida and Trigo, 2012)	24,67

Table 2. 38 Top 20 articles, based on Average rating of [Frequency, Points, (Points/Frequency)]

At this point, from the 109 unique articles, we exclude 15 articles, as non-relevant (as their context is not related with the search topics) or as not applicable to the analysis (as they represent a body of collective works from conferences, reports, articles in language other than English, etc.)

Included in the remaining 94 items, there are:

- Two books
- Seven patents
- Five theses (two MSc. two Ph.D. and one MBA).

A fact worth noticing is the presence of seven patents, the sum of which is concerning Enterprise Risk Management, operational risk assessment and control. These patents were

issued from respected organizations and firms, namely Bank of America, SAP SE, Oracle Inc., Grant Thornton LLP, CA Inc. etc.

2.17 Author frequency

For the 94 articles, we calculated the frequency of the appearance of every contributor (author or co-author), with the results depicting in table 2.38

Authors	Articles
1	17
1	7
3	6
3	5
4	4
8	3
19	2
148	1

Table 2. 39 Author frequency

As shown in the table above, there most influential author (W. M. P. van der Aalst) appears as a contributor in 17 articles, while the second most influential author (Mieke Jans), appears as a contributor in 7 articles. There are 187 unique authors that have contributed in these 94 articles, and namely the authors who have participated in over one article are shown in the table and chart below:

Authors	Contribution	Percentage
W. M. P. van der Aalst	17	6,0%
M. Jans	7	2,5%
B. Baesens	6	2,1%
F. Caron	6	2,1%
J. Vanthienen	6	2,1%
A.K.A. de Medeiros	5	1,8%
A.J.M.M. Weijters	5	1,8%
B.F. van Dongen	5	1,8%
G. Governatori	4	1,4%
M. Alles	4	1,4%
M. Vasarhelyi	4	1,4%
S. Sadiq	4	1,4%
A. Pika	3	1,1%
A. Trigo	3	1,1%
A.H.M. ter Hofstede	3	1,1%
C. Fidge	3	1,1%
D. Olson	3	1,1%
D. Wu	3	1,1%
H.M.W. Verbeek	3	1,1%
M. Wynn	3	1,1%
A. Rozinat	2	0,7%
A. Elgammal	2	0,7%
A.P.B. da Silva Etges	2	0,7%
A. Chatzipoulidis	2	0,7%
E. Pulvermüller	2	0,7%
F. Belfo	2	0,7%
G. FengJuan	2	0,7%
J. M. van der Werf	2	0,7%
K. Namiri	2	0,7%
K. Vanhoof	2	0,7%
M. El Kharbili	2	0,7%
M. Papazoglou	2	0,7%
N. Lybaert	2	0,7%
O. Turetken	2	0,7%
R. Accorsi	2	0,7%
S.J.H. van Kervel	2	0,7%
T. Stocker	2	0,7%
W. XiaoHui	2	0,7%
W.J van den Heuvel	2	0,7%

Table 2. 40 Author contribution

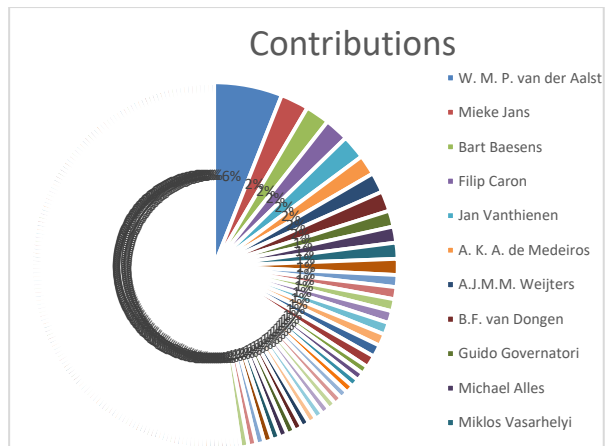


Figure 2. 13 Author contribution

2.18 Publication Year frequency

Concerning the dated the examined articles were published, are depicted in the following table and histogram.

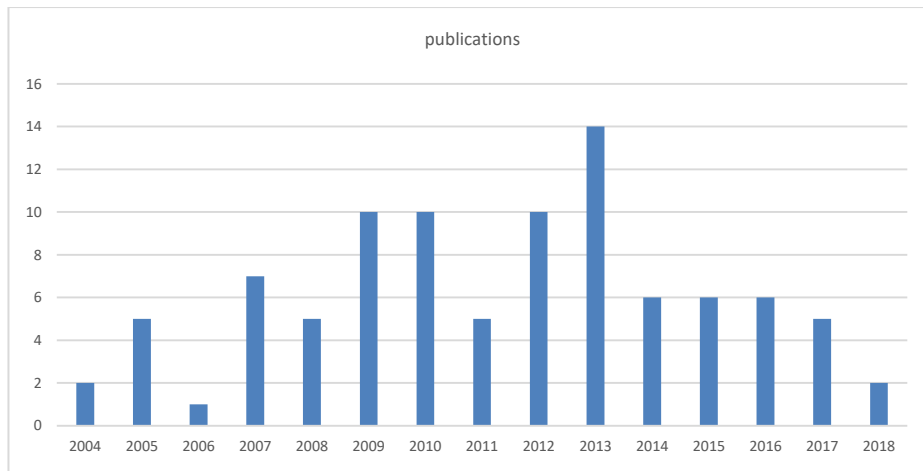


Figure 2. 14 Publication year frequency chart

Year	Publications
2004	2
2005	5
2006	1
2007	7
2008	5
2009	10
2010	10
2011	5
2012	10
2013	14
2014	6
2015	6
2016	6
2017	5
2018	2

Table 2. 41 Publication year frequency

As it is depicted, the most prolific year was 2013, with 14 publications, followed by 2009, 2010 and 2012 with 10 publications in each year. In the last three years (from 2014 to 2018), there seems to be a stabilization in the rate of important articles, in the area of 5 – 6 articles per year.

2.19 Media of publication

Conferences, Workshops, Congresses, Symposiums	Appearances	Percentage
International Conference on Business Process Management	4	11,4%
Annual ACM Symposium on Applied Computing	2	5,7%
Conference on ENTERprise Information Systems (CENTERIS)	2	5,7%
Conference on Business Informatics	2	5,7%
European Conference on Information Systems (ECIS)	2	5,7%
International Conference on Granular Computing	2	5,7%
Americas Conference on Information Systems	1	2,9%
BPM Demonstration Track	1	2,9%
CEE eDem and eGov Days Conference	1	2,9%
Enterprise Engineering Working Conference - Advances in Enterprise Engineering	1	2,9%
European Accounting Association	1	2,9%
Information Security Solutions Europe Conference	1	2,9%
International Conference on Advanced Information Systems Engineering	1	2,9%
International Conference on Advances in Energy Engineering	1	2,9%
International Conference on Application and Theory of Petri Nets	1	2,9%
International Conference on Design Science Research in Information Systems (DESRIST)	1	2,9%

International Conference on Management Science & Engineering	1	2,9%
International Conference on Research Challenges in Computer Science	1	2,9%
International Conference on System Sciences	1	2,9%
International Enterprise Distributed Object Computing Conference Workshops	1	2,9%
International Workshop on Database and Expert Systems Application	1	2,9%
International Workshop on Governance, Risk and Compliance	1	2,9%
Open Interop Workshop on Enterprise Modelling and Ontologies for Interoperability	1	2,9%
Pacific Asia Conference on Information Systems (PACIS)	1	2,9%
Management Accounting Section Research and Case Conference	1	2,9%
Workshop on Open Source and Design of Communication	1	2,9%
Workshop on Semantic Business Process and Product Lifecycle Management (SBPM)	1	2,9%

35

Table 2. 42 Media of publication

The most popular media of publication when it comes to conferences is i) the *International Conference on Business Process Management*, followed by ii) the *Annual ACM Symposium on Applied Computing*, iii) the *Conference on ENTERprise Information Systems (CENTERIS)*, iv) the *Conference on Business Informatics*, and v) the *European Conference on Information Systems (ECIS)*.

Table 2. 1 Media of publication

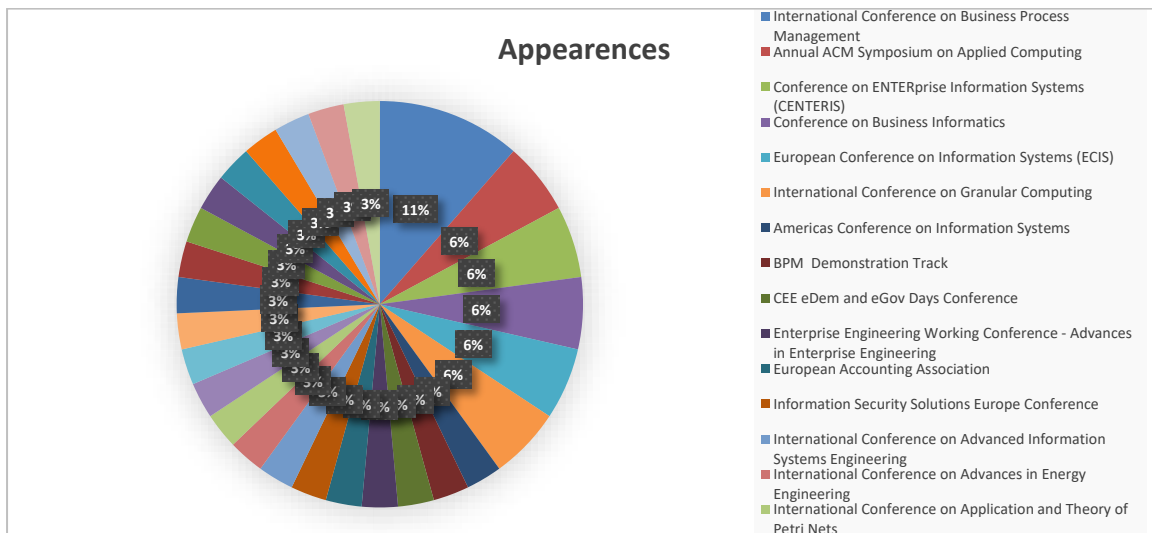


Figure 2. 15 Media of publication pie chart

2.20 Journals, Theses, Patents, Books frequency

Journals, Theses, Patents, Books	Appearances	Percentage
United States, Patent Application Publication	7	12%
Business Process Management Journal	4	7%
Decision Support Systems	3	5%
SSRN (Social Science Research Network) Electronic Journal	3	5%
Computers in Industry	2	4%
Information Sciences	2	4%
Journal of Risk Research	2	4%
Springer -Handbook on Business Process Management 2,	2	4%
Accounting Horizons	1	2%
Book - Springer	1	2%
Book - World Scientific	1	2%
Communications of the Association for Information Systems	1	2%
Computer - IEEE Computer Society	1	2%
EDPACS - The EDP Audit, Control, and Security Newsletter	1	2%
Electronic Notes in Theoretical Computer Science	1	2%
Expert Systems with Applications	1	2%
Global Business Expansion: Concepts, Methodologies, Tools, and Applications	1	2%
IEEE Software	1	2%
Information Systems Frontiers	1	2%
Information Systems Management	1	2%
International Journal of Accounting Information Systems	1	2%
Journal of Business Continuity & Emergency Planning	1	2%
Journal of Information System Security	1	2%
Journal of Information Systems	1	2%
Lecture Notes in Informatics (LNI) - Series of the Gesellschaft für Informatik (GI) in Business Process, Services Computing and Intelligent Service Management	1	2%
Management Intelligent Systems - Advances in Intelligent Systems and Computing Series	1	2%
Managerial Auditing Journal	1	2%
MIS Quarterly	1	2%
Modern Economy	1	2%
Omega	1	2%
Requirements Engineering	1	2%
Book chapter of process Mining: Data Science in Action	1	2%
Data Mining and Knowledge Discovery	1	2%
Enterprise Risk Management Models - Springer Texts in Business and Economics	1	2%
The Accounting Review	1	2%
University Helsinki Metropolia of Applied Sciences	1	2%
University of Hasselt	1	2%
University of Macedonia	1	2%
University of Masaryk	1	2%
University of Twente	1	2%

57

Table 2. 43 Media of publication frequency

The most popular media of publication when it comes to non-conference types of publication, which includes journals, academic theses, books, etc. is i) the *U.S. Patent Application Publication*, followed by ii) the *Business Process Management Journal*, iii) the *Decision Support Systems Journal* and iv) the *SSRN (Social Science Research Network) Electronic Journal*. In a peculiar manner, the most popular medium of publication is the U.S. Patent Application Publication. This is rather interesting and intriguing, as it shows the true potential and power of process mining, business process management and enterprise risk management. An industrial tool, focused on articulation and the solidness of the business processes, in order to create a fool proof mechanism for the modern entrepreneurial world.

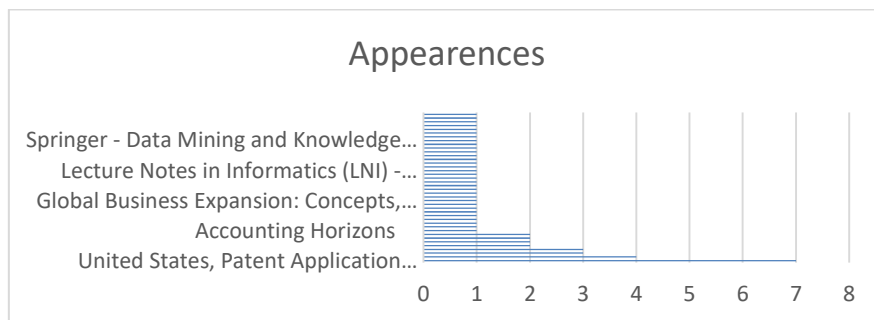


Figure 2. 16 Media of publication frequency

2.21 Conclusions drawn from the review of the “Risk - Process” Ontology related literature

Process Mining & Business Process Management

The search for “*Process Mining*” AND “*Business Process Management*” has the top place in the results in the corresponding Google Scholar search, with 7.100 results. In the top 20 articles, there were 107 authors involved (a result somehow biased, as one article of them, the “*Process Mining Manifesto*” had 77 authors. As long as the authors are concerned, there is undeniably a hardcore of authors, as one author (W.M.P. van der Aalst) has contributed in 10 out the top 20 articles (50%). The busiest years for the publications were 2004, 2005 and 2007,

with 4 publications in each year. The majority of the articles were published in journals, with: a) Business Process Management Journal, and b) Computers in Industry, to occupy the highest place with 3 publications each.

Process Mining & Business Process Intelligence

The search for “*Process Mining*” AND ‘*Business Process Intelligence*’ has yielded the 2nd result in the corresponding Google Scholar search, with 1.230 results (an 83% decrease from the top result). In the top 20 articles, there were 103 authors involved (a result biased, as the presence of “*Process Mining Manifesto*” once again, with 77 authors anomalizes the findings. As long as the authors are concerned, there is undeniably a hardcore of authors, as one author has contributed (W.M.P. van der Aalst, once again) in 13 out the top 20 articles (65%). The busiest year for the publications was 2005 with 4 publications, followed by 2007 and 2010, with 3 publications in each year. The majority of the articles were published in proceedings of conferences with the International Conference on Business Process Management to have the lion's share with 5 articles (25%), followed by Computers in Industry Journal, with 3 publications.

Process Mining & Internal Audit

The search for “*Process Mining*” AND ‘*Governance, Risk Management and Compliance*’ has yielded the 3rd place in the results in the corresponding Google Scholar search, with 200 results (an 84% decrease from the second result). In the top 20 articles, there were 52 authors involved. As long as the authors are concerned, there is also present a hardcore of authors, but a softer one, in comparison with the previous searches. The most contributing author (Mieke Jans) is appearing in 7 out the top 20 articles (35%). The busiest year for the publications was 2013 with 4 publications, followed by 2011, 2012 and 2014, with 3 publications in each year. The majority of the articles were published in journals, with Journal of Information Systems to have the lion's share with 3 articles

Process Mining & Enterprise Risk Management

The search for “Process Mining” AND ‘Governance, Risk Management and Compliance” has yielded the 4th place in the results in the corresponding Google Scholar search, with 140 results (a 30% decrease from the 3rd result). In the top 18 articles (two articles were ruled out as irrelevant), there were 45 authors involved. As long as the authors are concerned, there is an even softer hardcore of authors, as there are 3 authors (Bart Baesens, David Olson and Desheng Wu) which contributed the most, with 3 appearances each (17%). The busiest by far year for the publications was 2013 with 5 publications (28%), followed by 2009, 2010, 2011 and 2014, with 2 publications in each year. Concerning the media of publication, a peculiar finding is that the lion's share in the publications (4 publications) is held by the United States Patent Application Publication, a fact alone of great importance as it depicts the impact of process mining to Enterprise Risk Management in an industrial level, as the patents are held by corporations such as SAP SE, Oracle Inc., Core Systems Group and Bank of America Corp.

Process Mining & Governance, Risk Management and Compliance

The search for “Process Mining” AND ‘Governance, Risk Management and Compliance” has yielded the last place in the results in the corresponding Google Scholar search, with just 41 results (a 71% decrease from the 4th result). In the top 20 articles, there were 54 authors involved. The hardcore of authors is no longer existent, as the two most contributing authors (Guido Governatori and Shazia Sadiq) are appearing in just 3 articles each (15%). The busiest years for the publications was 2009 and 2013 with 4 publications in each year. Like the previous search, once again, the lion's share in the publications (5 publications) is held by the United States Patent Application Publication, a fact alone of great importance as it depicts the impact of process mining to Enterprise Risk Management in an industrial level, as the patents are held by corporations such as SAP AG, Computers Associates Inc. and Bank of America Corp.

2.22 Conclusions drawn from the focused review of the “Risk” Ontology related literature

The aim in this focused search was to find the “Holy Grail” of articles (if it could be such a publication). An article (or even a small group of articles), that would cover the topics mentioned in our search, appear consistently in each one of our searches and score high grades in the metrics that were examined by. The article which would combine the best practices, the most references, the best reputation etc.

The search in Google Scholar came up with a total of 247 articles, which finally concluded in 109 unique articles (as a number of articles were appearing more than once and 15 articles were excluded as non-relevant). The search for “process mining” AND “audit” came with the most results (3.470 results), whereas the least results came from the search for "process mining" AND "enterprise risk management" AND "business process risk", which resulted in just 7 results.

Then the articles were rated through the four metrics constructed (i. Article frequency, ii. Article points, iii. Points/Frequency, iv) Average rating of Frequency, Points & Points/Frequency).

Two were the articles that stood out and gathered the most points in all metrics: The first one was the: “A comprehensive investigation of the applicability of process mining techniques for enterprise risk management” by Caron et al., 2013b, and the second one was the: “Current research in risk-aware business process management: overview, comparison, and gap analysis”, by Suriadi et al., 2014. These two –highly influential- articles, are considered to be the pinnacle of the focused literature research on the “Risk” elements of our ontology.

Adding to this, also a fact worth noticing is the presence of seven patents, the sum of which is concerning Enterprise Risk Management, operational risk assessment and control. These patents were issued from respected organizations and firms, namely Bank of America, SAP SE, Oracle Inc., Grant Thornton Llp, CA Inc. etc.

Chapter 3

Ontology investigation through Google Trends

Having presented an extensive – in depth and width - literature review in the previous chapter, in this chapter we try to present a different, non-academic, approach towards the elements of the “R – P” ontology. As a point of reference, there will be the most uncompromising and sincere factor nowadays; the volume and the texture of internet searches in the Google platform. Internet search data may provide valuable insights into patterns of behavior. In fact, the application of Internet data in business research holds promise and may complement and extend the data foundations that presently exist. One tool that allows users to interact with Internet search data is Google Trends, a free, publically accessible online portal of Google Inc. Google Trends analyzes a portion of the three billion daily Google Search searches and provides data on geospatial and temporal patterns in search volumes for user-specified terms.

3.1 The rationale behind the use of Google trends tool in our analysis

There are several reasons why Google Trends has become such a popular source for big data research and applications. First, Google Search provides an excellent platform for observing researchers' information seeking activities. It offers instant reflection of the needs, wants, demands and interests of its users. Second, Google Trends is easy to use because Google not only collects data but also provides a variety of options for comparison. Even prior to the launch of Google Trends, in fact, there had been a lot of preceding research which utilized the search information in the fields of risk management and business process management.

Google Trends is an analysis tool which provides information on the monthly request frequencies of search terms that can be specified by country, time span, category, and media for the period of January 2004 to the present month. Google Trends provides the total volume for requested search terms, normalized in a way that countries of different size can be compared. Normalizing takes into account

the total number of search requests for each country which itself is not reported. Reported normalized scores are values between 0 and 100. For insufficient data, the value 0 is displayed. The exact algorithm used by Google Trends remains, for the most part, unknown. [However, Google provides some explanations to their results. Search terms that are requested rarely and repeated requests of the same term from the same user within a specific (but not defined) time span are excluded from the analysis].

According to Wikipedia (https://en.wikipedia.org/wiki/Google_Trends, accessed 26.08.2018), Google Trends is a public web facility of Google Inc., based on Google Search, that shows how often a particular search-term is entered relative to the total search-volume across various regions of the world, and in various languages. The horizontal axis of the main graph represents time (starting from 2004), and the vertical is how often a term is searched for relative to the total number of searches, globally. Below the main graph, popularity is broken down by regions and cities. From the data given in the corresponding Figures and Tables, we attempt to draw some introductory remarks about the amount of impact the terms searched, i.e. the extent of their notability in the global World Wide Web, depending on its presence in searches conducted.

3.2 Interest over time

Numbers represent search interest relative to the highest point on the chart for the given region and time. A value of 100 is the peak popularity for the term. A value of 50 means that the term is half as popular. At table 3.1 are depicted the monthly scores awarded by Google Trends on the "interest over time" line graph. These scores express the popularity of that term over a specified time range. Google Trends scores are based on the absolute search volume for a term, relative to the number of searches received by Google. The timeline scores obtained from the search in Google Trends in December 2018 (searches conducted worldwide, from January 2004 to December 2018, category: business & industrial) for the terms of the "R-P" ontology:

Month	Process Mining	Enterprise Management	Risk	Internal Audit	Governance, Management and Compliance	Risk and Process Intelligence	Business Process Management
January-04	62	42		75	77	0	82
February-04	30	45		100	78	99	82

March-04	76	63	76	66	61	87
April-04	29	71	85	73	71	88
May-04	25	74	82	78	0	87
June-04	38	50	74	100	41	98
July-04	67	70	65	79	0	91
August-04	37	67	73	70	100	91
September-04	91	74	77	65	37	92
October-04	35	75	79	78	37	94
November-04	23	100	80	62	0	87
December-04	32	47	60	71	0	83
January-05	28	47	57	68	61	100
February-05	100	73	77	72	49	80
March-05	33	71	75	53	54	97
April-05	37	69	68	54	31	96
May-05	41	68	83	53	66	92
June-05	49	83	69	42	27	81
July-05	17	68	80	47	27	71
August-05	32	76	66	49	53	89
September-05	15	76	81	54	60	86
October-05	21	76	60	39	56	69
November-05	62	93	65	51	22	78
December-05	34	67	47	49	22	69
January-06	35	65	62	78	29	80
February-06	43	58	63	57	30	68
March-06	58	75	63	54	17	77
April-06	40	62	71	48	64	76
May-06	36	66	68	39	33	64
June-06	22	69	70	51	18	76
July-06	16	67	62	51	17	75
August-06	25	59	57	61	16	77
September-06	28	72	60	54	15	62
October-06	30	66	68	61	21	79
November-06	30	67	62	50	14	66
December-06	26	34	50	54	28	46
January-07	23	57	59	59	12	68
February-07	49	67	60	53	13	76
March-07	14	50	58	49	11	78
April-07	33	67	58	54	30	68
May-07	47	62	67	53	20	69
June-07	43	61	65	52	32	70
July-07	23	60	59	52	26	73
August-07	15	58	61	60	15	74
September-07	30	56	56	49	29	70
October-07	21	69	61	56	35	80
November-07	31	64	61	49	25	72
December-07	14	49	46	44	18	55
January-08	12	54	55	53	16	66
February-08	18	54	63	52	20	68
March-08	26	58	58	50	27	65
April-08	33	60	55	48	8	77
May-08	18	63	58	46	26	65
June-08	26	60	60	50	34	72
July-08	25	58	54	56	29	67
August-08	18	61	54	51	22	64
September-08	32	53	54	49	24	67
October-08	34	60	58	43	12	65
November-08	14	52	47	44	26	69
December-08	22	60	41	39	32	54

January-09	30	47	48	51	18	60
February-09	21	53	55	50	12	67
March-09	17	61	57	54	19	70
April-09	14	60	50	41	14	63
May-09	22	60	58	46	22	66
June-09	12	51	61	45	38	70
July-09	25	49	51	47	27	59
August-09	17	47	49	39	16	55
September-09	13	52	57	39	20	67
October-09	21	53	53	38	17	59
November-09	18	53	57	38	26	60
December-09	19	38	43	35	17	48
January-10	23	46	50	35	18	52
February-10	9	47	58	34	25	65
March-10	27	55	60	38	29	66
April-10	18	50	55	40	17	63
May-10	20	54	61	45	13	70
June-10	22	49	55	43	22	63
July-10	10	54	51	39	21	57
August-10	20	40	51	37	26	58
September-10	25	41	49	39	15	61
October-10	16	42	50	40	15	61
November-10	15	45	48	40	20	58
December-10	12	39	41	34	18	45
January-11	18	38	49	35	15	52
February-11	21	40	48	40	19	61
March-11	16	48	51	40	34	59
April-11	15	44	50	38	27	54
May-11	18	44	56	40	31	57
June-11	27	43	49	38	14	55
July-11	19	41	44	35	24	54
August-11	17	41	44	35	17	53
September-11	23	42	48	36	19	58
October-11	18	41	44	33	25	58
November-11	25	39	49	34	18	58
December-11	12	34	36	27	22	41
January-12	17	34	42	31	24	51
February-12	27	39	46	33	28	58
March-12	28	39	48	34	22	58
April-12	21	43	44	34	18	57
May-12	25	41	49	38	21	54
June-12	25	40	47	34	24	52
July-12	16	35	46	32	16	49
August-12	12	31	42	36	12	54
September-12	21	43	46	32	19	54
October-12	21	39	49	35	28	54
November-12	20	35	47	33	26	52
December-12	18	25	33	30	14	39
January-13	13	32	44	35	19	44
February-13	19	36	41	34	23	51
March-13	23	35	43	35	18	51
April-13	29	40	48	35	25	53
May-13	29	33	43	31	17	54
June-13	20	36	45	34	15	49
July-13	23	35	39	32	16	50
August-13	14	33	39	30	16	48
September-13	16	36	42	31	18	50
October-13	24	37	46	36	23	52

November-13	27	33	43	31	11	50
December-13	17	28	33	28	20	38
January-14	20	30	40	31	17	44
February-14	26	33	45	35	19	49
March-14	25	37	43	35	21	51
April-14	26	36	46	34	15	51
May-14	31	36	44	33	20	52
June-14	21	33	44	38	10	49
July-14	20	32	42	32	24	50
August-14	20	35	41	32	18	46
September-14	23	37	47	37	17	53
October-14	27	36	48	32	21	52
November-14	45	33	45	32	27	49
December-14	35	27	34	25	18	37
January-15	25	33	41	30	14	43
February-15	23	35	42	34	26	49
March-15	36	34	45	36	29	53
April-15	48	35	45	31	31	47
May-15	32	32	45	32	18	50
June-15	22	36	42	34	16	47
July-15	25	33	38	34	16	47
August-15	24	32	39	35	21	44
September-15	33	37	43	35	15	47
October-15	41	39	42	37	23	49
November-15	29	32	44	32	21	46
December-15	29	26	33	27	14	38
January-16	29	29	39	31	13	35
February-16	30	33	42	36	21	43
March-16	27	37	43	35	24	46
April-16	28	36	43	34	20	44
May-16	30	34	45	35	18	42
June-16	34	33	44	35	15	44
July-16	29	30	34	32	19	37
August-16	25	30	37	34	14	39
September-16	26	34	41	32	18	43
October-16	36	37	40	32	16	43
November-16	48	36	42	34	20	43
December-16	26	29	33	28	16	34
January-17	32	32	38	31	18	39
February-17	35	35	43	35	15	45
March-17	42	36	43	37	20	47
April-17	43	35	41	35	25	42
May-17	38	33	42	35	24	46
June-17	38	31	38	35	13	40
July-17	32	30	39	32	14	39
August-17	35	30	39	32	16	41
September-17	50	34	41	32	23	44
October-17	48	43	43	34	24	44
November-17	59	39	44	35	20	45
December-17	37	29	33	28	19	32
January-18	42	37	39	32	29	38
February-18	46	32	41	36	20	44
March-18	40	37	41	33	18	44
April-18	51	35	42	37	28	45
May-18	57	34	42	36	19	43
June-18	53	30	38	31	18	38
July-18	50	32	34	35	21	37
August-18	44	35	37	36	8	42

September-18	57	35	39	33	12	44
October-18	55	33	43	39	19	48
November-18	55	36	40	35	18	40
December-18	41	41	37	35	29	39

Table 3 . 1 Timetable of the scores obtained

3.4 Presentation of Hi's and Low's

In the tables below, there are presented the Top 20 and the Bottom 20 scores for the search terms. Some remarks about the time stamps of these scores are also made, in order to clarify and interpret the scores.

Process Mining Hi's and Low's

Process Mining					
Sorting	Month	Scores	Sorting	Month	Scores
Top 1	Feb-05	100	Bottom 1	Feb-10	9
Top 2	Sep-04	91	Bottom 2	Jul-10	10
Top 3	Mar-04	76	Bottom 3	Jan-08	12
Top 4	Jul-04	67	Bottom 6	Jun-09	12
Top 5	Jan-04	62	Bottom 5	Dec-10	12
Top 6	Nov-05	62	Bottom 4	Dec-11	12
Top 7	Nov-17	59	Bottom 10	Aug-12	12
Top 8	Mar-06	58	Bottom 9	Sep-09	13
Top 9	May-18	57	Bottom 8	Jan-13	13
Top 10	Sep-18	57	Bottom 7	Mar-07	14
Top 11	Oct-18	55	Bottom 15	Dec-07	14
Top 12	Nov-18	55	Bottom 14	Nov-08	14
Top 13	Jun-18	53	Bottom 13	Apr-09	14
Top 14	Apr-18	51	Bottom 12	Aug-13	14
Top 15	Sep-17	50	Bottom 11	Sep-05	15
Top 16	Jul-18	50	Bottom 17	Aug-07	15
Top 17	Jun-05	49	Bottom 16	Nov-10	15
Top 18	Feb-07	49	Bottom 19	Apr-11	15
Top 19	Apr-15	48	Bottom 18	Jul-12	16
Top 20	Nov-16	48	Bottom 20	Sep-13	16

Table 3 . 2 Top 20 and Bottom 20 scores for Process Mining

The internet searches for the topic “process mining” reached their peak in February 2005 (score 100) and their lowest point in February 2010 (score 9). The distance between the highest and the lowest point is 91 (100 – 9), a score that indicates a great fluctuation in trend. Out of the top 20 scores, 11 of

them were obtained within the last 5 years. Out of the bottom 20 scores, all of them were obtained out of the last 5 years.

Internal Audit Hi's and Low's

Internal Audit					
Sorting	Month	Scores	Sorting	Month	Scores
Top 1	Feb-04	100	Bottom 1	Dec-17	33
Top 2	Apr-04	85	Bottom 2	Dec-16	33
Top 3	May-05	83	Bottom 3	Dec-15	33
Top 4	May-04	82	Bottom 6	Dec-13	33
Top 5	Sep-05	81	Bottom 5	Dec-12	33
Top 6	Nov-04	80	Bottom 4	Jul-18	34
Top 7	Jul-05	80	Bottom 10	Jul-16	34
Top 8	Oct-04	79	Bottom 9	Dec-14	34
Top 9	Sep-04	77	Bottom 8	Dec-11	36
Top 10	Feb-05	77	Bottom 7	Dec-18	37
Top 11	Mar-04	76	Bottom 15	Aug-18	37
Top 12	Jan-04	75	Bottom 14	Aug-16	37
Top 13	Mar-05	75	Bottom 13	Jun-18	38
Top 14	Jun-04	74	Bottom 12	Jun-17	38
Top 15	Aug-04	73	Bottom 11	Jan-17	38
Top 16	Apr-06	71	Bottom 17	Jul-15	38
Top 17	Jun-06	70	Bottom 16	Sep-18	39
Top 18	Jun-05	69	Bottom 19	Jan-18	39
Top 19	Apr-05	68	Bottom 18	Aug-17	39
Top 20	May-06	68	Bottom 20	Jul-17	39

Table 3 . 3 Top 20 and Bottom 20 scores for Internal Audit

The internet searches for the topic “internal audit” reached their peak in February 2004 (score 100) and their lowest point in December 2017, December 2016, December 2015, December 2013 and December 2012 (score 33). The distance between the highest and the lowest point is 67 (100 – 33), a score that indicates a medium fluctuation in trend. Out of the top 20 scores, none of them were obtained within the last 5 years. Out of the bottom 20 scores, 18 of them were obtained within the last 5 years, a fact that is indicative of a low interest for this topic in current searches.

Enterprise Risk Management Hi's and Low's

Enterprise Risk Management

Sorting	Month	Scores	Sorting	Month	Scores
Top 1	Nov-04	100	Bottom 1	Dec-12	25
Top 2	Nov-05	93	Bottom 2	Dec-15	26
Top 3	Jun-05	83	Bottom 3	Dec-14	27
Top 4	Aug-05	76	Bottom 6	Dec-13	28
Top 5	Sep-05	76	Bottom 5	Jan-16	29
Top 6	Oct-05	76	Bottom 4	Dec-16	29
Top 7	Oct-04	75	Bottom 10	Dec-17	29
Top 8	Mar-06	75	Bottom 9	Jan-14	30
Top 9	May-04	74	Bottom 8	Jul-16	30
Top 10	Sep-04	74	Bottom 7	Aug-16	30
Top 11	Feb-05	73	Bottom 15	Jul-17	30
Top 12	Sep-06	72	Bottom 14	Aug-17	30
Top 13	Apr-04	71	Bottom 13	Jun-18	30
Top 14	Mar-05	71	Bottom 12	Aug-12	31
Top 15	Jul-04	70	Bottom 11	Jun-17	31
Top 16	Apr-05	69	Bottom 17	Aug-15	32
Top 17	Jun-06	69	Bottom 16	Nov-15	32
Top 18	Oct-07	69	Bottom 19	Jan-17	32
Top 19	May-05	68	Bottom 18	Feb-18	32
Top 20	Jul-05	68	Bottom 20	Jul-18	32

Table 3 . 4 Top 20 and Bottom 20 scores for Enterprise Risk Management

The internet searches for the topic “Enterprise Risk Management” reached their peak in November 2004 (score 100) and their lowest point in December 2012 (score 25). The distance between the highest and the lowest point is 75 (100 – 25), a score that indicates a medium-to-strong fluctuation in trend. Out of the top 20 scores, none of them were obtained within the last 5 years. In fact, all of them were obtained in the first 5 years. Out of the bottom 20 scores, 19 of them were obtained within the last 5 years, a fact that is indicative of a low interest for this topic in current searches.

Governance, Risk Management and Compliance Hi’s and Low’s

Governance, Risk Management and Compliance					
Sorting	Month	Scores	Sorting	Month	Scores
Top 1	Jun-04	100	Bottom 1	Dec-14	25
Top 2	Jul-04	79	Bottom 2	Dec-11	27
Top 3	Feb-04	78	Bottom 3	Dec-15	27
Top 4	May-04	78	Bottom 6	Dec-13	28
Top 5	Oct-04	78	Bottom 5	Dec-16	28
Top 6	Jan-06	78	Bottom 4	Dec-17	28
Top 7	Jan-04	77	Bottom 10	Dec-12	30
Top 8	Apr-04	73	Bottom 9	Aug-13	30
Top 9	Feb-05	72	Bottom 8	Jan-15	30

Top 10	Dec-04	71	Bottom 7	Jan-12	31
Top 11	Aug-04	70	Bottom 15	May-13	31
Top 12	Jan-05	68	Bottom 14	Sep-13	31
Top 13	Mar-04	66	Bottom 13	Nov-13	31
Top 14	Sep-04	65	Bottom 12	Jan-14	31
Top 15	Nov-04	62	Bottom 11	Apr-15	31
Top 16	Aug-06	61	Bottom 17	Jan-16	31
Top 17	Oct-06	61	Bottom 16	Jan-17	31
Top 18	Aug-07	60	Bottom 19	Jun-18	31
Top 19	Jan-07	59	Bottom 18	Sep-17	32
Top 20	Feb-06	57	Bottom 20	Jan-18	32

Table 3 . 5 Top 20 and Bottom 20 scores for Governance, Risk Management and Compliance

The internet searches for the topic “for Governance, Risk Management and Compliance” reached their peak in June 2004 (score 100) and their lowest point in December 2014 (score 25). The distance between the highest and the lowest point is 75 (100 – 25), a score that indicates a medium-to-strong fluctuation in trend. Out of the top 20 scores, none of them were obtained within the last 5 years. In fact, all of them were obtained in the first 5 years. Out of the bottom 20 scores, 13 of them were obtained within the last 5 years.

Business Process Intelligence Hi’s and Low’s

Business Process Intelligence					
Sorting	Month	Scores	Sorting	Month	Scores
Top 1	Aug-04	100	Bottom 1	Jan-04	0
Top 2	Feb-04	99	Bottom 2	May-04	0
Top 3	Apr-04	71	Bottom 3	Jul-04	0
Top 4	May-05	66	Bottom 6	Nov-04	0
Top 5	Apr-06	64	Bottom 5	Dec-04	0
Top 6	Mar-04	61	Bottom 4	Apr-08	8
Top 7	Jan-05	61	Bottom 10	Aug-18	8
Top 8	Sep-05	60	Bottom 9	Jun-14	10
Top 9	Oct-05	56	Bottom 8	Mar-07	11
Top 10	Mar-05	54	Bottom 7	Nov-13	11
Top 11	Aug-05	53	Bottom 15	Jan-07	12
Top 12	Feb-05	49	Bottom 14	Oct-08	12
Top 13	Jun-04	41	Bottom 13	Feb-09	12
Top 14	Jun-09	38	Bottom 12	Aug-12	12
Top 15	Sep-04	37	Bottom 11	Sep-18	12
Top 16	Oct-04	37	Bottom 17	Feb-07	13
Top 17	Oct-07	35	Bottom 16	May-10	13
Top 18	Jun-08	34	Bottom 19	Jan-16	13
Top 19	Mar-11	34	Bottom 18	Jun-17	13

Top 20	May-06	33	Bottom 20	Jul-17	14
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Table 3 . 6 Top 20 and Bottom 20 scores for Business Process Intelligence

The internet searches for the topic “Business Process Intelligence” reached their peak in August 2004 (score 100) and their lowest point in January 2004, May 2004, July 2004, November 2004 and December 2004 (score 0). The distance between the highest and the lowest point is 100 (100 – 0), a score that indicates an absolute fluctuation in trend. Out of the top 20 scores, none of them were obtained within the last 5 years. In fact, 18 of them were obtained in the first 5 years. Out of the bottom 20 scores, 6 of them were obtained within the last 5 years

Business Process Management Hi’s and Low’s

Business Process Management					
Sorting	Month	Scores	Sorting	Month	Scores
Top 1	Jan-05	100	Bottom 1	Dec-17	32
Top 2	Jun-04	98	Bottom 2	Dec-16	34
Top 3	Mar-05	97	Bottom 3	Jan-16	35
Top 4	Apr-05	96	Bottom 6	Dec-14	37
Top 5	Oct-04	94	Bottom 5	Jul-16	37
Top 6	Sep-04	92	Bottom 4	Jul-18	37
Top 7	May-05	92	Bottom 10	Dec-13	38
Top 8	Jul-04	91	Bottom 9	Dec-15	38
Top 9	Aug-04	91	Bottom 8	Jan-18	38
Top 10	Aug-05	89	Bottom 7	Jun-18	38
Top 11	Apr-04	88	Bottom 15	Dec-12	39
Top 12	Mar-04	87	Bottom 14	Aug-16	39
Top 13	May-04	87	Bottom 13	Jan-17	39
Top 14	Nov-04	87	Bottom 12	Jul-17	39
Top 15	Sep-05	86	Bottom 11	Dec-18	39
Top 16	Dec-04	83	Bottom 17	Jun-17	40
Top 17	Jan-04	82	Bottom 16	Nov-18	40
Top 18	Feb-04	82	Bottom 19	Dec-11	41
Top 19	Jun-05	81	Bottom 18	Aug-17	41
Top 20	Feb-05	80	Bottom 20	Aug-18	42

Table 3 . 7 Top 20 and Bottom 20 scores for Business Process Management

The internet searches for the topic “Business Process Intelligence” reached their peak in January 2005 (score 100) and their lowest point in December 2017 (score 32). The distance between the highest and the lowest point is 68 (100 – 32), a score that indicates a medium fluctuation in trend. Out of the

top 20 scores, none of them were obtained within the last 5 years. In fact, all of them were obtained in the first 5 years. Out of the bottom 20 scores, 18 of them were obtained within the last 5 years, a fact that is indicative of a low interest for this topic in current searches.

3.5 A summary of the findings on Hi's and Low's

We observe that all of the top 5 scores for all searches are spotted in years 2004 – 2005, a fact that is rather strange, as our belief was that there should have been an upward surge in the quantity of the searches for the terms in examination in the last few years at last. A rather peculiar fact is that most of the bottom scores, regardless of the year being, occur in month December.

3.6 Examination of the elements trendline

A trendline is the outcome of a linear trend estimation, linear least squares regression tool which is a statistical technique which provides some correlation to data points in order to aid interpretation of data. The series of values of the examined elements are treated as a time series, and trend estimation can be used to make and justify statements about tendencies in the data, by relating the measurements to the times at which they occurred. This model can then be used to describe the behaviour of the observed data. Linear trend estimation expresses data as a linear function of time, and can also be used to determine the significance of differences in a set of data linked by a categorical factor. In particular, it may be useful to determine if measurements exhibit an increasing or decreasing trend which is statistically distinguished from random behaviour.

Process mining trendline

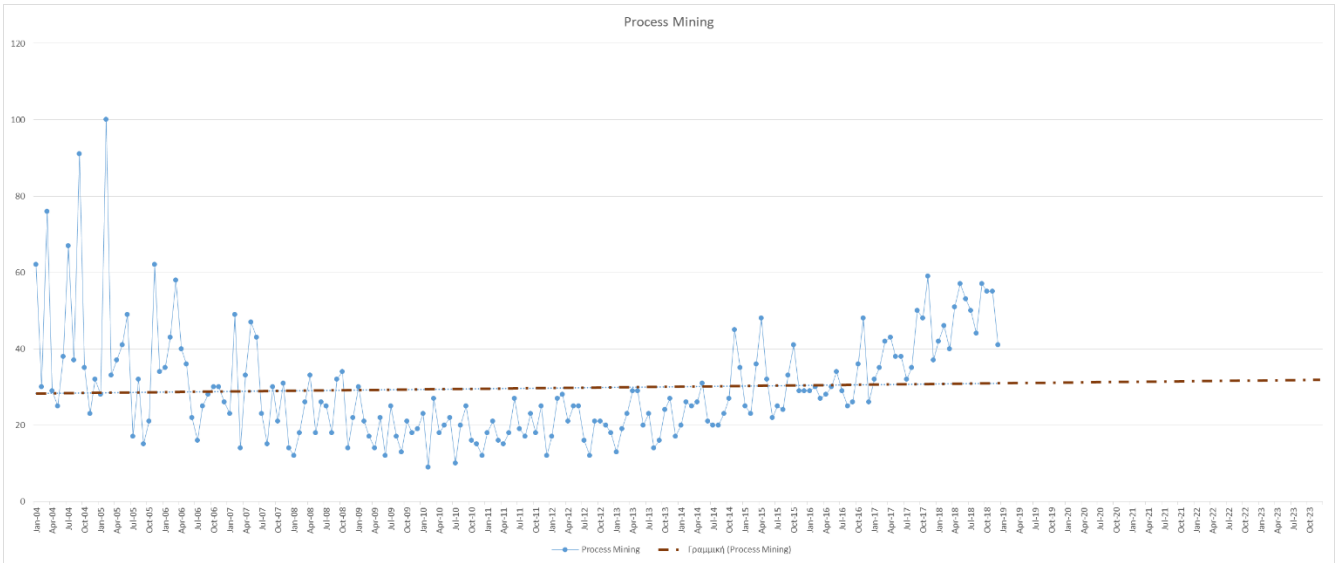


Figure 3. 1 Process mining trendline

As Figure 3.1 depicts, the linear trendline for process mining is pointing slightly upwards for the next five years, according to the prediction made based on the existing timeline. In this case a slight rise in interest concerning process mining is expecting in the near future.

Internal Audit trendline

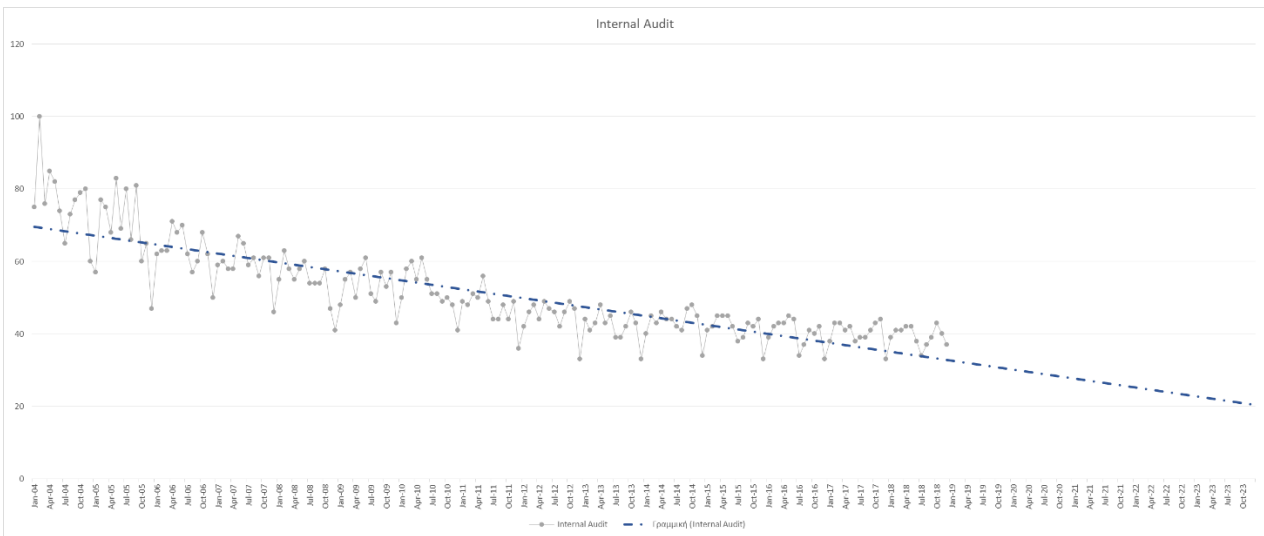


Figure 3. 2 Internal Audit trendline

As Figure 3.2 depicts, the linear trendline for internal audit is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abidance is expected for the next five years.

Enterprise Risk Management trendline

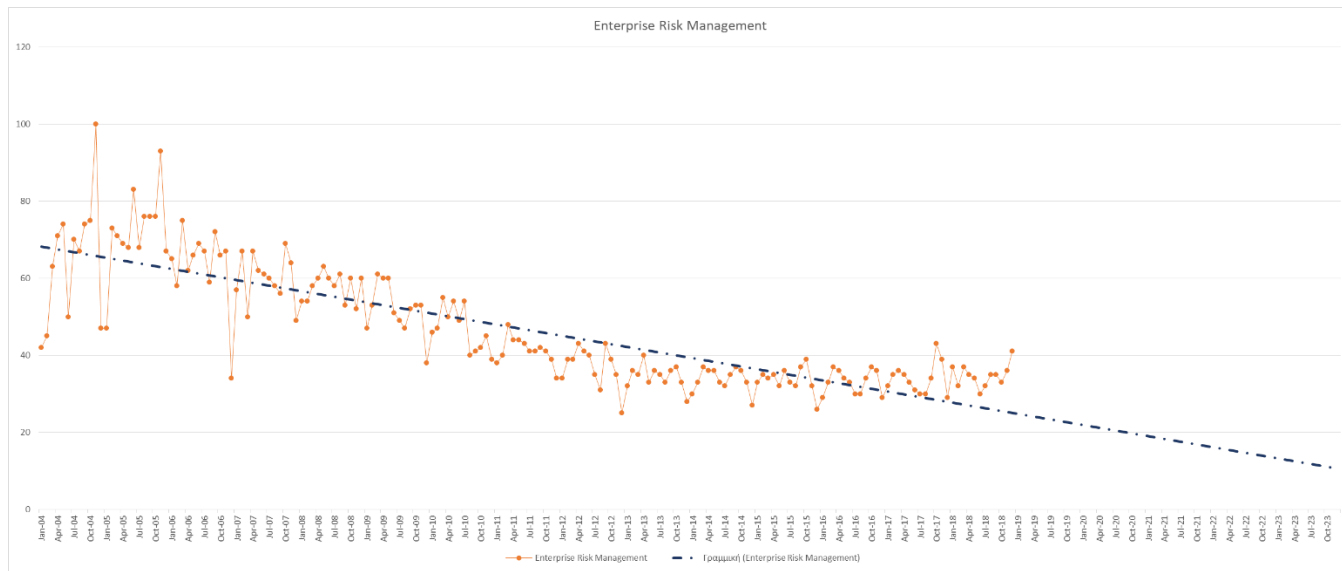


Figure 3. 3 Enterprise Risk Management trendline

As Figure 3.3 depicts, the linear trendline for Enterprise Risk Management is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abidance is expected for the next five years.

Governance, Risk Management and Compliance trendline

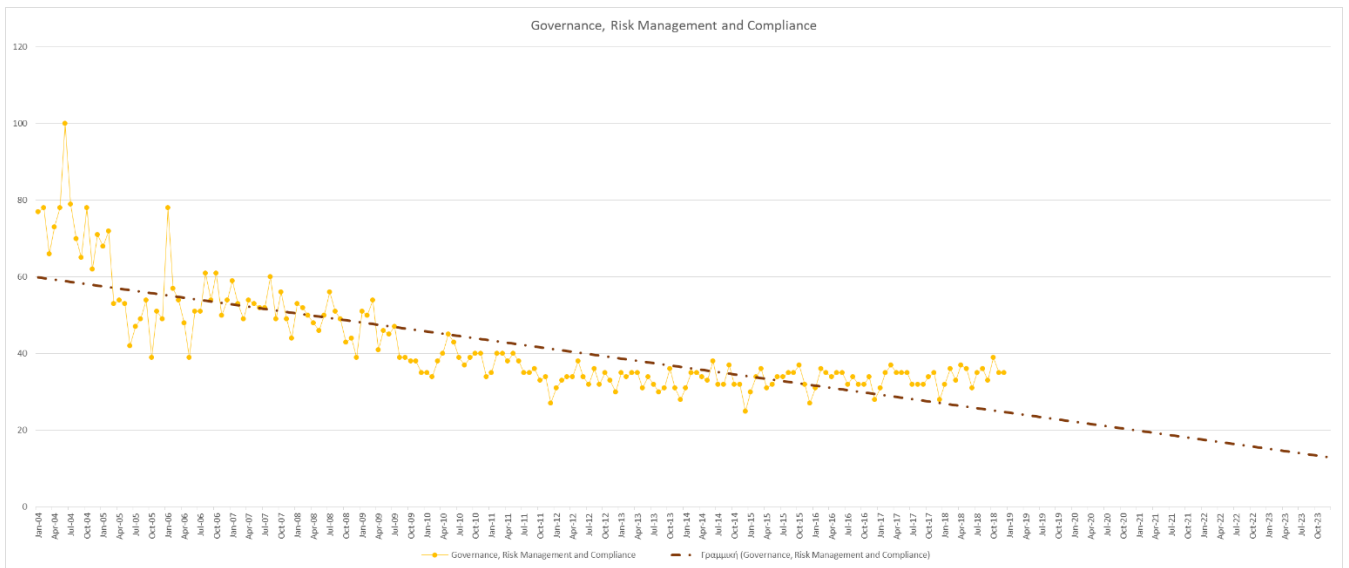


Figure 3. 4 Governance, Risk Management & Compliance trendline

As Figure 3.4 depicts, the linear trendline for Governance, Risk Management & Compliance is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abidance is expected for the next five years.

Business process intelligence trendline

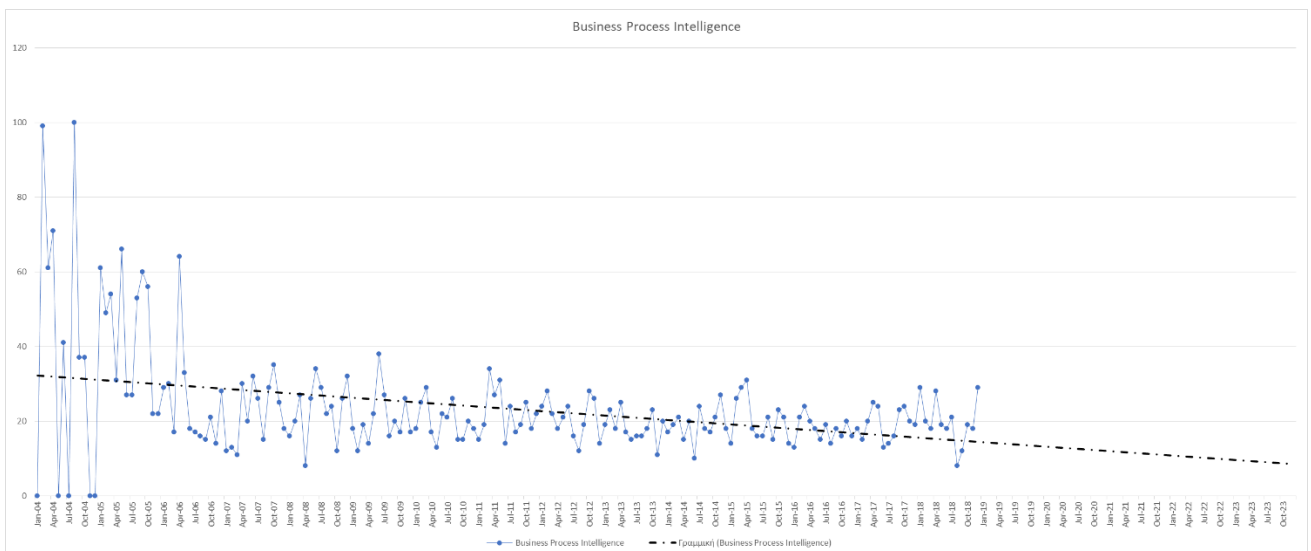


Figure 3. 5 Business Process Intelligence trendline

As Figure 3.5 depicts, the linear trendline for Business Process Intelligence is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abundance is expected for the next five years.

Business Process Management trendline

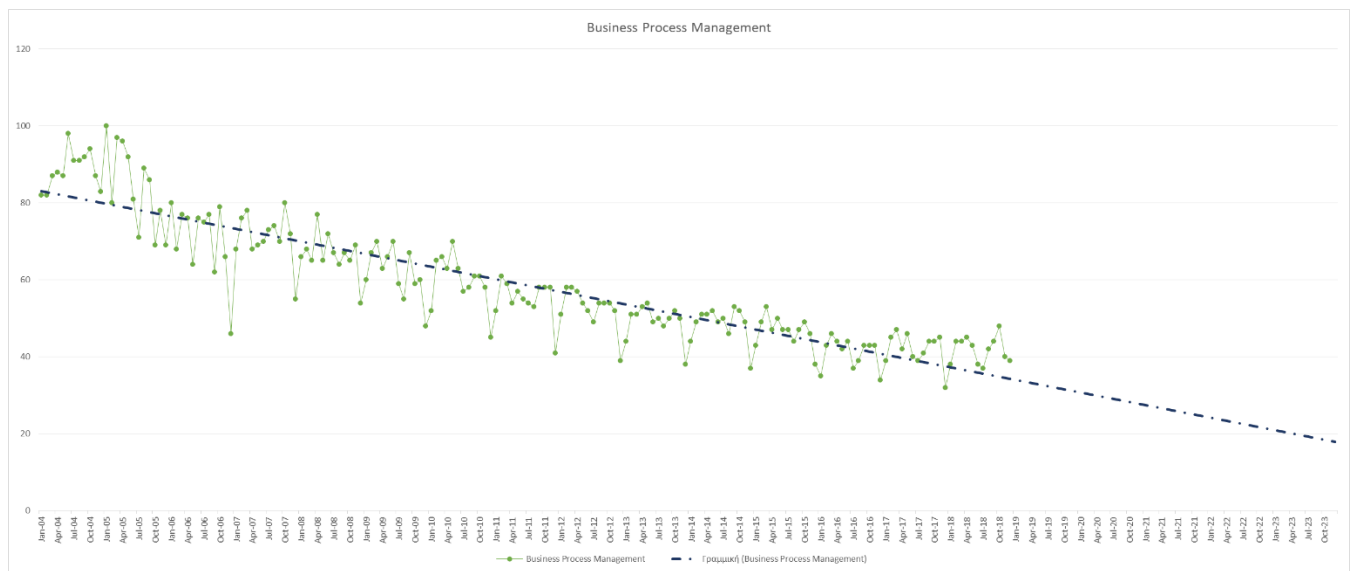


Figure 3. 6 Business Process Management trendline

As Figure 3.6 depicts, the linear trendline for Business Process Management is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abundance is expected for the next five years.

3.7 A summary of the findings on trendlines

A peculiar fact is observed: the internet searches reach their lowest point in every December of each year. As stated earlier in both the GRC and the BPI analyses, this can be only interpreted with a sense of humor, and assume that every December, with the winter holiday season in mind, everyone, including the BPM professionals, search the internet for more pleasant topics.

3.8 Top 20 countries in internet searches for our elements

The top countries selector allows the researcher to see in which location the term was most popular during the specified time frame. Scores are calculated on a scale from 0 to 100, where 100 is the location with the most popularity as a fraction of total searches in that location, a value of 50 indicates a location which is half as popular. A value of 0 indicates a location where there was not enough data for this term. An important note is that a higher score means a higher proportion of all searches/queries, not a higher absolute search/query count. Practically, a tiny country where 10% of the queries are for "process mining" will get ten times the score of a giant country where only 1% of the queries are for "process mining".

#	Process Mining	Enterprise Risk Management	Risk	Internal Audit	Governance, Risk Management and Compliance	Business Process Intelligence	Business Process Management					
1	Netherlands	100	Botswana	100	Mozambique	100	St. Helena	100	India	100	Cuba	100
2	South Africa	80	Zimbabwe	32	Cape Verde	98	Singapore	96	United States	41	Belize	38
3	Australia	46	Namibia	17	Togo	45	Qatar	85			Peru	35
4	Belgium	44	Zambia	15	Rwanda	45	United Arab Emirates	82			Ecuador	33
5	Germany	43	Ghana	12	Cameroon	43	South Africa	68			Colombia	28
6	South Korea	42	Kenya	11	Burundi	40	Oman	60			St. Helena	15
7	Chile	40	Singapore	10	Angola	40	Barbados	58			Chile	14
8	Austria	39	Jamaica	9	Zimbabwe	39	Bahrain	52			Nicaragua	13
9	Switzerland	37	South Africa	9	Swaziland	35	Luxembourg	44			El Salvador	13
10	Philippines	32	St. Helena	8	Gabon	35	India	44			Guatemala	13
11	Peru	28	Nigeria	8	Lesotho	34	Zambia	43			Honduras	12
12	Iran	24	Tanzania	7	Uganda	33	Kenya	41			Panama	12
13	Nigeria	24	El Salvador	6	Liberia	31	Australia	38			Namibia	11
14	India	18	China	6	Namibia	31	China	34			Costa Rica	11
15	Canada	16	Ecuador	5	Botswana	31	Canada	33			Bolivia	8
16	Portugal	15	Qatar	5	Congo Brazzaville	30	Hong Kong	31			Paraguay	8
17	China	12	Malaysia	5	Malawi	30	United Kingdom	30			Dominican Republic	7
18	Italy	11	Hong Kong	5	Romania	29	New Zealand	28			Mexico	7
19	Colombia	10	United Arab Emirates	5	Benin	28	United States	28			Angola	7
20	Russia	10	Uganda	4	Cote d ivoir	28	Malaysia	26			Singapore	7

Table 3 . 8 Top 20 countries for the search terms

Process Mining

The top five countries in the internet searches for the topic “process mining” are: i. Netherlands (100), ii. South Africa (80), iii. Australia (46), iv. Belgium (44) and v. Germany (43). The top place comes from The Netherlands, an expected result as in Eindhoven is the home of TUE (Eindhoven University of Technology) and the DSC/e (Data Science Center Eindhoven), where Prof.dr.ir. Wil van der Aalst (the godfather of process mining) was the scientific director. The second top result (80) comes from the country of South Africa and to the review is not relevant to process mining, as we acknowledge that it comes from searches conducted for mines, as the region of South Africa (and Africa in general), is rich in miners and precious metals. [Note: According to Wikipedia, the mineral industry of Africa is the largest mineral industries in the world. Africa is the second largest continent, with 30 million km² of land, which implies large quantities of resources. For many African countries, mineral exploration and production constitute significant parts of their economies and remain keys to economic growth. Africa is richly endowed with mineral reserves and ranks first or second in quantity of world reserves of gold, bauxite, cobalt, industrial diamond, phosphate rock, platinum-group metals (PGM), vermiculite, and zirconium]. The third top result comes from the country of Australia (46) and is directly connected with the academic field of process mining.

Enterprise Risk Management

The top 20 results in both country and city are dominating by the African region. Namely, the top 3 countries are Botswana, Zimbabwe, and Zambia.

This is a very strange finding indeed, as one might assume that the most prominent area of the internet searches for ERM would be the U.S.A., or a country in the core of E.U., where there are institutions, organizations and structures in general, that are most commonly identified with the essence of ERM.

Internal Audit

Once again, 19 out of the top 20 results in country dominating by the African continent. Namely, the top 3 countries are Mozambique, Cape Verde and Togo.

As the previous finding concerning Enterprise Risk Management, this is a very peculiar finding indeed, as one might assume that the most prominent area for the internet searches of the topic of “internal

audit” would be the U.S.A., or a country in the core of E.U., where there are institutions, organizations and structures in general, that are most commonly identified with the essence of internal audit.

Governance, Risk Management and Compliance

Concerning GRC, the top 3 countries are: St. Helena (100), followed by Singapore (96) and Qatar (85). United Arab Emirates (61) and South Africa (60). The aforementioned results are in a way expected, as Singapore, Qatar, UAE and South Africa are regions where there is a remarkable concentration of wealth and businesses. On the other hand, the small island of St. Helena comes as a surprise, as it is not characterized neither by its concentration of wealth, nor by its dominating presence of organizations and businesses in general. In fact, it is one of the most remote places in the entire world!

Business process intelligence

There are only two results in the internet searches by country concerning the topic of business process intelligence: i. India (100) and United States (41).

Business Process Management

The top country concerning the internet searches for the topic of Business Process Management is Cuba (100). The next countries of the top 5 are: ii. Belize (38), iii. Peru (35), iv. Ecuador (33) and v. Colombia (28). Once again, all the top 5 results come as a surprise, as these regions are not the typical BPM research regions. Judging by the common sense, we find it quite difficult for a BPM researcher to function properly in Colombia or Belize. Another quite peculiar fact is the presence of many Latin American, Indian and African countries and cities in the top 20 results.

3.9 Top 20 cities

#	Process Mining	Enterprise Risk Management	Internal Audit	Governance, Risk Management and Compliance	Business Process Intelligence	Business Process Management						
1	Eindhoven	100	Gaborone	100	Maputo	100	Naberezhnye Chelny	100	New York	100	San Isidro	100

2	Munich	9	Harare	33	Chiyoda	35	Pimpri-Chinchwad	37	Miraflores	77
3			Chiyoda	18	Bucharest	32	Gurgaon	28	Quito	67
4			Accra	14	Abidjan	31	Bengaluru	22	Trujillo	66
5			Sandton	14	Luanda	29	Sandton	20	La Victoria	60
6			Nairobi	11	Kampala	29	Noida	19	Santiago de Surco	56
7			Pretoria	10	Pretoria	24	Hyderabad	15	BreÅ±a	55
8			Johannesburg	10	Chuo	20	Singapore	14	San MartÃn de Porres	53
9			Beijing	10	BogotÃj	20	Abu Dhabi	14	Medellin	51
10			Singapore	9	Johannesburg	18	Doha	14	BogotÃj	51
11			Shanghai	7	Sandton	17	Dubai	13	San Juan de Lurigancho	51
12			Quito	7	Dar es Salaam	17	Johannesburg	13	Cartagena	49
13			Abu Dhabi	7	Cali	16	Porto Alegre	10	Pimpri-Chinchwad	47
14			Cape Town	6	Gurgaon	16	Ottawa	10	Cali	46
15			Lagos	6	Nairobi	15	Shanghai	10	Samborondon	43
16			Kuala Lumpur	6	Abu Dhabi	15	Montreal	10	Barranquilla	39
17			Washington	6	Medellin	15	Mumbai	9	Arequipa	33
18			Toronto	5	San Salvador	14	Sydney	8	Gurgaon	29
19			Makati	5	Doha	13	Chennai	8	Santiago	26
20			Dubai	5	Tehran	13	New York	7	Noida	26

Table 3 . 9 Top 20 cities for the search terms

Process Mining

The top result in city comes from the city of Eindhoven. This comes as no surprise, bearing in mind that in Eindhoven, Netherlands, is the home of TUE (Eindhoven University of Technology) and the DSC/e (Data Science Center Eindhoven), where Prof.dr.ir. Wil van der Aalst (the godfather of process mining) was the scientific director.

Enterprise Risk Management

As in the top 20 results by country, most of the top 20 results by city are dominated by cities from the African and Asian continents. The top 5 cities are: i. Gaborone (100), ii. Harare (33), iii. Chiyoda (18), iv. Accra (14), and v. Sandton (14). Once again, this is a very strange finding indeed, as one might assume that the most prominent area of the internet searches for ERM would be the U.S.A., or a country in the core of E.U., where there are institutions, organizations and structures in general, that are most commonly identified with the essence of ERM.

Internal Audit

Once again, all the top 20 results in both country and city are dominating by the African region. Namely, the top 5 cities are: i. Maputo (100), ii. Chiyoda (35), iii. Bucharest (32), iv. Abidjan (31) and v. Luanda (29). The only European/western city in the top 20 list is Bucharest. This is a very strange finding indeed, as one might assume that the most prominent area for the internet searches of the topic of “internal audit” would be the U.S.A., or a country in the core of E.U., where there are institutions, organizations and structures in general, that are most commonly identified with the essence of internal audit.

Governance, Risk Management and Compliance

The top city (100) is Naberezhnye Chelny of Tatarstan Republic, Russia, the next top city is Pimpri-Chinchwad in India (37), followed by: iii. Gurgaon (28), iv. Bengaluru (22) and v. Sandton (20) which are a strange choice of cities (to say the least) for top searches about Governance, Risk Management and Compliance.

Business process intelligence

The only city that appears as a result in the internet searches for the topic of Business process intelligence is New York City (100).

Business Process Management

The top city is San Isidro (100), followed by: ii. Miraflores (77), iii. Quito (67), iv. Trujillo (66) and v. La Victoria (60), which are, again, a strange choice of cities (to say the least) for top searches about Business Process Management. Quite peculiar is the presence of many South American cities in the top 20 results.

3.6 Top Related Topics

The top related topics are the most popular topics. Scoring is on a relative scale where a value of 100 is the most commonly searched topic and a value of 50 is a topic searched half as often as the most

popular term, and so on. For the elements of our analysis, their top related topics are presented in the table below:

#	Process Mining		Enterprise Risk Management		Internal Audit		Governance, Risk Management and Compliance		Business Process Intelligence		Business Process Management	
1	Process	100	Risk	100	Audit	100	Regulatory compliance	100	Business intelligence	100	Management	100
2	Mining	49	Business	89	ISO	14	SAP SE	78	Business process	58	Business process	93
3	Business process	24	Management	80	ISO 9000	6	Risk	68	Management	40	Process	54
4	Data	10	Risk management	79	Quality	6	Governance	53	Business	29	Process	25
5	Data mining	8	COSO	16	Training	6	Management	46	Process	28	IBM	19
6	Disco	8	Environmental Resources Management	9	Risk	5	Risk management	34	Data	26	Software	17
7	Process	5	Insurance	4	Institute of Internal Auditors	5	Security	11	Intelligence	19	Best practice	14
8	Wil van der Aalst	5	Risk assessment	3	Course	4	Access control	11	Business process management	16	Workflow	13
9	Mineral	5	Audit	3	Checklist	3	Oracle Corporation	9	System	16	Business Process Model and Notation	12
10	SAP SE	4	Deloitte	2	Certification	3	Glass fiber reinforced concrete	7	Information	11	Tool	12
11	Platinum	4	ISO	2	Report	3	Information technology	6	Process	11	Good manufacturing practice	11
12	Iron	3	Governance	2	Accounting	3	Role	6	Application software	9	Oracle Corporation	8
13	Ore	3	Regulatory compliance	2	Auditor	2	Gartner	6	Data warehouse	9	Quality	8
14	Prom	3	Internal control	2	Technical standard	2	Audit	5	Strategy	8	Beats Per Minute	7
15	Workflow	3	Operational risk	2	Internal control	2	Process	5	Analytics	8	Gartner	7
16	Copper	2	ISO 31000	2	Function	2	Process control	5	Analysis	8	SAP SE	7
17	Process modeling	2	Software framework	2	ISO 14000	2	Firefighter	4	Decision-making	7	Open-source model	7
18	Health Care	2	Enterprise resource planning	2	Risk management	2	Magic Quadrant	4	Software	7	Hazard analysis and critical control points	6
19	Data science	2	Governance, risk management and compliance	2	Quality management system	2	ServiceNow	4	Organization	6	Business process modeling	6
20	Gold mining	2	Certification	2	Control	2	Enterprise risk management	4	Architecture	6	Bizagi	5

Table 3 . 10 Top 20 Related Topics for the search terms

Process Mining

From the top 20 related topics, the vast majority of them (15) are dealing with business processes, relevant software, etc. and the remaining 5 of them are related to the mining industry.

Thus, from the homogeneity of the results, it is safe to conclude that business processes are the dominant relevant topic in searches for Process Mining.

Enterprise Risk Management

All of the top 20 related topics, are revolving around the notion of Enterprise Risk Management. The top result is the search for the word “risk”, whereas the following results span from searches about the ERM framework and organizations to employment as an auditor to finance, industry standards, etc. Overall, there is a strong homogeneity of the results in the Top Related Topics which indicates that the searches are not biased, and extremely focused around the notion of ERM.

Internal Audit

All of the top 20 related topics, are dealing, one way or another, with the notion of audit. The top result is the search for the word “audit”, whereas the following results span from searches about the employment as an auditor to finance, industry standards, etc. Overall, there is a strong homogeneity of the results in the Top Related Topics which indicates that the searches are not biased, and extremely focused.

Governance, Risk Management and Compliance

All of the top 20 related topics, are dealing, one way or another, with the notion of GRC. The top topic is Regulatory compliance (100), followed by SAP SE (79), Risk (66), Governance (43) and Management (38). The following results span from searches about the GRC framework and organizations to industry standards, software etc. Out of the top 20 related topics the only result which is not appropriate is the search for “Glass fiber reinforced concrete”. Overall, there is a strong homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused around the notion of GRC.

Business Process Intelligence

All of the top 20 related topics, are dealing, one way or another, with the notion of Business Process Intelligence. The top 5 topics are: i. Business intelligence (100), ii. Business process (58), iii.

Management (40), iv. Business (29) and v. Process (28). The top 20 results span from searches about the BPI framework and organizations to industry standards, software etc. Out of the top 20 related topics there is no result which is not connected to Business Process Intelligence. Overall, there is a strong homogeneity of the results in the Top Related Topics which indicates that the searches are not biased, and extremely focused around the notion of Business Process Intelligence.

Business Process Management

All of the top 20 related topics, are dealing, one way or another, with the notion of Business Process Management. The top topic comes for Management (100), followed by similar searches for other business processes and relevant software packages by IBM SAP, Bizagi etc. The top 20 results span from searches about the BPM framework and organizations to industry standards, software etc. Out of the top 20 related topics there is no result which is not connected to Business Process Management. Overall, there is a strong homogeneity of the results in the Top Related Topics which indicates that the searches are not biased, and extremely focused around the notion of Business Process Management

3.7 Rising Related Topics

The rising related topics are topics with the biggest increase in search frequency since the last time period. The majority of the topics mentioned had a tremendous increase, a “breakout”, which is a more than 5000% growth in searches, probably because these topics are new and had few (if any) prior searches. For the elements of our analysis, their rising related topics are presented in the table below:

#	Process Mining	Enterprise Risk Management	Internal Audit	Governance, Risk Management and Compliance	Business Process Intelligence	Business Process Management
1	Business process	Risk assessment	Question	SAP SE	Business intelligence	Business Process Model and Notation
2	Data	Audit	OHSAS 18001	Access control	Management	Oracle Corporation
3	Data mining	Deloitte	Role	Oracle Corporation	Business	Bizagi
4	Disco	Internal control	Quality management	Glass fiber reinforced concrete	Process	ISO
5	Process	Operational risk	Regulatory compliance	Information technology	Data	Appian Corporation
6	Wil van der Aalst	ISO 31000	Internship	Role	Intelligence	Methodology

7	Mineral	Software framework	Auditor's report	Gartner	System	Intalio Inc.
8	SAP SE	Enterprise resource planning	ISO 19011	Audit	Information	Information technology
9	Platinum	Governance, risk management and compliance	Evaluation	Process	Process	Pegasystems
10	Iron	Certification	ISO/IEC 17025	Process control	Application software	jBPM
11	Ore	Implementation	File format	Firefighter	Data warehouse	Java
12	Prom	Internal audit	ISO/TS 16949	Magic Quadrant	Strategy	Business intelligence
13	Workflow	Enterprise Rent-A-Car	Sarbanesâ€Oxley Act	ServiceNow	Analytics	IBM WebSphere
14	Copper	Process	Public sector	Enterprise risk management	Analysis	Sigma
15	Process modeling	Risk appetite	Audit plan	User	Decision-making	Camunda BPM
16	Health Care	Risk	Auditor	MetricStream	Software	METASTORM INC
17	Data science	Risk management	Technical standard	Software framework	Organization	IBM
18	Gold mining	Management	Risk management	Governance	Architecture	SAP SE
19	Logfile	Insurance	Training	Risk	Data mining	Process
20	Iron ore	Business	ISO	Regulatory compliance	Enterprise resource planning	Beats Per Minute

Table 3 . 11 Rising Related Topics for the search terms

Process Mining

In accordance with the results in the top 20 related topics in process mining, the top 20 rising topics in process mining, present a picture where, once again, the majority of them (13) are dealing with business processes, relevant software, etc., while 7 of them, are related with the mineral industry. Thus, from the homogeneity of the results, it is safe to conclude that the area of business processes is the dominant area in searches for Process Mining.

Enterprise Risk Management

All of the top 20 top related topics, are dealing, one way or another, with the notion of ERM. The top result is the topic "risk assessment", whereas the following results span from searches about the ERM framework and organizations to employment as an auditor to finance, industry standards, etc. Corresponding to the results from the we get the same picture in the rising related topics, where, again, all of the results are consistently dealing with the business audit and ERM perspective, consultancy, etc. Overall, there is a strong homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused around the notion of ERM.

Internal Audit

All of the top 20 related topics, are dealing, one way or another, with the notion of audit. The top result is the search for the word “question”, whereas the following results span from searches about the employment as an auditor to finance, industry standards, etc. Correspondingly, we get the same picture in the rising related topics, where, again, all of the results are consistently dealing with the business audit perspective, consultancy, etc. Overall, there is a strong homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused.

Governance, Risk Management and Compliance

All of the top 20 related topics, are dealing, one way or another, with the notion of GRC. The top search topic is SAP SE with all of the results are consistently dealing with the business audit and GRC perspective, organizations, consultancy, etc. Overall, there is a strong homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused around the notion of GRC.

Business process intelligence

All of the top 20 rising related topics results are consistently dealing with the BPI perspective, organizations, consultancy, etc. Overall, there is a strong homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused around the notion of BPI.

Business Process Management

All of the top 20 rising related topics are consistently dealing with the business processes and BPM perspective, organizations, consultancy, etc. Overall, there is a strong homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused around the notion of BPM.

3.8 Top Related Queries

The top related queries are the most popular queries. Scoring is on a relative scale where a value of 100 is the most commonly searched query and a value of 50 is a query searched half as often as the

most popular query, and so on. For the elements of our analysis, their top related queries are presented in the table below:

#	Process Mining		Enterprise Risk Management		Internal Audit		Governance, Risk Management and Compliance		Business Process Intelligence		Business Process Management	
1	mining	100	risk	100	audit	100	grc	100	business process management	100	bpm	100
2	process mining	99	enterprise	93	internal audit	77	compliance	31	bi process	40	business process	47
3	process	95	enterprise risk	92	auditor	46	compliance risk	29	what is business intelligence	28	business management	42
4	process of mining	20	risk management	82	auditoria	43	sap	25	business analytics	15	process management	41
5	data mining	8	enterprise risk management	77	auditoria interna	42	grc sap	24	etl process	9	business management process	40
6	mining processes	7	enterprise management	76	iso	34	risk and compliance	17	business intelligence analyst	8	procesos	24
7	celonis	5	erm	51	internal auditor	29	governance	15	artificial intelligence	6	gestion	23
8	celonis process mining	5	erm risk	20	át...éf" ç)Éæÿ»	18	governance risk	14			bpm process	17
9	disco process mining	4	coso	17	interne audit	14	risk management	10			bpms	15
10	disco	4	erm coso	14	iso 9001	14	governance risk compliance	10			gestion de procesos	13
11	what is process mining	4	erm risk management	13	auditor interno	13	grc risk	7			bpm business process	11
12	process mining pdf	3	erm enterprise risk management	10	revision	12	compliance management	7			bpm management	10
13	process mining tools	3	risk management framework	8	auditorias	11	compliance risk management	7			ibm	10
14	process mining software	3	enterprise risk management framework	7	interne revision	10	grc in sap	5			prozessmanagement	9
15	mineria de procesos	2	erm framework	6	audit intern	10	risk and compliance management	4			ibm bpm	8
16	iron ore mining process	2	coso framework	4	iso internal audit	10	grc security	3			business process management bpm	8

17	platinum mining	1	coso enterprise risk management	4	internal auditors	10	grc access control	3	gestion por procesos	7
18	proces mining	1	business risk	4	auditorias internas	10	what is grc	3	workflow	6
19	process mining book	1	risk assessment	4	auditing	10	sap grc access control	3	bpmn	6
20			risk definition	3	internal auditing	9	grc software	3	proceso de gestion	6

Table 3 . 12 Top Related Queries for the search terms

Process Mining

In all the top 20 related queries, the vast majority of them (17) are dealing with business processes, relevant software, etc. and only 3 are related with the mineral industry. Thus, from the homogeneity of the results, it is safe to conclude that the searches are not biased and strongly focused.

Internal Audit

All of the top 20 related queries are, as expected, dealing with the notion of audit. Once again, The top result (100) is the search for the word “audit” and once again the following results span from searches about the employment as an auditor to finance, industry standards, etc. An important finding is that for the first time searches in the Latin American and Chinese language are noticed, a fact that mirrors a rising concern about internal audit and related business tools in a vast part out of the Western world. Overall, we observe a solid homogeneity of the results in the Top Related Topics which indicates that the searches are not biased, and extremely focused.

Enterprise Risk Management

All of the top 20 related queries are, as expected, dealing with the notion of ERM. Once again, the top result (100) is the search for the word “risk” and once again the results are dealing with searches about industry standards, certifications, firms etc. Overall, we observe a solid homogeneity of the results in the Top Related Topics which indicates that the searches are not biased, and extremely focused.

Governance, Risk Management and Compliance

All of the top 20 related queries are, as expected, dealing with the notion of GRC. Once again, the top result (100) is the search for the word “risk” and once again the results are dealing with searches about industry standards, certifications, firms etc. Overall, we observe a solid homogeneity of the results in the Top Related Topics which indicates that the searches are not biased, and extremely focused.

Business process intelligence

All of the top 20 related queries are, as expected, dealing with the notion of BPI. Once again, the top result (100) is the search for the word “risk” and once again the results are dealing with searches about industry standards, certifications, firms etc. Overall, we observe a solid homogeneity of the results in the Top Related Topics which indicates that the searches are not biased, and extremely focused.

Business Process Management

All of the top 20 related queries are, as expected, dealing with the notion of BPM. Once again, the top result (100) is the search for the word “risk” and once again the results are dealing with searches about industry standards, certifications, firms etc. Overall, we observe a solid homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused.

3.9 Rising Related Queries

The rising related queries are queries with the biggest increase in search frequency since the last time period. The majority of the queries mentioned had a tremendous increase, a “breakout”, which is a more than 5000% growth in searches, probably because the topics of these queries are new and had few (if any) prior searches. For the elements of our analysis, their rising related queries are presented in the table below:

#	Process Mining	Enterprise Risk Management	Internal Audit	Governance, Risk Management and Compliance	Business Process Intelligence	Business Process Management
---	----------------	----------------------------	----------------	--	-------------------------------	-----------------------------

1	data mining	enterprise risk assessment	checklist	sap	what is business intelligence	ibm bpm
2	celonis	enterprise risk management pdf	internal audit manager	grc sap	business analytics	oracle bpm
3	celonis process mining	financial risk management	curso auditor interno	risk and compliance	etl process	business process manager
4	disco process mining	enterprise risks	auditoria interna iso 9001	governance risk	business intelligence analyst	bpm alimentos
5	disco	enterprise risk management software	curso de auditor interno	governance risk compliance	artificial intelligence	bpm que es
6	process mining pdf	operational risk	curso de auditor interno	grc risk		bizagi
7	process mining tools	enterprise risk manager	internal audit course	compliance risk management		procesos bpm
8	process mining software	enterprise risk control	curso auditoria interna	grc in sap		bpm bizagi
9	mineria de procesos	risk management training	iso 9001 internal audit checklist	risk and compliance management		appian
10	proces mining	risk management process	normas de auditoria interna	grc access control		bpm tools
11	process mining book	iso 31000	internal auditor certification	what is grc		tibco
12		operational risk management	internal audit courses	sap grc access control		lombardi
13		erm model	que es auditoria interna	grc software		bpm en alimentos
14		insurance erm	curso de auditoria interna	grc governance risk compliance		lombardi bpm
15		enterprise risk management training	pwc internal audit			erp
16		risk management	plan de auditoria interna	risk & compliance		business process management pdf
17		erm definition	ohsas 18001	grc risk management		bpm tutorial
18		deloitte enterprise risk services	iso 9001 internal auditor training	sap grc 10		bmp
19		risk management plan	director of internal audit	it grc		ibm business process manager
20		risk management certification	iso 19011	sap security		intalio

Table 3 . 13 Rising Related Queries for the search terms

Process Mining

As presented in the top rising related queries, the vast majority of them (18) are dealing with business processes, relevant software, etc. and only 2 are related with the mineral industry. Thus, from the homogeneity of the results, it is safe to conclude that the searches are not biased and strongly focused.

Internal Audit

From the rising related topics table, we notice searches in the Latin American, Arabic and Russian languages. A fact that clearly depicts that internal auditing is a matter of worldwide concern. Overall, we observe a solid homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused.

Enterprise Risk Management

All of the top rising related queries are, as expected, dealing with the notion of ERM. Overall, we observe a solid homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused.

Governance, Risk Management and Compliance

All of the top rising related queries are, as expected, dealing with the notion of GRC. Overall, we observe a solid homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused.

Business process intelligence

All of the top rising related queries are, as expected, dealing with the notion of Business process intelligence and once again the results are dealing with searches about industry standards, certifications, firms etc. Overall, we observe a solid homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused.

Business Process Management

All of the rising related queries are, as expected, dealing again with the notion of BPM. The results are dealing with searches about industry standards, certifications, firms etc. Overall, we observe a solid homogeneity of the results in the Top Related Topics and Top Rising Related Topics, which indicates that the searches are not biased, and extremely focused.

3.10 Conclusions for the investigation of the “R – P” ontology through Google trends

Through the use of Google Trends tool we tried to shed some light on the non-academic side of the elements of the “R – P” ontology. What was examined was the performance (scores) of the Ontology’s elements in searches conducted worldwide, from January 2004 to December 2018, in the “Business & Industrial” category. The factors examined were: i) Interest over time, ii) Hi’s and Low’s, iii) elements actual and 5-year predicted trendline, iv) Top 20 countries, v) Top 20 cities, vi) Top Related Topics, vii) Rising Related Topics, viii) Top Related Queries, and ix) Rising Related Queries.

The most striking fact is that all elements, apart from Process Mining, are poorly performing in the last decade, and their 5-year prediction is also presented with a clear downward trendline. Process mining is performing better than the other elements and there is a predicted slightly upward trendline, but overall the results were far below our initial expectations.

Due to the construction of the Google Trends score, where a higher score means a higher proportion of all searches/queries, and not a higher absolute search/query count, we had the presence of some strange results, like the remote island of St. Helena or the dominance from African or South American countries in many categories. That comes as a result of the fact that a tiny country where e.g. 1% of the queries are for "process mining" will get ten times the score of a big country where only 0,1% of the queries are for "process mining".

In other, the results on searches and queries were pretty solid and coherent with the only distortion coming from the scores of Process mining, where there were presents a small number of searches for mining activities and related terminology.

Chapter 4

A statistical analysis of the Google Trends timelines through SPSS

SPSS Statistics is a software package used for interactive, or batched, statistical analysis. Long produced by SPSS Inc., it was acquired by IBM in 2009 and since then the current versions are named IBM SPSS Statistics. SPSS is a widely used program for statistical analysis in social science and economics and it is also used by market researchers, health researchers, survey companies, governments, marketing organizations, data miners, and others. The original SPSS manual (Nie, Bent & Hull, 1970) has been described by (Wellman, 1998) as one of "sociology's most influential books" for allowing ordinary researchers to do their own statistical analysis.

4.1 The rationale behind the statistical analysis of time series

Time series is a series of data points indexed in time order. Most commonly, a time series is a sequence taken at successive equally spaced points in time. Thus it is a sequence of discrete-time data. Time series analysis comprises methods for analyzing time series data in order to extract meaningful statistics and other characteristics of the data.

In order to analyze the time series of the scores obtained, the statistical measures will be:

- Frequency tables
- Descriptive statistics
- Correlations
- Non-parametric correlations

4.2 Process mining Frequency Table

Process Mining			
Score	Frequency	Percent	Cumulative Percent
25	12	6,67	6,7
18	9	5	11,7
21	9	5	16,7
23	9	5	21,7
20	7	3,89	25,6
26	7	3,89	29,4
29	7	3,89	33,3
30	7	3,89	37,2
17	6	3,33	40,6
27	6	3,33	43,9
32	6	3,33	47,2
12	5	2,78	50
14	5	2,78	52,8
16	5	2,78	55,6
22	5	2,78	58,3
35	5	2,78	61,1
15	4	2,22	63,3
28	4	2,22	65,6
33	4	2,22	67,8
19	3	1,67	69,4
34	3	1,67	71,1
36	3	1,67	72,8
37	3	1,67	74,4
38	3	1,67	76,1
41	3	1,67	77,8
43	3	1,67	79,4
48	3	1,67	81,1
13	2	1,11	82,2
24	2	1,11	83,3
31	2	1,11	84,4
40	2	1,11	85,6
42	2	1,11	86,7
49	2	1,11	87,8
50	2	1,11	88,9
55	2	1,11	90
57	2	1,11	91,1
62	2	1,11	92,2
10	1	0,56	92,8
100	1	0,56	93,3
44	1	0,56	93,9
45	1	0,56	94,4
46	1	0,56	95
47	1	0,56	95,6
51	1	0,56	96,1
53	1	0,56	96,7
58	1	0,56	97,2

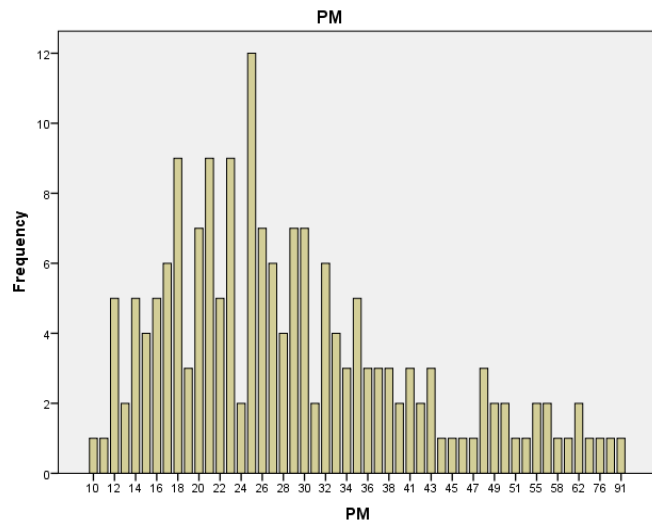


Figure 4. 1 Process Mining Google Trends Timeline bar chart

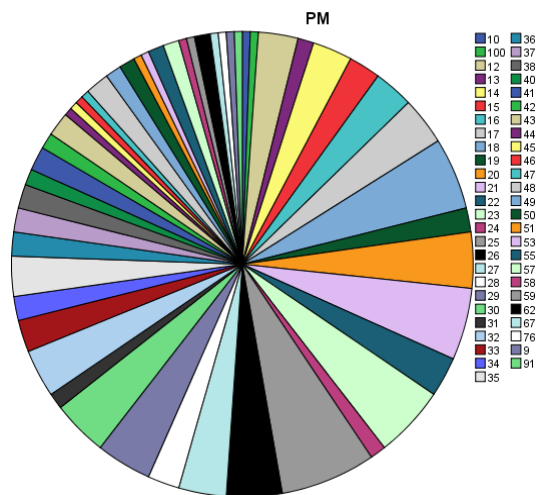


Figure 4. 2 Process Mining Google Trends Timeline pie chart

59	1	0,56	97,8
67	1	0,56	98,3
76	1	0,56	98,9
9	1	0,56	99,4
91	1	0,56	100
Total	180	100	

Table 4. 1 Frequency table for Process Mining

4.3 Enterprise Risk Management Frequency Table

Enterprise Risk Management			
Score	Frequency	% in desc. order	Cumulative %
33	12	6,67	6,67
35	12	6,67	13,33
36	11	6,11	19,44
32	8	4,44	23,89
34	8	4,44	28,33
37	8	4,44	32,78
39	7	3,89	36,67
60	7	3,89	40,56
30	6	3,33	43,89
41	6	3,33	47,22
67	6	3,33	50,56
47	5	2,78	53,33
40	4	2,22	55,56

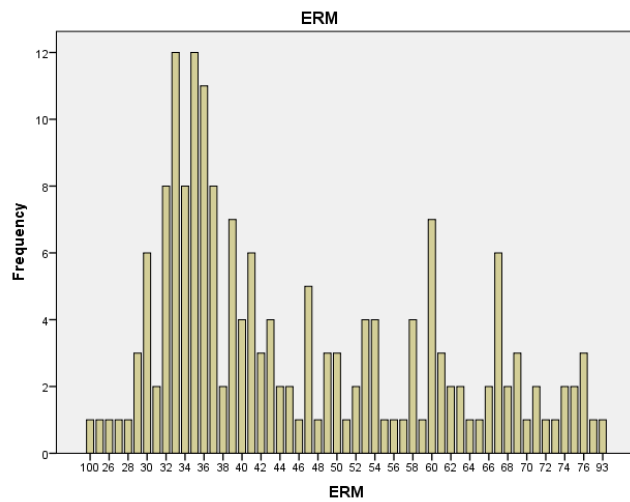


Figure 4. 3 Enterprise Risk Management Google Trends Timeline bar chart

43	4	2,22	57,78
53	4	2,22	60
54	4	2,22	62,22
58	4	2,22	64,44
29	3	1,67	66,11
42	3	1,67	67,78
49	3	1,67	69,44
50	3	1,67	71,11
61	3	1,67	72,78
69	3	1,67	74,44
76	3	1,67	76,11
31	2	1,11	77,22
38	2	1,11	78,33
44	2	1,11	79,44
45	2	1,11	80,56
52	2	1,11	81,67
62	2	1,11	82,78
63	2	1,11	83,89
66	2	1,11	85
68	2	1,11	86,11
71	2	1,11	87,22
74	2	1,11	88,33
75	2	1,11	89,44
100	1	0,56	90
25	1	0,56	90,56
26	1	0,56	91,11
27	1	0,56	91,67
28	1	0,56	92,22
46	1	0,56	92,78
48	1	0,56	93,33
51	1	0,56	93,89
55	1	0,56	94,44
56	1	0,56	95
57	1	0,56	95,56
59	1	0,56	96,11
64	1	0,56	96,67
65	1	0,56	97,22
70	1	0,56	97,78
72	1	0,56	98,33
73	1	0,56	98,89
83	1	0,56	99,44
93	1	0,56	100
Total	180	100	

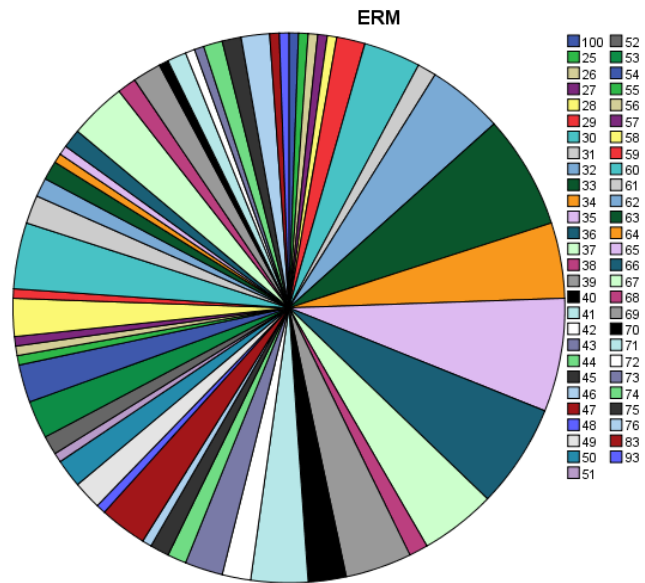


Figure 4. 4 Enterprise Risk Management Google Trends Timeline pie chart

Table 4. 2 Frequency table for Enterprise Risk Management

4.4 Internal Audit Frequency Table

Internal Audit			
Score	Frequency	% in desc. order	Cumulative %
100	12	6,67	6,67
33	12	6,67	13,33
34	10	5,56	18,89
36	10	5,56	24,44
37	8	4,44	28,89
38	7	3,89	32,78
39	7	3,89	36,67
40	7	3,89	40,56
41	7	3,89	44,44
42	6	3,33	47,78
43	6	3,33	51,11
44	5	2,78	53,89
45	5	2,78	56,67
46	5	2,78	59,44
47	5	2,78	62,22
48	5	2,78	65
49	5	2,78	67,78
50	4	2,22	70
51	4	2,22	72,22
53	3	1,67	73,89
54	3	1,67	75,56
55	3	1,67	77,22
56	3	1,67	78,89
57	3	1,67	80,56
58	3	1,67	82,22
59	3	1,67	83,89
60	3	1,67	85,56
61	2	1,11	86,67
62	2	1,11	87,78
63	2	1,11	88,89
65	2	1,11	90
66	2	1,11	91,11
67	1	0,56	91,67
68	1	0,56	92,22
69	1	0,56	92,78
70	1	0,56	93,33
71	1	0,56	93,89
73	1	0,56	94,44
74	1	0,56	95
75	1	0,56	95,56
76	1	0,56	96,11
77	1	0,56	96,67
79	1	0,56	97,22
80	1	0,56	97,78
81	1	0,56	98,33
82	1	0,56	98,89
83	1	0,56	99,44
85	1	0,56	100

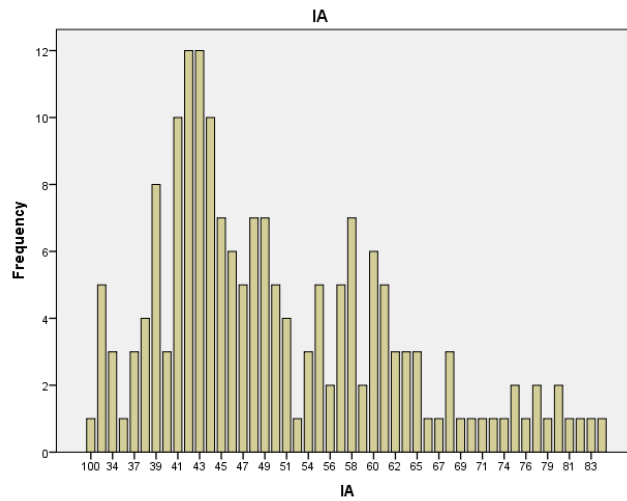


Figure 4. 5 Internal Audit Google Trends Timeline bar chart

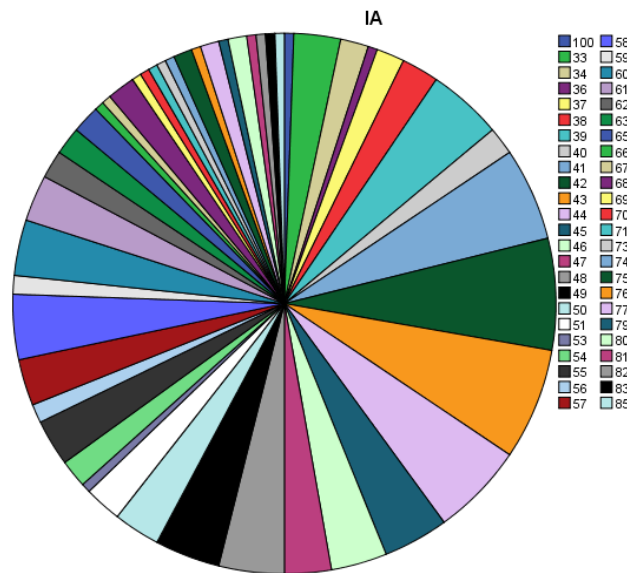


Figure 4. 6 Internal Audit Google Trends Timeline pie chart

Total	180	100	
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Table 4. 3 Frequency table for Internal Audit

4.5 Governance, Risk Management and Compliance Frequency Table

Governance, Risk Management and Compliance			
Score	Frequency	% in desc. order	Cumulative %
100	24	13,33	13,33
25	16	8,89	22,22
27	16	8,89	31,11
28	9	5	36,11
30	8	4,44	40,56
31	8	4,44	45
32	7	3,89	48,89
33	7	3,89	52,78
34	6	3,33	56,11
35	6	3,33	59,44
36	6	3,33	62,78
37	5	2,78	65,56
38	5	2,78	68,33

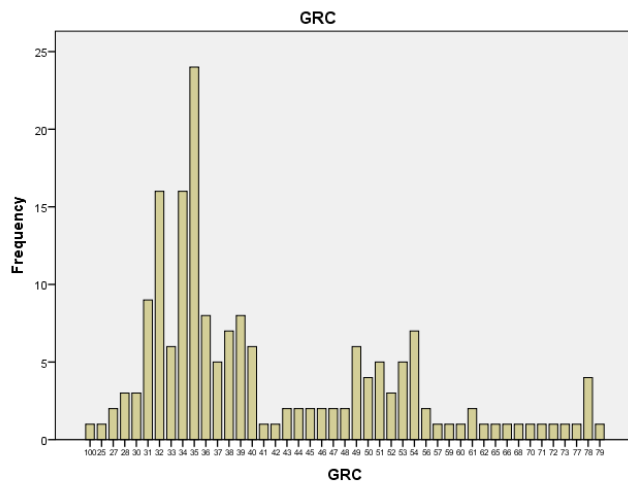


Figure 4. 7 Governance, Risk Management and Compliance Google Trends Timeline bar chart

39	5	2,78	71,11
40	4	2,22	73,33
41	4	2,22	75,56
42	3	1,67	77,22
43	3	1,67	78,89
44	3	1,67	80,56
45	2	1,11	81,67
46	2	1,11	82,78
47	2	1,11	83,89
48	2	1,11	85
49	2	1,11	86,11
50	2	1,11	87,22
51	2	1,11	88,33
52	2	1,11	89,44
53	2	1,11	90,56
54	1	0,56	91,11
56	1	0,56	91,67
57	1	0,56	92,22
59	1	0,56	92,78
60	1	0,56	93,33
61	1	0,56	93,89
62	1	0,56	94,44
65	1	0,56	95
66	1	0,56	95,56
68	1	0,56	96,11
70	1	0,56	96,67
71	1	0,56	97,22
72	1	0,56	97,78
73	1	0,56	98,33
77	1	0,56	98,89
78	1	0,56	99,44
79	1	0,56	100
Total	180	100	

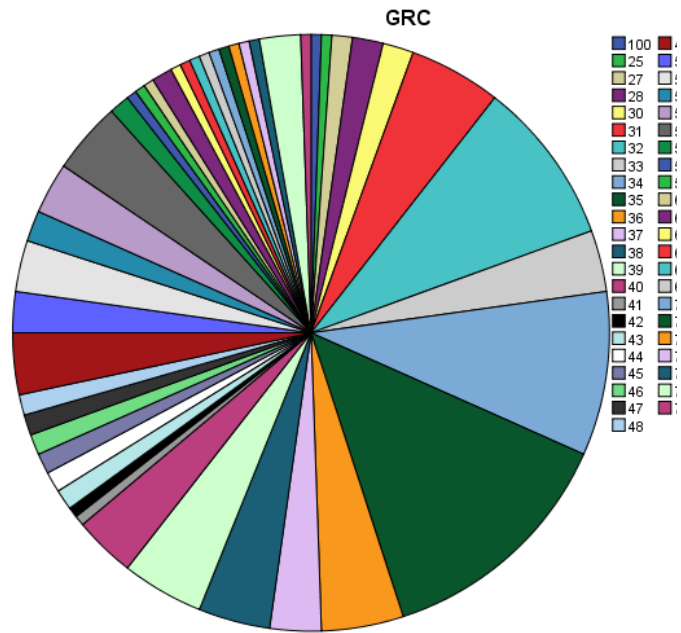


Figure 4. 8 Governance, Risk Management and Compliance Google Trends Timeline pie chart

Table 4. 4 Frequency table for Governance, Risk Management and Compliance

4.6 Business Process Intelligence Frequency Table

Business Process Intelligence			
Score	Frequency	% in desc. order	Cumulative %
18	18	10	10
16	11	6,11	16,11
20	11	6,11	22,22
15	10	5,56	27,78
19	10	5,56	33,33
17	9	5	38,33
21	9	5	43,33
14	8	4,44	47,78
24	8	4,44	52,22
22	7	3,89	56,11
26	7	3,89	60
29	7	3,89	63,89
27	6	3,33	67,22
0	5	2,78	70
12	5	2,78	72,78
25	5	2,78	75,56
13	4	2,22	77,78
23	4	2,22	80
28	4	2,22	82,22
31	3	1,67	83,89
11	2	1,11	85
30	2	1,11	86,11
32	2	1,11	87,22
34	2	1,11	88,33
37	2	1,11	89,44
61	2	1,11	90,56
8	2	1,11	91,67
10	1	0,56	92,22
100	1	0,56	92,78
33	1	0,56	93,33
35	1	0,56	93,89
38	1	0,56	94,44
41	1	0,56	95
49	1	0,56	95,56
53	1	0,56	96,11
54	1	0,56	96,67
56	1	0,56	97,22
60	1	0,56	97,78
64	1	0,56	98,33
66	1	0,56	98,89
71	1	0,56	99,44
99	1	0,56	100
Total	180	100	

Table 4. 5 Frequency table for Business Process Intelligence

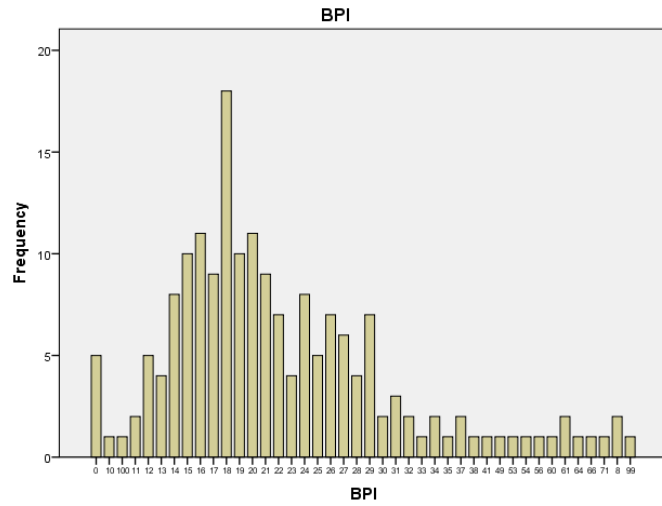


Figure 4. 9 Business Process Intelligence Google Trends Timeline bar chart

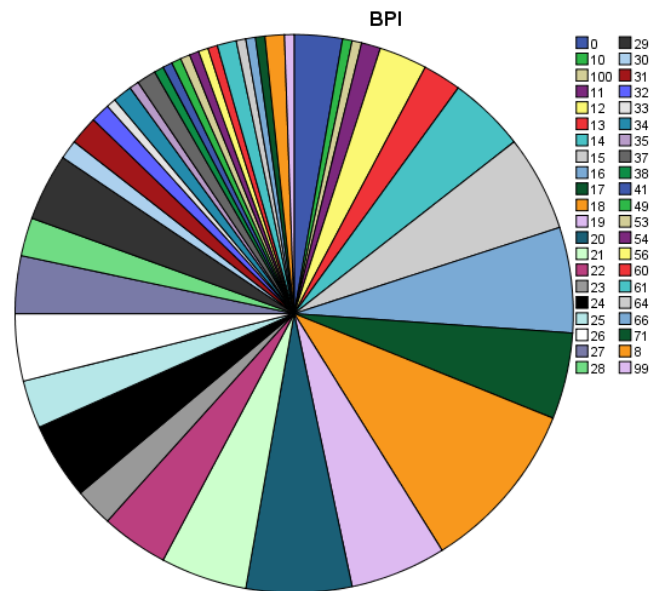


Figure 4. 10 Business Process Intelligence Google Trends Timeline pie chart

4.7 Business Process Management Frequency Table

Business Process Management			
Score	Frequency	% in desc. order	Cumulative %
100	10	5,56	5,56
32	8	4,44	10
34	7	3,89	13,89
35	7	3,89	17,78
37	7	3,89	21,67
38	6	3,33	25
39	5	2,78	27,78
40	5	2,78	30,56
41	5	2,78	33,33
42	5	2,78	36,11
43	5	2,78	38,89
44	5	2,78	41,67
45	4	2,22	43,89
46	4	2,22	46,11
47	4	2,22	48,33
48	4	2,22	50,56
49	4	2,22	52,78
50	4	2,22	55
51	4	2,22	57,22
52	4	2,22	59,44
53	3	1,67	61,11
54	3	1,67	62,78
55	3	1,67	64,44
57	3	1,67	66,11
58	3	1,67	67,78
59	3	1,67	69,44
60	3	1,67	71,11
61	3	1,67	72,78
62	3	1,67	74,44
63	3	1,67	76,11
64	3	1,67	77,78
65	3	1,67	79,44
66	2	1,11	80,56
67	2	1,11	81,67
68	2	1,11	82,78
69	2	1,11	83,89
70	2	1,11	85
71	2	1,11	86,11
72	2	1,11	87,22
73	2	1,11	88,33
74	2	1,11	89,44
75	1	0,56	90
76	1	0,56	90,56
77	1	0,56	91,11

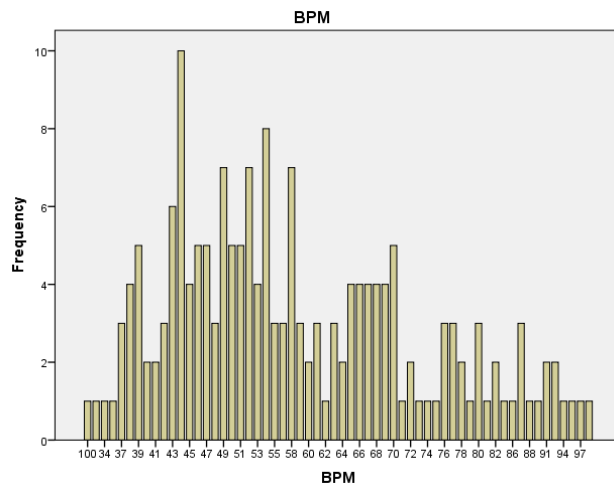


Figure 4. 11 Business Process Management Google Trends Timeline bar chart

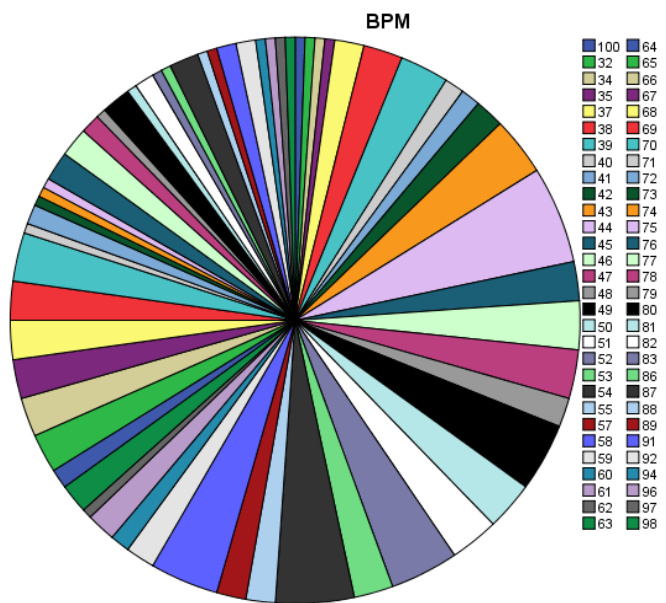


Figure 4. 12 Business Process Management Google Trends Timeline pie chart

78	1	0,56	91,67
79	1	0,56	92,22
80	1	0,56	92,78
81	1	0,56	93,33
82	1	0,56	93,89
83	1	0,56	94,44
86	1	0,56	95
87	1	0,56	95,56
88	1	0,56	96,11
89	1	0,56	96,67
91	1	0,56	97,22
92	1	0,56	97,78
94	1	0,56	98,33
96	1	0,56	98,89
97	1	0,56	99,44
98	1	0,56	100
Total	180	100	

Table 4. 6 Frequency table for Business Process Management

4.8 Descriptive statistics

Based on Table 4.7 we can underline a few remarks concerning the statistical findings:

Statistics						
	PM	ERM	IA	GRC	BPI	BPM
Number of values valid	180	180	180	180	180	180
Mean	29.66	46.60	51.21	42.33	23.31	58.64
Std. Error of Mean	1.065	1.118	.931	.958	1.046	1.168
Median	26.00	41.00	48.00	37.00	20.00	54.00
Mode	25	33 ^a	42 ^a	35	18	44
Std. Deviation	14.291	15.005	12.497	12.848	14.040	15.666
Variance	204.238	225.135	156.175	165.071	197.109	245.428
Skewness	1.711	.878	1.050	1.565	2.684	.668
Kurtosis	4.545	.087	.911	2.595	10.331	-.324
Range	91	75	67	75	100	68
Minimum	9	25	33	25	0	32
Maximum	100	100	100	100	100	100
Sum	5338	8388	9217	7619	4196	10555

Table 4. 7 Descriptive statistics

- i) The range of the scores varies from 100 (as the lowest score was 0 for Business Process Intelligence) to 67 (the lowest score for Internal Audit). A small value in range states that the fluctuation is small and the searches for the topic are coherent and continuous throughout the examined period (2004 - 2018).
- ii) The mean for the time series of elements varies from the lowest values of 23,81 (for Business Process Intelligence) to the top value of 58,64 (for Business Process Management). A small value in the mean states that the volume of searches for the topic under consideration is not sizable and respectfully, as the topic is not popular, is not considered of great importance. On the other hand, a great value in the mean, states that the volume of searches for the topic under consideration is sizable and respectfully, as the topic is popular and of great importance.

4.3.1. Correlations

A common metric of correlation in statistics is the Pearson correlation coefficient.

The Pearson correlation coefficient is a measure of the linear correlation between two variables and takes a range of values from +1 to -1.

A value of 0 indicates that there is no association (linear relation) between the two variables. A value greater than 0 indicates a positive association. That is, as the value of one variable increases, so does the value of the other variable. From the results presented in Table 4.9 of Correlations, the element that seems to have a biggest correlation with Process Mining is Enterprise Risk Management, with a value of 0,257.

Another metric of the relation between Process Mining and the other elements, is covariance. Covariance is a measure of the joint variability of two variables. If the greater values of one variable mainly correspond with the greater values of the other

variable, and the same holds for the lesser values, (i.e., the variables tend to show similar behavior), the covariance is positive. In the opposite case, when the greater values of one variable mainly correspond to the lesser values of the other, (i.e., the variables tend to show opposite behavior), the covariance is negative. The sign of the covariance therefore shows the tendency in the linear relationship between the variables. From the results presented in Table 4.9 of Correlations, the element that seems to have a biggest covariance with Process Mining is again Enterprise Risk Management, with a value of 47,114

Correlations						
		PM	ERM	IA	GRC	BPI
PM	Pearson Correlation	1	.145	.167*	.257**	.145
	Sig. (2-tailed)		.053	.025	.001	.052
	Sum of Squares and Cross-products	36.558.644	5.550.200	5.330.744	8.433.322	5.214.289
	Covariance	204.238	31.007	29.781	47.114	29.130

Table 4. 8 Correlations

4.3.2 Non-parametric Correlations table

Kendall rank correlation coefficient, commonly referred to as Kendall's tau coefficient, is a statistic used to measure the ordinal association between two measured quantities. A tau test is a non-parametric hypothesis test for statistical dependence based on the tau coefficient. It is a measure of rank correlation: the similarity of the orderings of the data when ranked by each of the quantities. Intuitively, the Kendall correlation between two variables will be high when observations have a similar (or identical for a correlation of 1) rank (i.e. relative position label of the observations within the variable: 1st, 2nd, 3rd, etc.) between the two variables, and low when observations have a dissimilar (or fully different for a correlation of -1) rank between the two variables.

Spearman's rank correlation coefficient or Spearman's rho, is also a nonparametric measure of rank correlation (statistical dependence between the rankings of two

variables). It assesses how well the relationship between two variables can be described using a monotonic function. The Spearman correlation between two variables is equal to the Pearson correlation between the rank values of those two variables; while Pearson's correlation assesses linear relationships, Spearman's correlation assesses monotonic relationships (whether linear or not). If there are no repeated data values, a perfect Spearman correlation of +1 or -1 occurs when each of the variables is a perfect monotone function of the other. Intuitively, the Spearman correlation between two variables will be high when observations have a similar (or identical for a correlation of 1) rank (i.e. relative position label of the observations within the variable: 1st, 2nd, 3rd, etc.) between the two variables, and low when observations have a dissimilar (or fully opposed for a correlation of -1) rank between the two variables. Spearman's coefficient is appropriate for both continuous and discrete ordinal variables.

Nonparametric Correlations						
			PM	ERM	IA	GRC
Kendall's tau	PM	Correlation Coefficient	1.000	-.016	-.011	.055
		Sig. (2-tailed)	.	.758	.831	.286
Spearman's rho	PM	Correlation Coefficient	1.000	-.015	-.012	.087
		Sig. (2-tailed)	.	.845	.877	.248

Table 4. 9 Non-parametric Correlations

From the Table 4.10 of non-parametric correlations, it is once more observed that the element with the greater resemblance to Process Mining is Governance, Risk Management & Compliance with a Kendall's tau of 0,055 and a Spearman's rho of 0.087

4.4 Remarks for the building of the model

The model building summary for the ontology elements is presented in Table 4.15 and Figure 4.21 below.

Target: PM

	Step		
	1	2	3
Information Criterion	947.956	940.804	936.797
GRC_transformed	✓	✓	✓
Effect BPM_transformed		✓	✓
BPI_transformed			✓

The model building method is Forward Stepwise using the Information Criterion. A checkmark means the effect is in the model at this step.

Table 4. 10 Model Building Summary

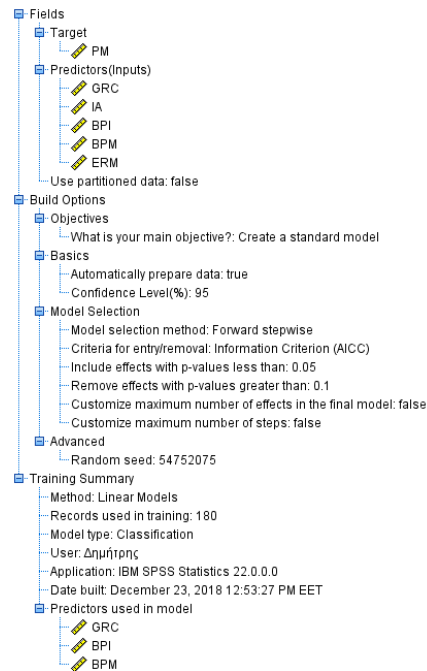


Figure 4. 13 Model Building Summary

4.4.1 Regression method

The method used in SPSS for regression was Automatic Linear Modeling. In statistics, linear regression is a linear approach to modelling the relationship between a scalar response (or dependent variable) and one, or more, explanatory variables (or independent variables). The case of one explanatory variable is called simple linear regression. In linear regression, the relationships are modeled using linear predictor functions whose unknown model parameters are estimated from the data. Such models are called linear models. Most commonly, the conditional mean of the response given the values of the explanatory variables (or predictors) is assumed to be an affine function of those values. Like all forms of regression analysis, linear regression focuses on the conditional probability distribution of the response given the values of the

predictors, rather than on the joint probability distribution of all of these variables, which is the domain of multivariate analysis.

We set Process Mining as the target (dependent) variable, where the input independent variables (predictors) were i. Enterprise Risk Management, ii. Internal Audit, iii. Governance, Risk Management & Compliance, iv. Business Process Intelligence and v. Business Process Management.

4.4.2. Confidence Interval

The confidence level (interval) was set to 95%. In statistics, a confidence interval is a type of interval estimate, computed from the statistics of the observed data, which might contain the true value of an unknown population parameter. The confidence level is designated prior to examining the data. The interval has an associated confidence level that, loosely speaking, quantifies the level of confidence that the parameter lies in the interval. More strictly speaking, the confidence level represents the frequency (i.e. the proportion) of possible confidence intervals that contain the true value of the unknown population parameter. In other words, if confidence intervals are constructed using a given confidence level from an infinite number of independent sample statistics, the proportion of those intervals that contain the true value of the parameter will be equal to the confidence level. Confidence intervals consist of a range of potential values of the unknown population parameter. However, the interval computed from a particular sample does not necessarily include the true value of the parameter. Based on the (usually taken) assumption that observed data are random samples from a true population, the confidence interval obtained from the data is also random.

4.4.3 Model selection method

Forward Stepwise chosen as the model selection method. In statistics, stepwise regression is a method of fitting regression models in which the choice of predictive variables is carried out by an automatic procedure. In each step, a variable is considered for addition to or subtraction from the set of explanatory variables based on some pre-specified criterion. Usually, this takes the form of a sequence of F-tests or t-tests, but other techniques are possible, such as adjusted R², Akaike information criterion, Bayesian information criterion, Mallows's Cp, PRESS or false discovery rate. The frequent practice of fitting the final selected model followed by reporting estimates and confidence intervals without adjusting them to take the model building process into account has led to calls to stop using stepwise model building altogether or to at least make sure model uncertainty is correctly reflected. Forward selection, involves starting with no variables in the model, testing the addition of each variable using a chosen model fit criterion, adding the variable (if any) whose inclusion gives the most statistically significant improvement of the fit, and repeating this process until none improves the model to a statistically significant extent.

4.4.4 Criterion for the model selection method

As the criterion for the Forward Stepwise was chosen Akaike's Information Criterion Correction (AICC). The Akaike information criterion (AICC) is an estimator of the relative quality of statistical models for a given set of data. Given a collection of models for the data, AICC estimates the quality of each model, relative to each of the other models. Thus, AICC provides a means for model selection. AICC is founded on information theory. When a statistical model is used to represent the process that generated the data, the representation will almost never be exact; so some information will be lost by using the model to represent the process. AICC estimates the relative information lost by a given model: the less information a model loses, the higher the quality of that model. (In making an estimate of the information lost, AICC deals with the trade-off between the goodness of fit of the model and the simplicity of the model.) The summary of the model, as obtained by SPSS is presented in Figures 4.14 – 4.18

Target	PM
Automatic Data Preparation	On
Model Selection Method	Forward Stepwise
Information Criterion	936.797

The information criterion is used to compare to models. Models with smaller information criterion values fit better.

Figure 4. 14 Model summary

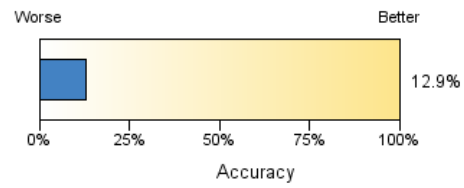


Figure 4. 15 Model accuracy

As it is the most important predictor for the element of process mining, according to the behavior of the scores obtained from the internet searches, is the element of Governance, Risk Management & Compliance. Next, in order of importance, come Business Process Management and Business Process Intelligence.

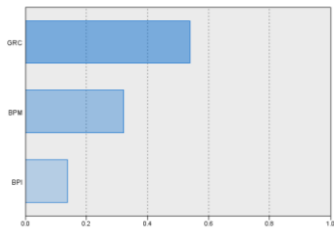


Figure 4. 16 Predictor importance (Target: Process Mining)

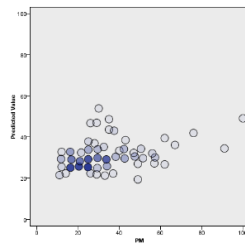


Figure 4. 17 Predicted by observed (Target: Process Mining)

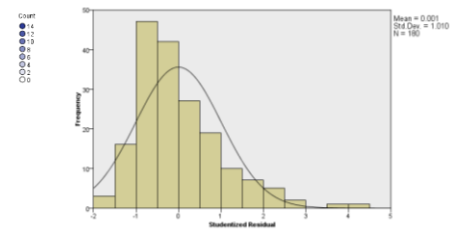


Figure 4. 18 Residuals (Target: Process Mining)

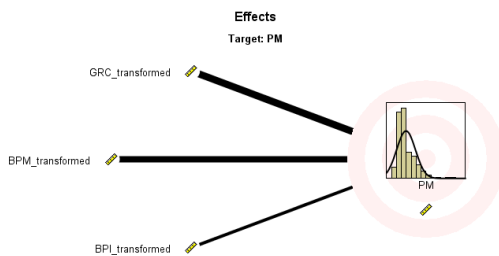
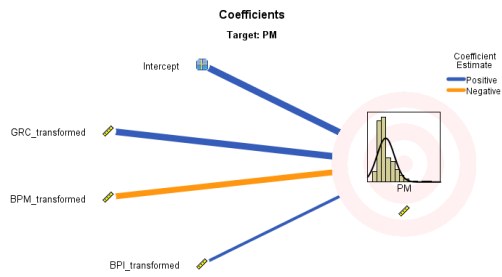


Figure 4. 19 Diagram of effects of independent variables

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5,249.324	3	1,749.775	9.836	.000
Residual	31,309.320	176	177.894		
Corrected Total	36,558.644	179			

Table 4. 11 List of effects of independent variables



**Coefficients
Target: PM**

Model Term	Coefficient ▼	Std.Error	t	Sig.	95% Confidence Interval		Importance
					Lower	Upper	
Intercept	20.437	3.923	5.209	.000	12.694	28.180	
GRC_transformed	0.785	0.161	4.867	.000	0.467	1.103	0.540
BPM_transformed	-0.506	0.135	-3.757	.000	-0.771	-0.240	0.322
BPI_transformed	0.256	0.104	2.463	.015	0.051	0.461	0.138

Figure 4. 20 Diagram of coefficients of independent variables

Table 4. 12 List of coefficients of independent variables

On Figure 4.21 there are graphically plotted the estimated means for the top significant effects at 95% confidence level ($p < 0,05$), for Process Mining as a target and the remaining five elements as predictors.

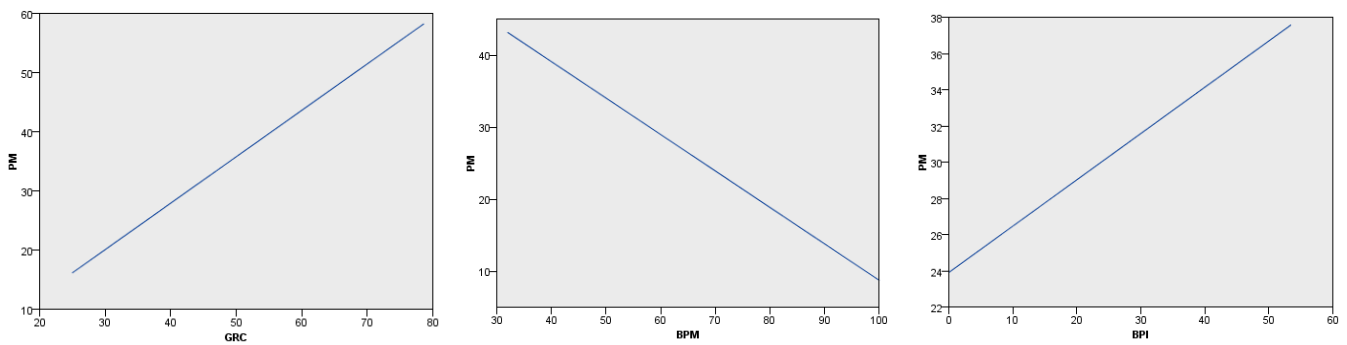


Figure 4. 21 Estimated means for the top significant effects ($p < 0,05$)

4.5 Conclusions from the obtained results

From the obtained results, we conclude that the element which resembles the most to the behaviour of Process Mining internet searches is i) Governance, Risk Management & Compliance, followed by ii) Business Process Management and iii) Business Process Intelligence.

Chapter 5

5. A comparative analysis of the findings

In this section of the thesis, a brief comparative analysis of our findings will be done in order to gain an insight on the research process and summarize the thesis.

5.1 Summary of the findings concerning the literature review of the “Risk – Process” ontology

Process Mining & Business Process Management

The search for “*Process Mining*” AND “*Business Process Management*” has the top place in the results in the corresponding Google Scholar search, with 7.100 results. In the top 20 articles, there were 107 authors involved (a result somehow biased, as one article of them, the “*Process Mining Manifesto*” had 77 authors. As long as the authors are concerned, there is undeniably a hardcore of authors, as one author (W.M.P. van der Aalst) has contributed in 10 out the top 20 articles (50%). The busiest years for the publications were 2004, 2005 and 2007, with 4 publications in each year. The majority of the articles were published in journals, with: a) *Business Process Management Journal*, and b) *Computers in Industry*, to occupy the highest place with 3 publications each.

Process Mining & Business Process Intelligence

The search for “*Process Mining*” AND “*Business Process Intelligence*” has yielded the 2nd result in the corresponding Google Scholar search, with 1.230 results (an 83% decrease from the top result). In the top 20 articles, there were 103 authors involved (a result biased, as the presence of “*Process Mining Manifesto*” once again, with 77

authors anomalizes the findings. As long as the authors are concerned, there is undeniably a hardcore of authors, as one author has contributed (W.M.P. van der Aalst, once again) in 13 out the top 20 articles (65%). The busiest year for the publications was 2005 with 4 publications, followed by 2007 and 2010, with 3 publications in each year. The majority of the articles were published in proceedings of conferences with the International Conference on Business Process Management to have the lion's share with 5 articles (25%), followed by Computers in Industry Journal, with 3 publications.

Process Mining & Internal Audit

The search for "Process Mining" AND 'Governance, Risk Management and Compliance' has yielded the 3rd place in the results in the corresponding Google Scholar search, with 200 results (an 84% decrease from the second result). In the top 20 articles, there were 52 authors involved. As long as the authors are concerned, there is also present a hardcore of authors, but a softer one, in comparison with the previous searches. The most contributing author (Mieke Jans) is appearing in 7 out the top 20 articles (35%). The busiest year for the publications was 2013 with 4 publications, followed by 2011, 2012 and 2014, with 3 publications in each year. The majority of the articles were published in journals, with Journal of Information Systems to have the lion's share with 3 articles

Process Mining & Enterprise Risk Management

The search for "Process Mining" AND 'Governance, Risk Management and Compliance' has yielded the 4th place in the results in the corresponding Google Scholar search, with 140 results (a 30% decrease from the 3rd result). In the top 18 articles (two articles were ruled out as irrelevant), there were 45 authors involved. As long as the authors are concerned, there is an even softer hardcore of authors, as there are 3 authors (Bart Baesens, David Olson and Desheng Wu) which contributed the most, with 3 appearances each (17%). The busiest by far year for the publications was 2013 with 5 publications (28%), followed by 2009, 2010, 2011 and 2014, with 2 publications in each year. Concerning the media of publication, a peculiar finding is that the lion's share in the publications (4 publications) is held by the United States Patent

Application Publication, a fact alone of great importance as it depicts the impact of process mining to Enterprise Risk Management in an industrial level, as the patents are held by corporations such as SAP SE, Oracle Inc., Core Systems Group and Bank of America Corp.

Process Mining & Governance, Risk Management and Compliance

The search for “Process Mining” AND ‘Governance, Risk Management and Compliance’ has yielded the last place in the results in the corresponding Google Scholar search, with just 41 results (a 71% decrease from the 4th result). In the top 20 articles, there were 54 authors involved. The hardcore of authors is no longer existent, as the two most contributing authors (Guido Governatori and Shazia Sadiq) are appearing in just 3 articles each (15%). The busiest years for the publications was 2009 and 2013 with 4 publications in each year. Like the previous search, once again, the lion's share in the publications (5 publications) is held by the United States Patent Application Publication, a fact alone of great importance as it depicts the impact of process mining to Enterprise Risk Management in an industrial level, as the patents are held by corporations such as SAP AG, Computers Associates Inc. and Bank of America Corp.

5.2 Summary of the findings concerning the literature review the focused on the elements of the “Risk” triangle

The aim in this focused search was to find the “Holy Grail” of articles (if it could be such a publication). An article (or even a small group of articles), that would cover the topics mentioned in our search, appear consistently in each one of our searches and score high grades in the metrics that were examined by. The article which would combine the best practices, the most references, the best reputation etc.

The search in Google Scholar came up with a total of 247 articles, which finally concluded in 109 unique articles (as a number of articles were appearing more than once and 15 articles were excluded as non-relevant). The search for “*process mining*”

AND "audit" came with the most results (3.470 results), whereas the least results came from the search for "process mining" AND "enterprise risk management" AND "business process risk", which resulted in just 7 results.

Then the articles were rated through the four metrics constructed (i. Article frequency, ii. Article points, iii. Points/Frequency, iv) Average rating of Frequency, Points & Points/Frequency).

Two were the articles that stood out and gathered the most points in all metrics: The first one was the: "A comprehensive investigation of the applicability of process mining techniques for enterprise risk management" by Caron et al., 2013b, and the second one was the: "Current research in risk-aware business process management: overview, comparison, and gap analysis", by Suriadi et al., 2014. These two –highly influential- articles, are considered to be the pinnacle of the focused literature research on the "Risk" elements of our ontology

Adding to this, also a fact worth noticing is the presence of seven patents, the sum of which is concerning Enterprise Risk Management, operational risk assessment and control. These patents were issued from respected organizations and firms, namely Bank of America, SAP SE, Oracle Inc., Grant Thornton Llp, CA Inc. etc.

5.3 Summary of the findings of Google trends tool

Process Mining

The internet searches for the topic "process mining" reached their peak in February 2005 (score 100) and their lowest point in February 2010 (score 9). The distance between the highest and the lowest point is 91 (100 – 9), a score that indicates a great fluctuation in trend. Out of the top 20 scores, 11 of them were obtained within the last 5 years. Out of the bottom 20 scores, all of them were obtained out of the last 5 years.

The linear trendline for process mining is pointing slightly upwards for the next five years, according to the prediction made based on the existing timeline. In this case a slight rise in interest concerning process mining is expecting in the near future.

Business Process Management

The internet searches for the topic “Business Process Intelligence” reached their peak in January 2005 (score 100) and their lowest point in December 2017 (score 32). The distance between the highest and the lowest point is 68 (100 – 32), a score that indicates a medium fluctuation in trend. Out of the top 20 scores, none of them were obtained within the last 5 years. In fact, all of them were obtained in the first 5 years. The linear trendline for Business Process Management is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abidance is expected for the next five years

Business Process Intelligence

The internet searches for the topic “Business Process Intelligence” reached their peak in August 2004 (score 100) and their lowest point in January 2004, May 2004, July 2004, November 2004 and December 2004 (score 0). The distance between the highest and the lowest point is 100 (100 – 0), a score that indicates an absolute fluctuation in trend. Out of the top 20 scores, none of them were obtained within the last 5 years. In fact, 18 of them were obtained in the first 5 years. Out of the bottom 20 scores, 6 of them were obtained within the last 5 years. The linear trendline for Business Process Intelligence is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abidance is expected for the next five years.

Governance, Risk Management and Compliance

The internet searches for the topic “Governance, Risk Management and Compliance” reached their peak in June 2004 (score 100) and their lowest point in December 2014 (score 25). The distance between the highest and the lowest point is 75 (100 – 25), a score that indicates a medium-to-strong fluctuation in trend. Out of the top 20 scores,

none of them were obtained within the last 5 years. In fact, all of them were obtained in the first 5 years. Out of the bottom 20 scores, 13 of them were obtained within the last 5 years. The linear trendline for Governance, Risk Management & Compliance is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abidance is expected for the next five years

Internal Audit

The internet searches for the topic “internal audit” reached their peak in February 2004 (score 100) and their lowest point in December 2017, December 2016, December 2015, December 2013 and December 2012 (score 33). The distance between the highest and the lowest point is 67 (100 – 33), a score that indicates a medium fluctuation in trend. Out of the top 20 scores, none of them were obtained within the last 5 years. Out of the bottom 20 scores, 18 of them were obtained within the last 5 years, a fact that is indicative of a low interest for this topic in current searches. The linear trendline for internal audit is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abidance is expected for the next five years

Enterprise Risk Management

The internet searches for the topic “Enterprise Risk Management” reached their peak in November 2004 (score 100) and their lowest point in December 2012 (score 25). The distance between the highest and the lowest point is 75 (100 – 25), a score that indicates a medium-to-strong fluctuation in trend. Out of the top 20 scores, none of them were obtained within the last 5 years. In fact, all of them were obtained in the first 5 years. Out of the bottom 20 scores, 19 of them were obtained within the last 5 years, a fact that is indicative of a low interest for this topic in current searches. The linear trendline for Enterprise Risk Management is pointing downwards for the period examined and according to the prediction made based on the existing timeline a further abidance is expected for the next five years.

5.4 Summary of the findings of the statistical analysis of the ontology through SPSS

For scores between 75 – 100 the cells are colored yellow, for scores between 50 – 74 the cells are colored blue and for scores between 25 – 49 the cells are colored green.

Month	Process Mining	Enterprise Risk Management	Internal Audit	Governance, Risk Management and Compliance	Business Process Intelligence	Business Process Management
January-04	62	42	75	77	0	82
February-04	30	45	100	78	99	82
March-04	76	63	76	66	61	87
April-04	29	71	85	73	71	88
May-04	25	74	82	78	0	87
June-04	38	50	74	100	41	98
July-04	67	70	65	79	0	91
August-04	37	67	73	70	100	91
September-04	91	74	77	65	37	92
October-04	35	75	79	78	37	94
November-04	23	100	80	62	0	87
December-04	32	47	60	71	0	83
January-05	28	47	57	68	61	100
February-05	100	73	77	72	49	80
March-05	33	71	75	53	54	97
April-05	37	69	68	54	31	96
May-05	41	68	83	53	66	92
June-05	49	83	69	42	27	81
July-05	17	68	80	47	27	71
August-05	32	76	66	49	53	89
September-05	15	76	81	54	60	86
October-05	21	76	60	39	56	69
November-05	62	93	65	51	22	78
December-05	34	67	47	49	22	69
January-06	35	65	62	78	29	80
February-06	43	58	63	57	30	68
March-06	58	75	63	54	17	77
April-06	40	62	71	48	64	76
May-06	36	66	68	39	33	64
June-06	22	69	70	51	18	76
July-06	16	67	62	51	17	75
August-06	25	59	57	61	16	77
September-06	28	72	60	54	15	62
October-06	30	66	68	61	21	79
November-06	30	67	62	50	14	66
December-06	26	34	50	54	28	46
January-07	23	57	59	59	12	68
February-07	49	67	60	53	13	76
March-07	14	50	58	49	11	78
April-07	33	67	58	54	30	68
May-07	47	62	67	53	20	69
June-07	43	61	65	52	32	70

July-07	23	60	59	52	26	73
August-07	15	58	61	60	15	74
September-07	30	56	56	49	29	70
October-07	21	69	61	56	35	80
November-07	31	64	61	49	25	72
December-07	14	49	46	44	18	55
January-08	12	54	55	53	16	66
February-08	18	54	63	52	20	68
March-08	26	58	58	50	27	65
April-08	33	60	55	48	8	77
May-08	18	63	58	46	26	65
June-08	26	60	60	50	34	72
July-08	25	58	54	56	29	67
August-08	18	61	54	51	22	64
September-08	32	53	54	49	24	67
October-08	34	60	58	43	12	65
November-08	14	52	47	44	26	69
December-08	22	60	41	39	32	54
January-09	30	47	48	51	18	60
February-09	21	53	55	50	12	67
March-09	17	61	57	54	19	70
April-09	14	60	50	41	14	63
May-09	22	60	58	46	22	66
June-09	12	51	61	45	38	70
July-09	25	49	51	47	27	59
August-09	17	47	49	39	16	55
September-09	13	52	57	39	20	67
October-09	21	53	53	38	17	59
November-09	18	53	57	38	26	60
December-09	19	38	43	35	17	48
January-10	23	46	50	35	18	52
February-10	9	47	58	34	25	65
March-10	27	55	60	38	29	66
April-10	18	50	55	40	17	63
May-10	20	54	61	45	13	70
June-10	22	49	55	43	22	63
July-10	10	54	51	39	21	57
August-10	20	40	51	37	26	58
September-10	25	41	49	39	15	61
October-10	16	42	50	40	15	61
November-10	15	45	48	40	20	58
December-10	12	39	41	34	18	45
January-11	18	38	49	35	15	52
February-11	21	40	48	40	19	61
March-11	16	48	51	40	34	59
April-11	15	44	50	38	27	54
May-11	18	44	56	40	31	57
June-11	27	43	49	38	14	55
July-11	19	41	44	35	24	54
August-11	17	41	44	35	17	53
September-11	23	42	48	36	19	58
October-11	18	41	44	33	25	58
November-11	25	39	49	34	18	58
December-11	12	34	36	27	22	41
January-12	17	34	42	31	24	51
February-12	27	39	46	33	28	58
March-12	28	39	48	34	22	58
April-12	21	43	44	34	18	57
May-12	25	41	49	38	21	54
June-12	25	40	47	34	24	52
July-12	16	35	46	32	16	49

August-12	12	31	42	36	12	54
September-12	21	43	46	32	19	54
October-12	21	39	49	35	28	54
November-12	20	35	47	33	26	52
December-12	18	25	33	30	14	39
January-13	13	32	44	35	19	44
February-13	19	36	41	34	23	51
March-13	23	35	43	35	18	51
April-13	29	40	48	35	25	53
May-13	29	33	43	31	17	54
June-13	20	36	45	34	15	49
July-13	23	35	39	32	16	50
August-13	14	33	39	30	16	48
September-13	16	36	42	31	18	50
October-13	24	37	46	36	23	52
November-13	27	33	43	31	11	50
December-13	17	28	33	28	20	38
January-14	20	30	40	31	17	44
February-14	26	33	45	35	19	49
March-14	25	37	43	35	21	51
April-14	26	36	46	34	15	51
May-14	31	36	44	33	20	52
June-14	21	33	44	38	10	49
July-14	20	32	42	32	24	50
August-14	20	35	41	32	18	46
September-14	23	37	47	37	17	53
October-14	27	36	48	32	21	52
November-14	45	33	45	32	27	49
December-14	35	27	34	25	18	37
January-15	25	33	41	30	14	43
February-15	23	35	42	34	26	49
March-15	36	34	45	36	29	53
April-15	48	35	45	31	31	47
May-15	32	32	45	32	18	50
June-15	22	36	42	34	16	47
July-15	25	33	38	34	16	47
August-15	24	32	39	35	21	44
September-15	33	37	43	35	15	47
October-15	41	39	42	37	23	49
November-15	29	32	44	32	21	46
December-15	29	26	33	27	14	38
January-16	29	29	39	31	13	35
February-16	30	33	42	36	21	43
March-16	27	37	43	35	24	46
April-16	28	36	43	34	20	44
May-16	30	34	45	35	18	42
June-16	34	33	44	35	15	44
July-16	29	30	34	32	19	37
August-16	25	30	37	34	14	39
September-16	26	34	41	32	18	43
October-16	36	37	40	32	16	43
November-16	48	36	42	34	20	43
December-16	26	29	33	28	16	34
January-17	32	32	38	31	18	39
February-17	35	35	43	35	15	45
March-17	42	36	43	37	20	47
April-17	43	35	41	35	25	42
May-17	38	33	42	35	24	46
June-17	38	31	38	35	13	40
July-17	32	30	39	32	14	39
August-17	35	30	39	32	16	41

September-17	50	34	41	32	23	44
October-17	48	43	43	34	24	44
November-17	59	39	44	35	20	45
December-17	37	29	33	28	19	32
January-18	42	37	39	32	29	38
February-18	46	32	41	36	20	44
March-18	40	37	41	33	18	44
April-18	51	35	42	37	28	45
May-18	57	34	42	36	19	43
June-18	53	30	38	31	18	38
July-18	50	32	34	35	21	37
August-18	44	35	37	36	8	42
September-18	57	35	39	33	12	44
October-18	55	33	43	39	19	48
November-18	55	36	40	35	18	40
December-18	41	41	37	35	29	39

Table 5. 1 The scored-colored timetable of the elements

The majority of the highest scores 75 – 100 occurred in the first 4 years. An indication is that after April 2008 in all of our six elements there has not a value over 75, as the colored table of scores indicates. From June 2005 to December 2018 only the element of Process mining had achieved scores over 50. The most disappointing picture comes from the element of Business Process Intelligence, which for the most months under surveillance scored from 0 to 24. The highest performance in scores comes from the element of Business Process Management.

Year	Process Mining & Business Process Intelligence		Process Mining & Business Process Management		Process Mining & Internal Audit		Process Mining & Enterprise Risk Management		Process Mining & Governance, Risk Management and Compliance	
	Number of publications per year	%	Number of publication per year	%	Number of publications per year	%	Number of publications per year	%	Number of publications per year	%
2002	0	0%	0	0%	1	5%	0	0%	0	0%
2003	0	0%	1	5%	0	0%	0	0%	0	0%
2004	3	15%	4	20%	0	0%	0	0%	0	0%
2005	4	20%	4	20%	0	0%	0	0%	0	0%
2006	2	10%	0	0%	0	0%	0	0%	0	0%
2007	3	15%	4	20%	1	5%	1	6%	0	0%
2008	1	5%	1	5%	0	0%	0	0%	0	0%
2009	1	5%	1	5%	2	10%	2	11%	4	20%
2010	3	15%	0	0%	2	10%	2	11%	3	15%
2011	1	5%	1	5%	3	15%	1	6%	0	0%
2012	1	5%	1	5%	3	15%	2	11%	2	10%
2013	1	5%	0	0%	4	20%	5	28%	2	10%
2014	0	0%	2	10%	3	15%	2	11%	4	20%

2015	0	0%	1	5%	0	0%	2	11%	1	5%
2016	0	0%	0	0%	0	0%	0	0%	3	15%
2017	0	0%	0	0%	0	0%	1	6%	1	5%
2018	0	0%	0	0%	1	5%	0	0%	0	0%
	20	100%	20	100%	20	100%	18	100%	20	100%

Table 5. 2 The volume-of-publication-colored year table of the elements

The results from year of publication of the most popular articles are in a way contradictory with the scores of the Google Trends. On the one hand, the majority of the articles concerning a) *Process Mining AND Business Process Intelligence* and b) *Process Mining AND Business Process Management*, were published between 2004 and 2007. On the other hand, the majority of the articles concerning c) *Process Mining AND Internal Audit*, d) *Process Mining AND Enterprise Risk Management*, and e) *Process Mining AND Governance, Risk Management and Compliance*, were published between 2009 and 2016.

Chapter 6

Discussion & Conclusions

This chapter concludes the thesis, summarizes the main remarks and the discussions on the implementation of the “Risk – Process” ontology, as described in this thesis. Consequently, the limitations of research are provided along with future work that could be developed.

6.1 Main remarks

This section summarizes and underlines the main remarks and what was investigated in detail in the previous chapters.

Chapter 1 introduced the basic notion of the thesis, the “Risk – Process” ontology and provided a brief outline for each of the six examined elements of the ontology, namely: i) Process Mining, ii) Business Process Management, iii) Business Process Intelligence, iv) Governance, Risk Management & Compliance, v) Internal Audit , and vi) Enterprise Risk Management.

Chapter 2 presented the literature review of the thesis. A two-fold approach was selected concerning the approach and analysis of the relevant literature. The first section provided a broader systematic literature review on the relationship among process mining and the six aforementioned elements. In the second section of the review we conducted a more focused search for the element concerning the “Risk” triangle of the model. The rationale behind this two-fold approach is that to compare of the results produced by each search and to discuss the findings.

Chapter 3 attempted the ontology's investigation through the Google Trends tool. Through the use of Google Trends tool we tried to shed some light on the non-academic side of the elements of the "R – P" ontology. What was examined was the performance (scores) of the Ontology's elements in searches conducted worldwide, from January 2004 to December 2018, in the "Business & Industrial" category. The factors examined were: i) Interest over time, ii) Hi's and Low's, iii) elements actual and 5-year predicted trendline, iv) Top 20 countries, v) Top 20 cities, vi) Top Related Topics, vii) Rising Related Topics, viii) Top Related Queries, and ix) Rising Related Queries. The most striking fact is that all elements, apart from Process Mining, are poorly performing in the last decade, and their 5-year prediction is also presented with a clear downward trendline. Process mining is performing better than the other elements and there is a predicted slightly upward trendline, but overall the results were far below our initial expectations. Due to the construction of the Google Trends score, where a higher score means a higher proportion of all searches/queries, and not a higher absolute search/query count, we had the presence of some rather peculiar results, like the remote island of St. Helena or the dominance from African or South American countries in many categories. In other, the results on searches and queries were pretty solid and coherent with the only distortion coming from the scores of Process mining, where there were presents a small number of searches for mining activities and related terminology.

Chapter 4 took a step further the data presented in Chapter 3, as the scores of the "R-P" elements were statistically analyzed through SPSS. Time series analysis comprises methods for analyzing time series data in order to extract meaningful statistics and other characteristics of the data. In order to analyze the time series of the scores obtained, the statistical measures used were: i) Frequency tables, ii) Descriptive statistics, iii) Correlations, and iv) Non-parametric correlations.

The findings of chapters 2, 3 and 4 were put together in chapter 5.

6.2 Discussions

The primary question imposed in this body of work was if there are sufficient evidence - in both academic and business fields - to claim an imprint, an important contribution of Process Mining methodology to Risk Management. As (M. J. Jans et al., 2010) very vividly puts it, to understand why the process mining methodology offers such promised field for the “Risk – Process” ontology, all we have to do is to recall the way in which auditing used to be done. Until only a few decades ago, auditing meant filling out ledger books by hand and in most cases, the auditor had the role of a book-keeper. Consequently, the data which auditors had to rely came entirely from paper based ledgers. These archaic procedures were not just lacking of technology, but primary there were limitations concerning the reliance on manual auditing procedures. Hand written auditing suffer from what is called the “what you see is what you get” or WYSIWYG problem: the only information that is available to the auditors is the information presented to them, usually ledgers and other type of printed or hand written media. Hence, the auditors had no way of verifying who made those ledger entries and when they did so. If those entries have been falsified, erased and overwritten, added to or modified at another date and time by the same or other party, the auditor can detect that only through scrutiny of the physical evidence of the books.

This constraint auditors faced can be described using the term WYSIWYG—which is more commonly encountered in computer science—deliberately because it captures the fundamental difference that event logs can make to auditing. In practice, an event log is far more than a simple “chronological record of computer system activities”.

The event log not only provides the auditor with more data to analyze, but also because that additional data is recorded automatically and independently. In other words, an event log helps achieve the classic audit principle of “four eyes”. With the use of the event logs, the auditor is no longer restricted to the WYSIWYG ledger of transactions, but also is empowered with an independent set of “meta-data” about the circumstances. That meta-data represent much more than simple time stamps for transactions. By taking advantage of that tracking data, the event log enables the auditor to reproduce the history of any given transaction. It provides a full history of the process itself, not just the outcome of it.

This ability is inherent and within the technical nature of event logs and gives process mining its great power and its name: the ability through analysis of event logs to recreate the business processes of the organization. Such process views of the business are much more difficult to discern from transactional data alone, but feasible when that transactional data is supplemented by the meta-data and history contained in the event logs and made visible by the techniques of process mining.

6.3 Limitations

Limitations of the Literature review

As stated earlier, the database of choice was Google Scholar, as trial searches conducted on other database (Web of Science, Computer Science Bibliography – DBLP, Science Direct, IEEE Computer Society, ACM, Springer), showed that Google Scholar is by far the fullest and broadest medium of review. The problem with academic related databases is the exclusion on non-academic material and the omission of academic non-published material. In our opinion this fact can be limiting for an analysis like ours, that includes (apart from the review with the academic prism) a non-academic, business perspective. This is why a broader aspect must be considered when researchers are dealing with such cross-over methodologies that blend the business perspective with the academic prism.

Limitations of Google Scholar Search

As Wikipedia states (https://en.wikipedia.org/wiki/Google_Scholar#Limitations_and_Criticism, accessed 13 January 2019), Google Scholar has received a decent amount of criticism from the academic community. The main issues of controversy were:

- **Quality** – Some searchers consider Google Scholar of comparable quality and utility to commercial databases. The reviews recognize that its "cited by" feature in particular poses serious competition to Scopus and Web of Science. An early study,

from 2007, limited to the biomedical field, found citation information in Google Scholar to be "sometimes inadequate, and less often updated". The coverage of Google Scholar may vary by discipline compared to other general databases.

- **Lack of screening for quality** – Google Scholar strives to include as many journals as possible, including predatory journals, which "have polluted the global scientific record with pseudo-science, a record that Google Scholar dutifully and perhaps blindly includes in its central index."
- **Coverage** – Google Scholar does not publish a list of journals crawled or publishers included, and the frequency of its updates is uncertain. Bibliometric evidence suggests Google Scholar's coverage of the sciences and social sciences is competitive with other academic databases; however as of 2017, Scholar's coverage of the arts and humanities has not been investigated empirically and Scholar's utility for disciplines in these fields remains ambiguous. Especially early on, some publishers did not allow Scholar to crawl their journals. Elsevier journals have been included since mid-2007, when Elsevier began to make most of its ScienceDirect content available to Google Scholar and Google's web search. As of February 2008, the absentees still included the most recent years of the American Chemical Society journals. It is, therefore, impossible to know how current or exhaustive searches are in Google Scholar, although a recent study estimates that Google Scholar can find almost 90% (approximately 100 million) of all scholarly documents on the Web written in English. Large-scale longitudinal studies have found between 40–60% of scientific articles are available in full text via Google Scholar links.¹
- **Matthew effect** – Google Scholar puts high weight on citation counts in its ranking algorithm and therefore is being criticized for strengthening the Matthew effect; as highly cited papers appear in top positions they gain more citations while new papers hardly appear in top positions and therefore get less attention by the users of Google Scholar and hence fewer citations.
- **Google Scholar effect** – It is a phenomenon when some researchers pick and cite works appearing in the top results on Google Scholar regardless of their contribution to the citing publication because they automatically assume these

works' credibility and believe that editors, reviewers, and readers expect to see these citations.

- **Incorrect field detection** – Google Scholar has problems identifying publications on the arXiv preprint server correctly. Inter-punctuation characters in titles produce wrong search results, and authors are assigned to wrong papers, which leads to erroneous additional search results. Some search results are even given without any comprehensible reason.
- **Vulnerability to spam** – Google Scholar is vulnerable to spam. Researchers from the University of California, Berkeley and Otto-von-Guericke University Magdeburg, demonstrated that citation counts on Google Scholar can be manipulated and complete non-sense articles created with SCIdgen were indexed from Google Scholar. They concluded that citation counts from Google Scholar should only be used with care especially when used to calculate performance metrics such as the h-index or impact factor. Google Scholar started computing an h-index in 2012 with the advent of individual Scholar pages. Several downstream packages like *Harzing's Publish or Perish* also use its data. The practicality of manipulating h-index calculators by spoofing Google Scholar was demonstrated in 2010 by Cyril Labbe from Joseph Fourier University, who managed to rank "Ike Antkare" ahead of Albert Einstein by means of a large set of SCIdgen-produced documents citing each other (effectively an academic link farm).
- **Inability to shepardize case law** – As of 2010, Google Scholar was not able to shepardize case law, as Lexis can.

Limitations of statistical analysis

For the analysis of the data obtained we conducted the statistical analysis with the use of IBM SPSS v. 22. The aim was to model with the use of the simple linear regression the relationship between the target (dependent variable) of process mining using as explanatory (independent) variables the remaining five elements of the ontology: i. Enterprise Risk Management, ii. Internal Audit, iii. Governance, Risk Management & Compliance, iv. Business Process Intelligence and v. Business Process Management.

The SPSS statistical package has been considered for many years as a standard for data analysis. But in the last few years there has been a lot of fuss in the area of data science about the use of new, more powerful programming tools in quantitative analysis. The R programming language and the Python programming language are the most prominent and well received tools from both the academic and the business community. It would be interesting for a future researcher to use one (or both) of these programming languages, and examine the outcomes obtained.

6.4 Challenges for the future researches

As mentioned above, the challenges for the future researcher include among other:

- The use of a broader database for literature review, which will include also non-academic material.
- The use of a new, promising, programming languages for the statistical analysis.
- The exploration of non-typical sources of knowledge such as Google Trends, sources that will be able to provide not just qualitative, but also quantitative data, such as preferences, behavior and changes in trend.

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