Human Resource Allocation in Business Process Management and Process Mining: A Systematic Mapping Study

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ABSTRACT

Purpose- Human resource allocation is considered a relevant problem in Business Process Management (BPM). The successful allocation of available resources for the execution of process activities can impact on process performance, reduce costs, and obtain a better productivity of the resources. In particular, Process Mining is an emerging discipline that allows improvement of the resource allocation based on the analysis of historical data. This paper provides a broad review of primary studies published in the research area of human resource allocation in BPM and Process Mining.

Design/methodology/approach – A Systematic Mapping Study (SMS) was conducted in order to classify the proposed approaches to allocate human resources. A total of 2,370 studies published between January 2005 and July 2016 were identified. Through a selection protocol, a group of 95 studies were selected.

Findings - Human resource allocation is an emerging research area that has been evolving over time, generating new proposals that are increasingly applied to real case studies. The majority of proposed approaches relate to the period 2011 to 2016. Journals and conference proceedings are the most common venues. Validation research and evaluation research are the most common research types. There are two main evaluation methods: simulation and case studies.

Originality/value – This study aims to provide an initial assessment of the state of the art in the research area of Human Resource Allocation in BPM and Process Mining. To the best of our knowledge, this is the first research that has been conducted to date that generates a systematic mapping study in this research area.

KEYWORDS

Human resource allocation; Business process management; Process mining; Resource management; Systematic mapping study

1. Introduction

Business Process Management (BPM) is the art and science of overseeing how work is performed in an organization to ensure consistent outcomes and to take advantage of improvement opportunities (Dumas, Rosa, Mendling, & Reijers, 2013). Typically, these improvement opportunities include reductions in cost and execution times, enhanced quality and efficiency, as well as better productivity of processes (Arias, Rojas, Munoz-Gama, & Sepúlveda, 2015). In recent years, the use of information systems in different organizations has increased, thereby facilitating the storage of information

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relating to the activities that are executed in distinct processes (e.g., case ID, activity name, timestamp, resource) in event logs. This information, also known as event data, can be used to improve end-to-end processes (van der Aalst, 2016). Accordingly, there is an emerging discipline, called Process Mining, which focuses on extracting useful knowledge based on the information stored in the event logs (van der Aalst, 2016). Process Mining can be seen as a means to bridge the gap between *Data Science* and *Process Science*, where *Data science* refers to an interdisciplinary field that aims to extract real value from data, and *Process Science* refers to a broader discipline that combines knowledge from information technology and management sciences to improve and run operational processes (van der Aalst, 2016). Both BPM and Process Mining are interested in profoundly analyzing business processes. In conjunction with the methods, techniques and tools created for the design, execution and analysis of operational business processes (van der Aalst, 2013), there is also a central aspect to consider within BPM and Process Mining: the *resource perspective* (Dumas et al., 2013), also known as the organizational perspective (van der Aalst, 2016). This perspective focuses on the analysis of information related to the resources that are in charge of executing the activities of a business process (e.g., human resources, software systems, and equipment, among others) (Dumas et al., 2013). This helps to generate insights into how the resources work and it facilitates a more in-depth study of their behavior regarding the processes (Guo, Brown, & Rasmussen, 2013; Huang, Lu, & Duan, 2012a).

In particular, human resource allocation has been considered as a significant problem within the context of BPM (Huang, Lu, & Duan, 2012b; Wibisono, Nisafani, Bae, & Park, 2015; J. Xu, Liu, & Zhao, 2008; Zhao & Zhao, 2014), due to the influence that the correct allocation may have on the performance of the process (X. Liu, Chen, Ji, & Yu, 2014; Zhao & Zhao, 2014), on costs (Huang, van der Aalst, Lu, & Duan, 2011; Obregon, Kim, & Jung, 2013), and on the efficient use of resources during the process execution (Fadol, Barhem, & Elbanna, 2015; Kumar, van der Aalst, & Verbeek, 2002; J. Xu et al., 2008). As such, different approaches have been proposed in the literature with the aim of providing improved support to make the task of resource allocation more efficient, both to support the decision-making of the individual in charge of the relevant process when selecting a candidate, as well as during the allocation of a resource for executing each process activity.

Due to the importance of resource allocation in BPM, the contribution Process Mining can make, and the large variety of approaches that have been proposed, we performed a Systematic Mapping Study (SMS) (Petersen, Feldt, Mujtaba, & Mattsson, 2008). The aim of this paper is to identify and evaluate the number of research articles that have been published in the research area of human resource allocation (hereinafter and indistinctly, resource allocation) in BPM and Process Mining in the last decade. Although such resources may be either human or non-human (Russell, van der Aalst, ter Hofstede, & Edmond, 2005), we only considered human resources since they play a fundamental role in terms of executing and supervising business processes (Havur, Cabanillas, Mendling, & Polleres, 2015), and because human interactions form a substantial part of today's business processes (Schall, 2012). In our opinion, a study is required that systematizes and classifies the resource allocation approaches proposed under this research area, and which identifies certain important aspects: (i) the proposed approaches and the publishing vehicles used; (ii) the research types utilized; (iii) the evaluation methods utilized, and the use of real data to verify the proposed approaches; and (iv) a geographical breakdown to determine the distribution of different research groups at the international level. As such, this

work provide a comprehensive overview for researchers and practitioners interested in understanding the level of maturity reached by this research area.

The SMS are based using the guidelines proposed by Petersen et al. (2008). Consequently, we applied a series of inclusion and exclusion criteria to the set of 2,370 articles obtained from seven revised digital libraries, in order to filter them, and select a final amount of 95 primary studies. These primary studies were subsequently subjected to a process of information extraction in order to answer the following research questions:

(1) What are the most common *publishing vehicles* in which human resource allocation approaches have been published?
(2) What *research types* have been used in human resource allocation studies?
(3) Which *evaluation methods* are most frequently employed to validate human resource allocation approaches? Is real-life data involved?
(4) Which *geographical areas* have reported approaches to allocate human resources?

The rest of this paper is organized as follows. A literature review about the concepts of BPM, Process Mining and human resource allocation is documented in Section 2. Section 3 explains the need to perform an SMS. Section 4 describes the process followed to conduct the study. Section 5 presents the results obtained. Section 6 outlines the threats to the validity of the study. Finally, Section 7 concludes the paper and indicates the possible direction of future research.

2. Literature review

Business processes are essential for understanding how companies operate, and they also play an important role in the design and realization of flexible information systems (Weske, 2012). Companies have a number of processes associated with their daily activities (Cavalcante, Kesting, & Ulhøi, 2011). Their execution involves a collection of interrelated events and the activities or tasks to perform. Also, involves the decision points that affect the way in which the process is executed, and the performers, all with the objective of generating one or several results as final deliverable (Dumas et al., 2013). BPM has emerged as a comprehensive process-centered discipline (Rosemann & vom Brocke, 2015), which focuses on business process (Roeser & Kern, 2015), and provides a series of concepts, methods, tools and techniques to support the analysis and an adequate process management, but also generate insights to improve business processes. To achieve these goals, it is necessary to have information about process execution, which can be used for a further process analysis. BPM discipline can be seen as continuous cycle that involves a series of phases such as process identification; process modeling; process analysis; process redesign; process implementation and process monitoring and controlling (Dumas et al., 2013). Accordingly, Process Mining is considered as a young research discipline that aims to extract knowledge from event logs available in today's information systems, and provides an important bridge between data-driven approaches and business process modeling and analysis (van der Aalst et al., 2011). Through the use of Process Mining tools and techniques, the information about the processes and their activities can be analyzed from different process perspectives. Particularly, within the disciplines of BPM and Process Mining there is a rising interest in addressing research efforts to the *resource perspective* (Cabanillas, 2015; Zhao & Zhao, 2014).

The *resource perspective* (Dumas et al., 2013) focuses on the study of the interaction of resources during the execution of a process. Business process activities can be

performed by the company's employees manually or by the help of information systems, and is crucial that human resources and other enterprise resources play together well in order to achieve the company's business goals in an efficient and effective manner (Weske, 2012). Accordingly, one of the main challenges of this perspective relates to human resource allocation in business processes (Zhao & Zhao, 2014), since allocate resources is considered a central part of business processes (Huang et al., 2012b; Rosemann & vom Brocke, 2015; Wibisono et al., 2015; J. Xu et al., 2008; Zhao & Zhao, 2014) and strategic management (Ball & Deshmukh, 2013; Bauer & Hammerschmidt, 2005; Okumus, 2003; Wudhikarn, 2016).

The appropriate selection and allocation of resources to an activity may have a direct impact on the performance and efficiency with which a process is executed. In an attempt to make this task more efficient, a large number of studies have been proposed by researchers and practitioners over the last decade. As a consequence, there is now a plethora of studies that propose and apply different methods to allocate resources within BPM and Process Mining disciplines. For example, the Workflow Resource Patterns (Russell et al., 2005) propose a group of resource patterns broken down into distinct categories (e.g., Creation patterns, Push and Pull patterns), which can help demonstrate how resources can be used and represented in workflow systems. These resource patterns have been used across a variety of proposed approaches, providing support to the different allocation methods presented (Arias et al., 2015; Cabanillas et al., 2013; Cabanillas, Resinas, del-Río-Ortega, & Cortés, 2015; Stefansen, Rajamani, & Seshan, 2008; Talib, Volz, & Jablonski, 2010; Tan & van der Aalst, 2006). For instance, Stefansen et al. (2008) utilize distinct resource patterns as part of the resource allocation language called SOFTALLOC, in order to be able to manage different restrictions (soft constraints) during dynamic resource allocation. Cabanillas et al. (2015) use a set of eight Creation patterns to evaluate a proposed Resource Assignment Language (RAL) (Cabanillas, Resinas, & Cortés, 2011), which is a domain-specific language used to establish the conditions for selecting candidates to participate in the execution of process activities.

Furthermore, other techniques have been used by distinct resource allocation methods, including Machine Learning algorithms (Huang, Lu, & Duan, 2011; Huang, van der Aalst, et al., 2011; Y. Liu, Wang, Yang, & Sun, 2008; Ly, Rinderle, Dadam, & Reichert, 2005; Talib et al., 2010; R. Xu, Liu, Xie, Yuan, & Yang, 2014; Yingbo, Jianmin, & Jiaguang, 2007), Markov Models (Huang, van der Aalst, et al., 2011; Koschmider, Liu, & Schuster, 2011; van Hee, Serebrenik, Sidorova, Voorhoeve, & van der Wal, 2007), Data Mining techniques (Huang, Lu, & Duan, 2011; Sindhgatta, Ghose, & Dam, 2016), Constraints based-approaches (I. Barba, Weber, & Valle, 2011; I. a. Barba, Weber, Del Valle, & Jiménez-Ramírez, 2013), and Multi-agent systems (Hsieh & Lin, 2014; Kress, Melcher, & Seese, 2007), among others.

According to several authors (I. Barba et al., 2011; del-Río-Ortega, Resinas, Cabanillas, & Cortés, 2013; Zhao & Zhao, 2014), the *control-flow* process perspective (van der Aalst, 2016) has historically been the subject of more intense research activity compared to other process perspectives (e.g., *resource*). This could be an important reason why the management of resources within business processes has not reached the same level of maturity as other process perspectives (Cabanillas et al., 2015). Consequently, further work is required to quantify the amount of studies reported and to provide a general overview of the research area of resource allocation. Despite of the existence of studies that collect information about surveys in business process management (Roeser & Kern, 2015), few surveys have considered the analysis of human resources management as part of their research focus. For instance, Zucchi and Ed-

wards (1999) have introduced a literature review focusing on the aspects of human resource management (e.g., organisational structure and culture;) regarding to Business process re-engineering projects. Also, Huemann, Keegan, and Turner (2007) have conducted a literature review that involves human resource management from the point of view of a project-oriented company. Similarly, Rolim Ensslin, Ensslin, Back, and Tadeu de Oliveira Lacerda (2013) performed a study about human resource allocation in a project management model based on knowledge demand. Their systematic review process selected only eleven relevant papers on the topic of human resource management that focus on engineers' performance evaluation applied to a project management model. However, the conducted review does not consider approaches to allocate resources in business processes.

By means of this research, we seek to evaluate the current state of the art and latest trends in this research area. Towards that end, we have taken into account the resource allocation approaches by conducting a comprehensive analysis of primary studies from the disciplines of BPM and Process Mining.

3. Performing a systematic mapping study

Systematic research may be divided into three parts: primary studies, secondary studies and tertiary studies. Accordingly, primary studies are new studies on a specific topic; secondary studies synthesize the current state of research on a specific topic; and tertiary studies provide a summary of all the secondary studies already completed and published (Jalali & Wohlin, 2012). Secondary studies require a more comprehensive and extensive investigation with regard to the particular domain of research.

There are two well-known procedures that focus on analyzing previous research: Systematic Literature Review (SLR) and Systematic Mapping Study. There are similarities and differences between these secondary studies (B. A. Kitchenham, Budgen, & Brereton, 2011; Petersen, Vakkalanka, & Kuzniarz, 2015). Both perform similar steps for searching and selection of primary studies. However, they differ in the way the research questions, scope, analysis and dissemination of the results are applied. On the one hand, a SLR (B. Kitchenham, 2004) allows us to identify, evaluate and interpret all the available research related to specific research questions. Generally, a SLR focuses on very specific research questions that can be answered by empirical research, where every research question is answered and supported by detailed information obtained from individual research outcomes. Then, the corresponding results are aggregated (to a high specification) to answer the specific research questions. On the other hand, an SMS (B. Kitchenham & Charters, 2007; Petersen et al., 2008), also known as Scoping Study (Petersen et al., 2015), establishes if research evidence exists on a specific topic. An SMS aims to discover research trends from the definition of general research questions (e.g., researchers, publication trends over time, types of studies, among others). The outcomes of an SMS are presented at a higher level of granularity, categorized according to the dimensions specified for the analysis and counts of the number of papers regarding distinct categories. More details about the differences between SLRs and SMSs can be found in (B. A. Kitchenham et al., 2011; Petersen et al., 2015).

B. Kitchenham (2004) proposed an approach to software engineering grounded on the evidence-based medicine research for systematic literature studies. In a more recent version, B. Kitchenham and Brereton (2013) included snowballing from distinct reference lists of identified papers as primary studies in order to identify possible additional articles relevant to the topic, which were previously excluded due to possible

failures related to the search string. However, Kitchenham and Brereton did not make an explicit recommendation in relation to either a forward snowballing or a backward snowballing as part of the procedure. A forward snowballing is a search for papers that have been cited in pre-identified primary studies. Meanwhile, a backward snowballing is the search for papers that have cited the pre-identified primary studies. Nevertheless, regardless of whether a forward or a backward snowballing is performed, the majority of secondary studies do not use this approach due to the extra amount of work it entails (Jalali & Wohlin, 2012). But sometimes a full snowballing analysis (backward or forward) is not necessarily needed, it is possible to perform an snowballing analysis of a percentage of the papers and evaluate the results, seeing how many papers were not considered. In the specific case of this paper, a SMS was performed since the domain area is not considered or known to be fully developed. So, a high level analysis was done with the SMS, and later in the future a SLR will be considered.

The final product of a systematic literature study can be an SLR or an SMS (B. Kitchenham & Charters, 2007). Nonetheless, the procedures and guidelines of Kitchenham focus on SLR. Accordingly, and based on the procedure of B. Kitchenham (2004), Petersen et al. (2008) have proposed their own detailed approach for SMSs. Under their proposition, the use of specific and clear guidelines that are related to the reliability and reproducibility of the results of secondary studies are mandatory. Thus, this enables other independent researchers to repeat and identify similar results in the set of papers defined as primary studies.

The use of SMS enables evidence to be synthesized and the most up-to-date information in a specific research domain or topic to be fully understood. More specifically, the primary aim of this paper is to identify the current state of the art and latest trends in human resource allocation in the BPM and Process Mining research area in a broader sense. As a result, we opted to conduct an SMS with the use of backward snowballing as a way to validate the set of primary studies selected. The knowledge of this topic is dispersed and it is therefore necessary to understand the status of current research, to synthesize its findings, to examine the areas being explored by researchers, and to gauge the extent of the challenges being faced.

4. Research mapping method

In the literature, a few studies were found that provide a systematic review about resource management (see Section 2). However, there is no study that reviews the primary studies in the research area of human resource allocation. In this SMS, we addressed the following objectives:

- To identify what evidence is available in the research area of human resource allocation in BPM and Process Mining.
- To classify the primary studies in the aforementioned research area, with the aim of discovering research trends and characterizing the evidence according to important aspects, such as publishing vehicles, research types, evaluation methods and geographical analysis.

This section describes the mapping study conducted based on the process steps proposed by Petersen et al. (2008) (see Figure 1).

4.1. *Definition of research questions*

Considering the proposed objectives of this paper, we have subdivided our approach into clearly defined research questions (*Definition of research questions*) in order to

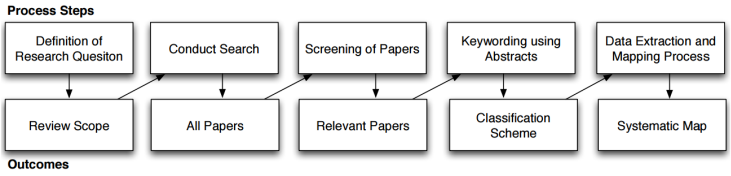

Figure 1.: Systematic mapping study process by Petersen et al. (2008)

focus on specific aspects of the overall evaluation. In devising these questions, we used the B. Kitchenham and Charters (2007) procedure, including the Population, Intervention, Comparison, Outcome and Context (PICOC) structure. Table 1 outlines the structure used. B. Kitchenham and Charters (2007) proposed the PICOC structure to capture the relevant aspects that must be considered when defining the research questions to be used in systematic studies. It should be noted that since the composition of this paper involved an SMS, the comparison of interventions does not apply.

Table 1.: Structure proposed by B. Kitchenham and Charters (2007) to devise research questions

Criteria	Description
Population	We consider studies that describe how human resources are allocated in business processes.
Intervention	Describe approaches (methods, strategies, techniques and tools) that are used to allocate human resources.
Comparison	N/A
Outcome	Describe the effectiveness of the allocation of resources.
Context	Describe the domain of use: in our case, studies in the BPM and Process Mining disciplines.

As discussed, the research questions pertaining to an SMS are usually generic and related to a particular research trend, for example to identify which regions and researchers are working in a particular domain, to understand the extent of publications relating to this domain in recent years, and how this research is being validated. Thus, our research questions are as follows. The first question is: *What are the most common publishing vehicles in which human resource allocation approaches have been published?* Answering this question will help understand the type of venue where the relevant research is being published, which reflects the maturity of the domain. For example, far more validation is needed in journal papers than conference or workshop papers.

The second research question is: *What research types have been used in human resource allocation studies?* Responding to this question will also help discover the maturity of this research area: a high number of primary studies classified as proposals indicates that the domain is new; a large amount of validation studies signals an increasing interest in the area and shows that efforts in that direction are becoming more fruitful; and evaluations in real scenarios mean that the domain has already accrued a certain amount of knowledge which is ready to be applied.

The third research question is: *Which evaluation methods are most frequently employed to validate human resource allocation approaches? Is real- life data involved?* This question offers insight as to whether or not there is a consensus among researchers in terms of how research being conducted in this area must be validated.

The final research question is: *Which geographical areas have reported approaches to allocate human resources?* This question would help identify clusters of knowledge according to international regions, as well as to determine specific research groups that

are dedicated to this particular research area.

4.2. *Conduct search strategy*

Based on these questions, and following a thorough review of the scope of certain search strategies (*Review Scope*), we identified the keywords to be used in the identification of the primary studies. Subsequently, we performed the *Conduct Search* phase. Table 2 outlines the keywords used, in addition to related synonyms that were also considered.

Table 2.: Search string

Keywords	**Synonyms**
Resource Allocation	"resource allocation", "resource assignment", "staff assignment", "staff allocation", "task allocation" , "task assignment" and "resource patterns"
Process Mining	"process mining"
Business Process Management	"business process management"

The search for primary studies was undertaken using the following digital libraries: ACM Digital Library, IEEE Xplore Digital Library, ScienceDirect, Scopus, Springer Link, Wiley and Web of Science. Notice that all publishing vehicles included in this paper were retrieved from the aforementioned digital libraries. Unfortunately not all search digital library operate in the same way or respect the same rules for searching strings, thus, a number of workarounds were performed during the first stage of our research (see Table 3).

Table 3.: Specific search conditions for each digital library

Digital Library	**Description**
ACM	The search was restricted to publication titles and abstracts. Since ACM subscribers are unable to export more than one article at a time, the articles had to be retrieved one by one and saved on an ACM personal binder. Only once all the articles searched for had been placed in the binder was it possible to export the primary studies and select the file format.
IEEE Xplore	The search was also restricted to titles and abstracts of publications via the selection of the "Metadata Only" option, in addition to the command search option. IEEE enables users to export in BibTeX files related to the search performed.
Science Direct	the search was conducted by selecting the advanced search followed by the expert search, which ensures more accurate search strings. It should be noted that the Science Direct library contains works from a broad range of areas, therefore, the searches were restricted to the subject of Computer Science, by adding the following sentence to the end of the search string: [All Sources (Computer Science)]. The primary studies selected were saved in a BibTeX file.
Scopus	The search was restricted to publication titles, abstracts and keywords, by adding the words "TITLE- ABS-KEY" before all search terms. As in the case with the Science Direct digital library, Scopus includes a broad range of works covering multiple areas, thus all searches were restricted to the subject of Computer Science by adding the following sentence at the end of the search string: AND (LIMIT-TO (SUBJAREA, "COMP")).
Springer Link	The advanced search option was used. As with Science Direct and Scopus, Springer is also multidisciplinary. Therefore, searches were restricted to Computer Science publications by adding the following sentence to the end of the search string: AND (SU = Computer Science) The search resulted in primary studies being saved in a CSV file.
Wiley	There was no search restriction with this library, thus the search was performed across all fields (using the tag All Fields). Wiley limits exports to just 20 primary studies per session, but exports are in BibTeX format.
Web of Science	The advanced search option was utilized, in addition to searches by titles and topics, which were exported in a BibTeX file.

Table 4 shows the specific search strings used in each digital library, including any relevant (aforementioned) restrictions. Table 5 outlines the results obtained from the

digital libraries searches. A total of 2,370 primary studies were selected as a result of the *All Papers* phase. After performing the digital libraries searches, we excluded any duplicate articles identified (420 articles). Thus, 1,950 articles were selected for the *Screening of Papers* phase.

Table 4.: Specific search strings for each digital library

Digital Library	**Search String**
ACM	("resource patterns" OR "resource allocation" OR "resource assignment" OR "staff allocation" OR "staff assignment" OR "task allocation" OR "task assignment") AND ("process mining" OR "business process management")
IEEE Xplore	(("resource patterns" OR "resource allocation" OR "resource assignment" OR "staff assignment" OR "staff allocation" OR "task allocation" OR "task assignment") AND ("process mining" OR "business process management"))
Science Direct	("resource patterns" OR "resource allocation" OR "resource assignment" OR "staff assignment" OR "staff allocation" OR "task allocation" OR "task assignment") AND ("process mining" OR "business process management")
Scopus	TITLE-ABS-KEY (("resource patterns" OR "resource allocation" OR "resource assignment" OR "staff assignment" OR "staff allocation" OR "task allocation" OR "task assignment") AND ("process mining" OR "business process management"))
Springer Link	("resource patterns" OR "resource allocation" OR "resource assignment" OR "staff assignment" OR "staff allocation" OR "task allocation" OR "task assignment") AND ("process mining" OR "business process management")
Wiley	("resource patterns" OR "resource allocation" OR "resource assignment" OR "staff assignment" OR "staff allocation" OR "task allocation" OR "task assignment") AND ("process mining" OR "business process management") in All Fields
Web of Science	(TS=(("resource patterns" OR "resource allocation" OR "resource assignment" OR "staff assignment" OR "staff allocation" OR "task allocation" OR "task assignment") AND ("process mining" OR "business process management")) or TI=(("resource patterns" OR "resource allocation" OR "resource assignment" OR "staff assignment" OR "staff allocation" OR "task allocation" OR "task assignment") AND ("process mining" OR "business process management"))) AND LANGUAGE: (English)

Table 5.: Number of papers retrieved from each digital library

Digital Library	**Search Results**
ACM	17
IEEE Xplore	19
ScienceDirect	268
Scopus	1,184
Springer Link	754
Wiley	110
Web of Science	18
Total	**2,370**

4.3. *Screening of papers*

In the *Screening of Papers* phase, the 1,950 papers were screened to evaluate whether, according to their titles and abstracts, they should be included in this SMS. Petersen et al. (2008) proposed two phases for initial analysis *Screening of Papers*; first, to conduct a search of only the titles of papers, and second, to perform another *Keywording search using Abstracts*, considering only abstracts. Therefore, the *Keywording search using Abstracts* phase will not be mentioned again in this article because it was applied in conjunction with the *Screening of Papers* phase. We decided to merge these two searches into one to maximize the performance and effort required. As such, all articles

were screened by at least two of the authors of this paper. If no consensus was reached regarding whether or not to include the article, a third author was required to screen the article and pass the deciding vote. The systematic mapping process applied is outlined in further detail in Figure 2.

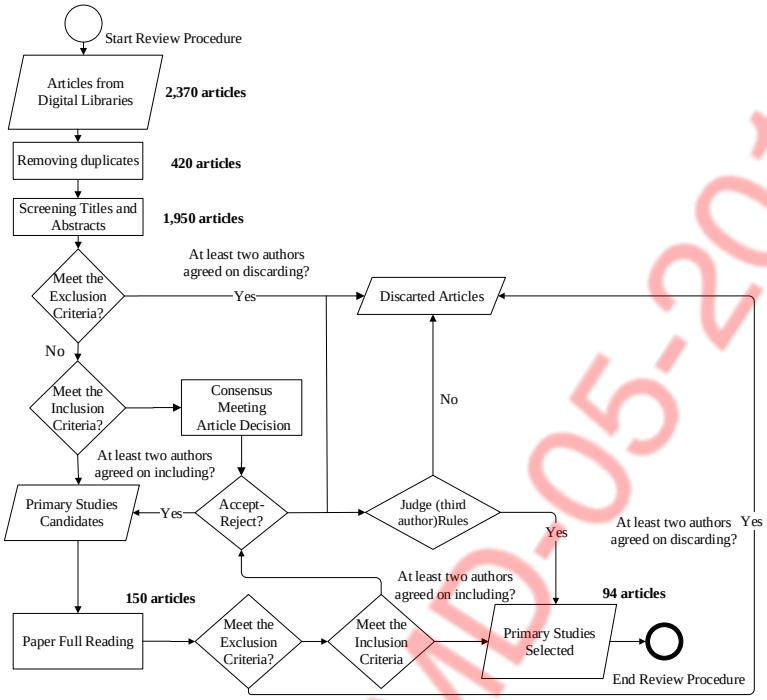

Figure 2.: Systematic mapping process performed considering Petersen et al. (2008) procedure

The inclusion criteria used during the *Screening of Papers* phase were as follows:

(1) Peer-reviewed articles in conferences, workshops, journals, or book parts
(2) The article was published between January 2005 and July 2016
(3) The article is published in English
(4) The article proposes a human resource allocation approach within the domain of Business Process Management or Process Mining
(5) The article includes a method/experiment/case study to validate the proposed approach

The reason for choosing the period between January 2005 and July 2016 was motivated by the need to provide a better support to the *resource perspective*, focusing on the resource allocation research area. Zur Muehlen (2004) develops guidelines of organizational aspects including resource allocation as a formal specification of resources involved in business process execution. Furthermore, the creation of the Workflow Resource Patterns (Russell et al., 2005) as a form of capture the various ways in which resources are represented and utilized in workflows, encouraged the appearance of new resource allocation approaches within business process management. Those approaches can be seen as an effort to provide a comprehensive treatment of the *resource perspective*. In order to discover the trends in this research area, we began our search in January 2005.

The exclusion criteria used to exclude articles were as follows:

(1) The article is not available online
(2) Articles in which the full text is not available
(3) The article does not propose a human resource allocation approach oriented to business processes
(4) The article only concerns the resource behavior
(5) The article only describes the creation of an organizational meta-model

Following the conclusion of the *Screening of Papers* phase, a set of 150 articles that meet our inclusion and exclusion criteria were obtained. According to Petersen et al. (2008), this phase marks the point at which researchers possess a series of *Relevant Papers* that require reading in full. Table 6 shows the breakdown of the amount of articles included during the mapping process.

Table 6.: Results obtained after the application of the guidelines

Phase	Amount of papers
All papers	2,370
After removing duplicates	1,950
After screening of papers	150
After full reading	94
Snowballing	1

The 150 articles selected after the *Screening of Papers* were read in their entirety by at least two authors, in an independent manner. If no consensus was forthcoming regarding their inclusion or exclusion based on the relevant criteria, the authors discussed the paper in question in an attempt to reach an agreement. If no such agreement was possible, a third author was required to read the article and cast the deciding vote. Overall, the authors read a total of 150 papers, which were subsequently reduced after full reading to the final set of 94 primary studies to be included in this SMS.

4.4. *Data Extraction*

The *Data Extraction* process used in this paper was designed to answer the four research questions. Furthermore, each article that passed the screening process was analyzed and the necessary data was extracted in line with the facets established in Table 7 and Table 8.

Table 7.: Classification of research types based on Nguyen et al. (2017)

Research Type	Description
Proposal of Solution	*"A novel solution for a problem or new significant extension to an existing technique."*
Validation Research	*"Investigating a proposed solution, which is novel and has not yet been implemented in practice. Investigations are carried out systematically, i.e., prototyping, simulation, experiments, mathematical systematic analysis and mathematical proof of properties."*
Evaluation Research	*"Evaluating a problem or an implemented solution in practice, i.e., case studies, field studies and field experiments."*

The information extracted from the articles also included: title, year, venue, author(s) and geographical region. Information related to the facets were, in some cases, stated by the authors of the articles, whereas in other cases they were implied or placed in a category that states that the author makes no clear mention of the facet. In this paper, none of the articles were classified according to more than one facet.

Subsequent to performing the Petersen et al. (2008) procedure for an SMS, we conducted an evaluation of whether snowballing was required. According to Jalali and Wohlin (2012), a backward snowballing is preferable when the domain area is not

Table 8.: Classification of evaluation methods based on Prat et al. (2015)

Evaluation method	Description
Running Example	Uses a hypothetical execution of a business process.
Simulation	Execute the experimental/simulation using synthetic data.
Case Study	Implement a case study using real-life data.
Several Case Studies	Implement two or more case studies using real-life data.

considered or known to be fully developed. In order to evaluate whether a snowballing for the full set of primary studies was required, we performed a backward snowballing with a small sample of the primary studies (10%). This sample was selected by the most senior author of this paper and was designed to represent the most relevant articles identified. As a result, only one paper met our inclusion/exclusion criteria, although even this was a marginal inclusion. Thus, we concluded that it was unnecessary to perform a full backward snowballing for this SMS.

5. Results obtained

The results of the data extraction meant that 95 articles were selected as primary studies, outlined in Appendix A (see Table 12). Based on the results obtained, it is possible to answer the proposed research questions, as follows.

5.1. *What are the most common publishing vehicles in which human resource allocation approaches have been published?*

Figure 3 depicts the distribution of the studies by venue. The *Journal* is the most common type of publishing vehicle, accounting for 42 studies (44%); followed closely by *Conference* proceeding with 39 studies (41%); *Workshop* proceeding with 12 studies (13%); and *Book parts*, with 2 studies (2%). Figure 4 outlines the distribution of venues per year. In general, it reveals that the majority of proposed approaches (67 primary studies, 71%) relate to the period 2011 to 2016.

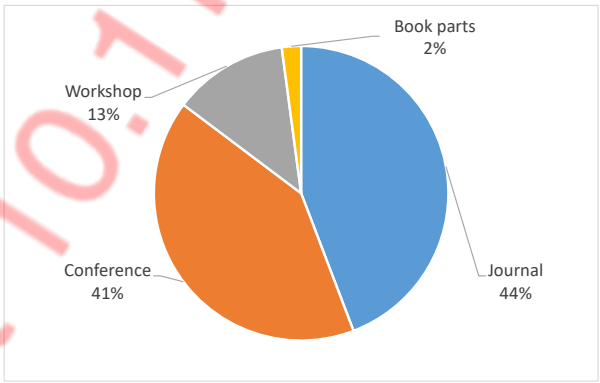

Figure 3.: Primary studies by venue

Journals usually relate to collections of academic articles that focus on publishing original research work written by researchers and experts in a particular discipline. The majority of journals are based on a peer-review evaluation process. This involves

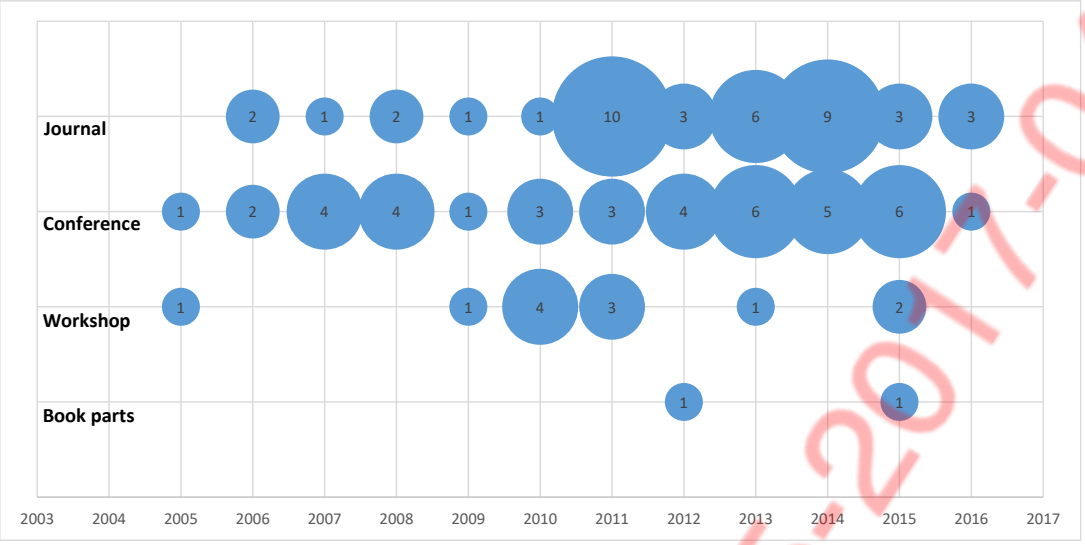

Figure 4.: Primary studies publication per year

experts in the field who are responsible for reviewing and evaluating the submitted articles and deciding whether to accept them for publication in the journal. Typically, several review iterations are performed.

Table 9 highlights the most relevant journals in which primary studies have been published. Those journals are: Data & Knowledge Engineering, with 4 publications; Expert Systems with Applications, with 3 publications; Information and Software Technology, with 3 publications; Concurrency and Computation: Practice and Experience, with 2 publications; Computers in Industry, with 2 publications; Computers & Industrial Engineering, with 2 publications; Information Systems, with 2 publications; International Journal of Computer Integrated Manufacturing, with 2 publications; and Knowledge-based Systems, also with 2 publications. Therefore, it is possible to note that no particular journal stands out above all others. Moreover, the distribution of publications across the entire period researched is not homogeneous. From 2006 to 2010, only 7 studies were published in journals. This amount increased fivefold between 2011 and 2016, in which 2011 (10 studies in total) and 2014 (9 in total) were the most active years in terms of articles publication in journals.

A *Conference* is generally regarded as a meeting in which researchers and practitioners present their work and discuss ideas about a particular discipline within the research community. Typically, the review process for conference papers includes the following steps: a) a predefined deadline for paper submission; b) only one review iteration; c) a program committee (or review committee) that reviews and discusses the submitted articles and makes a final decision on which articles are accepted; and d) notification to the authors, whereby they are informed as to whether their research paper was accepted or rejected. Generally, conference articles that follow a peer reviewed process are subsequently published in the conference proceedings.

The most relevant conferences were as follows: the International Conference on Business Process Management, with 6 publications; the Americas Conference on Information Systems (AMCIS), with 3 publications; the International Conference on Computer Supported Cooperative Work Design, with 3 publications; the International Conference on Service-oriented Computing, with 3 publications; the Asia-Pacific Conference on Business Process Management, with 2 publications; and the International

Table 9.: Primary studies published in journals, conferences, workshops and book parts

Publishing vehicle	Name	Article ID
Journals	Data & Knowledge Engineering	P4,P10,P38,P64
	Expert Systems with Applications	P23,P33,P51
	Information and Software Technology	P35,P76,P86
	Concurrency and Computation: Practice and Experience	P41,P60
	Computers in Industry	P13,P70
	Computers & Industrial Engineering	P54, P80
	Information Systems	P90,P95
	International Journal of Computer Integrated Manufacturing	P34,P42
	Knowledge-Based Systems	P14,P50
	Applied Intelligence	P66
	Computer Standards & Interfaces	P75
	Cybernetics and Systems	P3
	Dynamics in Logistics	P29
	Engineering Applications of Artificial Intelligence	P31
	Enterprise Information Systems	P65
	IEEE Transactions on Knowledge and Data Engineering	P36
	IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans	P46
	International Journal of Business Information Systems	P93
	International Journal of Industrial and Systems Engineering	P30
	International Journal of Production Research	P56
	Journal of Artificial Intelligence Research	P20
	Journal of Decision Systems	P78
	Journal of Information and Computational Science	P61
	Journal of Intelligent Manufacturing	P73
	Journal of Society for e-Business Studies	P71
	Knowledge and Information Systems	P92
	Ocean Engineering	P72
	World Wide Web Internet and Web Information Systems	P74
Conferences	International Conference on Business Process Management	P2,P6,P11,P16,P55,P62
	Americas Conference on Information Systems	P21,P48,P52
	International Conference on Computer Supported Cooperative Work in Design	P5,P53,P68
	International Conference on Service-Oriented Computing	P37,P63,P82
	Asia-Pacific Conference on Business Process Management	P58,P88
	International Conference on Software and System Process	P67,P84
	ACM symposium on Applied computing	P7
	Conference on Technologies and Applications of Artificial Intelligence	P87
	Construction Research Congress	P77
	European Conference on Information Systems	P44
	Information Systems Development	P59
	Hawaii International Conference on System Sciences	P8
	International Conference on Advanced Information Systems Engineering	P94
	International Conference on Availability, Reliability and Security	P28
	International Conference on Cloud and Green Computing	P45
	International Conference on Computer and Information Sciences	P69
	International Conference on Enterprise Information System	P12
	International Conference on Intelligent Computing	P91
	International Conference on Services Computing	P43
	International Conference on Smart Grids and Green IT Systems	P79
	International Conference on Software Engineering Advances	P15
	International Conference on Subject-Oriented Business Process Management	P47
	International Conference on Web Services	P17
	International Symposium on Technology Management and Emerging Technologies	P85
	New World Situation: New Directions in Concurrent Engineering	P24
	On the Move to Meaningful Internet Systems	P19
	Symposium on Theoretical Aspects of Software Engineering	P9
Workshops	Business Process Management Workshops	P1,P25,P39,P40,P57,P81,P83
	Business Information Systems Workshops	P32
	IEEE Workshop on Principles of Advanced and Distributed Simulation	P27
	International Conference on Data Mining Workshops	P22
	International Workshop on Agents and Data Mining Interaction	P18
	Workshop Proceedings Advances in Petri Nets and Concurrency	P26
Book parts	S-BPM in the Wild: Practical Value Creation	P89
	Service-Oriented Crowdsourcing	P49

Conference on Software and System Process with 2 publications. All the other conferences produced only one publication. It is also noteworthy that articles have been published during conferences throughout the analysis period (January 2005-July 2016). Since 2010, the number of conference articles increased. This could be interpreted as a growing trend in which ideas related to the research area of human resource allocation are being more frequently discussed among peers during conferences. Furthermore, it is possible to observe that the International Conference on Business Process Management stands out as the conference in which the greatest number of articles was presented.

A *Workshop* is a type of academic event that is smaller than a conference, and in general, the goal of which is to explore a research area and encourage research articles that focus on a specific topic. Workshops traditionally follow a review process to evaluate all submissions through a program committee, and the accepted papers are subsequently published in the proceedings of the workshop itself, or in conjunction with the conference within which the workshop is co-located. Regarding the workshops analyzed in this SMS, 7 studies presented herein stem from workshops that took place as part of the International Conference on Business Process Management. No single workshop produced more than one article that has been classified as a primary study. As can be seen in Figure 3, studies are published in workshops with less frequency than in journals or conferences.

Similar to the case of conferences, it was not possible to find a homogeneous distribution in relation to the amount of publications emanating from workshops. Clearly, the workshops executed as part of the International Conference on Business Process Management (e.g., International Workshop on Business Process Intelligence (BPI), International Workshop on Decision Mining & Modeling for Business Processes (DeMiMoP)) are more noteworthy than the others. This makes it possible to confirm that the focus of this particular conference, and its associated workshops, was aligned closely with the interests pertaining to research in human resource allocation.

Finally, the *Book parts* venue refers to chapters of books that are written with a focus on particular topics. This venue is subject to a rigorous review and approval process prior to publication. The publishing vehicle relating to sections of books reported only two publications: Crowdsourcing Tasks in BPEL4People (Schall, 2012), in the book 'Service-Oriented Crowdsourcing' (2012); and Role and Rights Management (Lawall, Schaller, & Reichelt, 2015), published in the book 'S-BPM in the Wild' (2015).

5.2. *What research types have been used in human resource allocation studies?*

Figure 5 shows the distribution of distinct resource allocation approaches according to the classification of research types mentioned by (Wieringa, Maiden, Mead, & Rolland, 2006), and discussed in (Petersen et al., 2015), which aims to organize studies. The research types considered were: *Proposal of Solution*, *Validation Research*, and *Evaluation Research* (outlined in Table 7). Table 10 classifies the primary studies according to research types.

Figure 6 shows that 52% of primary studies (50 studies) had applied *Validation Research* in order to evaluate the proposed human resource allocation approaches, thereby creating a prototype or tool, as well as having executed experiments using simulated or synthetic data. Also, 34% of primary studies (32 studies) were produced using *Evaluation Research*. This research type shows an increase in the amount of primary studies during the second half of the analysis period regarding the validation of the allocation approaches by means of case studies using real data (see Figure 5).

This can be understood from the need to validate the proposed approaches in real business scenarios, as well as to analyze the benefits that might be generated for process owners at the moment of selecting and allocating human resources.

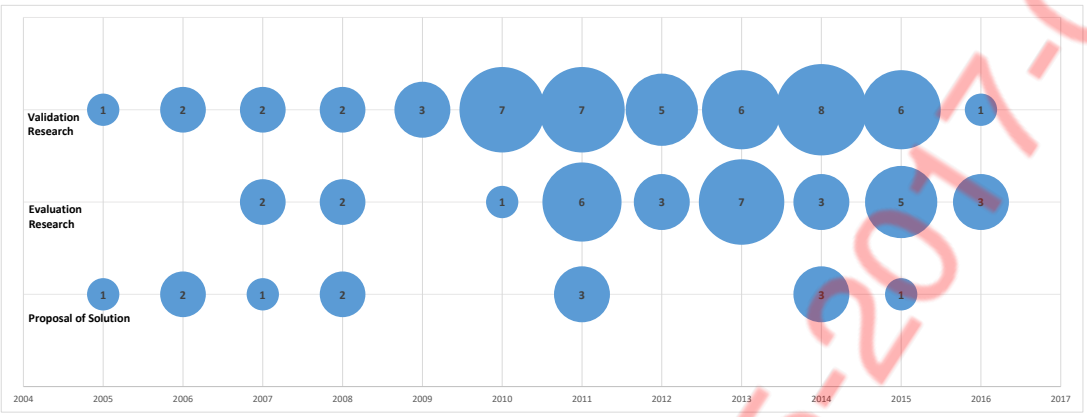

Figure 5.: Research types used to develop human resource allocation approaches

Table 10.: Primary studies classified by research type

Research Type	Article ID
Proposal of Solution	P1, P5, P6, P9, P15, P16, P40, P29, P35, P70, P77, P78, P85
Validation Research	P2, P3, P4, P10, P11, P12, P17, P18, P19, P20, P21, P22, P24, P25, P26, P27, P28, P32, P36, P37, P39, P41, P43, P44, P45, P46, P47, P49, P52, P53, P59, P60, P61, P63, P64, P67, P68, P72, P73, P74, P75, P79, P81, P83, P84, P87, P89, P90, P95
Evaluation Research	P7, P8, P13, P14, P23, P30, P31, P33, P34, P42, P38, P48, P50, P51, P54, P55, P56, P57, P58, P62, P65, P69, P71, P76, P80, P82, P86, P88, P91, P92, P93, P94

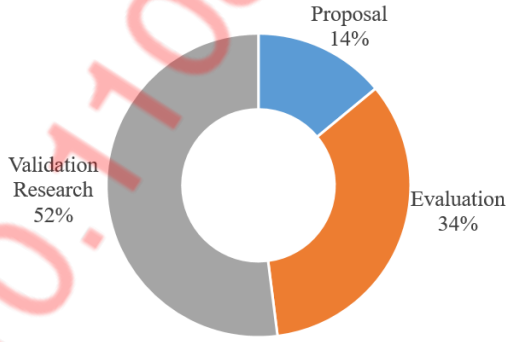

Figure 6.: Distribution of research types

Only 14% of primary studies (13 studies) were classified according to the *Proposal of Solution* type, whereby 9 of which were compiled between 2005 and 2011. This small number can be understood in light of the maturity-level currently sought by this research area, which in turn, naturally results in greater numbers of studies following the *Validation* and *Evaluation* research types. There is a tendency in which the proposed human resource allocation approaches are not only validated by means of experiments that use synthetic data and the implementation of prototypes and/or tools, but also

that engage in the practical implementation of a solution that runs case studies. As can be seen in Figure 5, since 2011, there has been no clear distinction between *Validation Research* and *Evaluation Research*. This may signify that this particular research area is emerging and is responsible for generating a large amount of ideas that are being evaluated, yet which require consolidation to be subsequently validated by means of applications in real contexts.

5.3. *Which evaluation methods are most frequently employed to validate human resource allocation approaches? Is real-life data involved?*

Having been inspired by Prat et al. (2015), the following evaluation methods were defined: *Running Example*, *Simulation*, *Case Study*, and *Several Case Studies* (outlined in Table 8). Notice that in a single article, more than one evaluation method might have been used, but only the most complex one is reported. Figure 7 provides a breakdown of the distribution of evaluation methods per year and Table 11 classifies the primary studies conforming those evaluation methods. As can be seen, the highest concentration of studies that use *Case Studies* was compiled from 2011 onwards, compared to studies that merely followed the strategy of *Running Example*, which was more common in the first half of the analysis period.

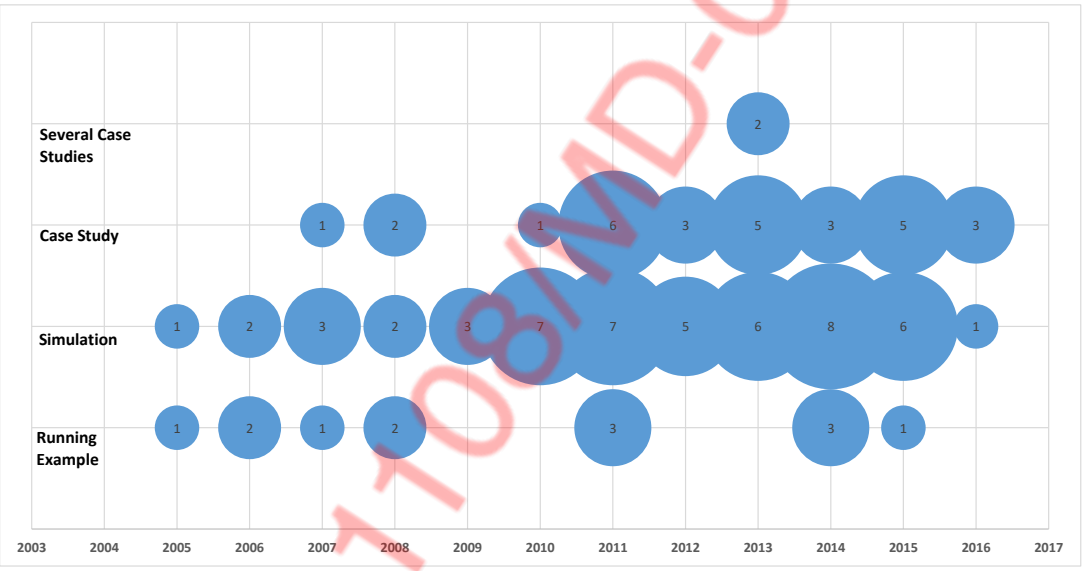

Figure 7.: Evaluation methods per year

Table 11.: Primary studies classified by evaluation method

Evaluation method	Article ID
Running Example	P1, P5, P6, P9, P15, P16, P40, P29, P35, P70, P77, P78, P85
Simulation	P2, P3, P4, P8, P10, P11, P12, P17, P18, P19, P20, P21, P22, P24, P25, P26, P27, P28, P32, P36, P37, P39, P41, P43, P44, P45, P46, P47, P49, P52, P53, P59, P60, P61, P63, P64, P67, P68, P72, P73, P74, P75, P79, P81, P83, P84, P87, P89, P90, P95
Case Study	P7, P13, P14, P23, P30, P31, P33, P34, P42, P38, P48, P50, P51, P55, P57, P58, P62, P65, P69, P71, P76, P80, P82, P86, P88, P91, P92, P93, P94
Several Case Studies	P54, P56

In turn, *Simulation* has been present in studies throughout the entire analysis pe-

riod, having been used with greater frequency since 2010. This indicates that the evaluation method through simulation is a very common method with which the approaches for allocating resources have been evaluated. However, the execution of case studies using real-life data is an evaluation method that is becoming increasingly prevalent in approaches for allocating resources.

To summarize, Figure 8 shows that just over half of the primary studies (51 studies - 54%) used *Simulation* as their evaluation method. This result is unsurprising since it is a common practice to recreate a work scenario, implement a prototype or a tool, and conduct an experimental evaluation using synthetic data in order to demonstrate the usefulness of the proposed approaches. The second most widely used evaluation method was *Case Study* (29 studies - 30%), reflecting an increasing interest in being able to perform the validation of the proposed approaches in real life scenarios, using real-life data.

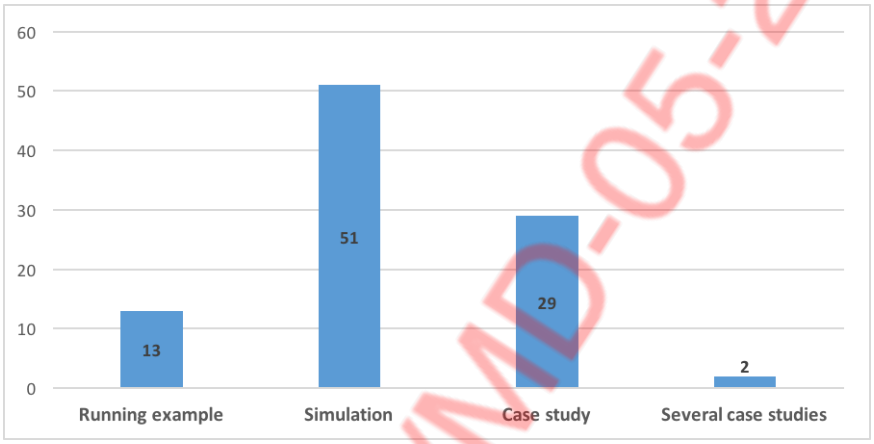

Figure 8.: Evaluation methods

In addition, 13 primary studies (14%) applied only the *Running Example* method to illustrate their approaches. In this case, the authors used a hypothetical execution of a business process in order to introduce their allocation approaches and, through the running example, illustrate the use of the proposed solution. Finally, only 2 primary studies (2%) reported more than one case study to evaluate their respective approaches. It is also noteworthy (see Figure 7) that the *Simulation* method was present across all the years of the analysis period of this paper, compared to the *Case Study* method, which shows a growing trend only in the last 5 years. This demonstrates that the research area of human resource allocation is progressing in the direction of studies based on experience, validating the proposed approaches in real cases.

5.4. *Which geographical areas have reported approaches to allocate human resources?*

Five different geographical areas were found in which human resource allocation approaches have been proposed (see Figure 9). There is a total of 23 different countries in which allocation approaches have been reported. This is broken down as follows: countries from Asia (43 studies - 46%), including China, with 22; Korea, with 6; Taiwan, with 5; India, with 3; Malaysia, with 3; Indonesia, with 2; the United Arab Emirates and Japan, with 1 each. Countries from Europe (41 studies - 43%): Germany, with 14; Austria, with 10; The Netherlands, with 6; Spain, with 3; Greece, with 2; and Sweden, the United Kingdom, Belgium, Poland, Denmark, and Italy, with 1 each. Countries from Oceania (5 studies- 5%): Australia, with all 5. Countries from North America (4

studies - 4%): the United States, with all 4. Countries from Latin America (2 studies - 2%): Argentina and Chile, with 1 each. There is no evidence of approaches to allocate human resources from Africa.

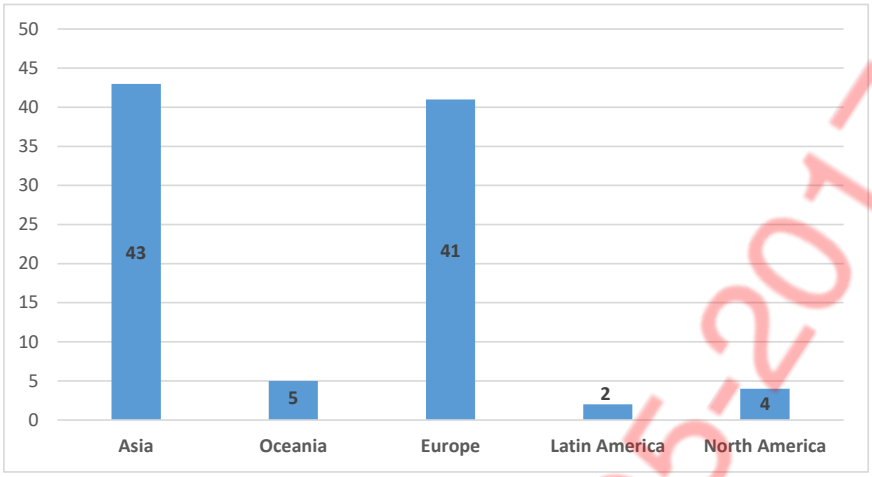

Figure 9.: Regional origin of the primary studies selected

By looking in greater detail, Figure 10 shows the geographical distribution of studies per year. It can be seen that, since 2005, there has been a growing trend of increasing numbers of studies across all regions, except North America, where four studies have been published over the course of four separate years (one per year), and in Latin America, where publications only began in 2015. Furthermore, it is possible to observe that both Asia and Europe have published studies every year, while in Oceania nothing has been published since 2013. This finding could represent a growing worldwide interest in the area of human resource allocation, with China standing out as the leader within this wider trend.

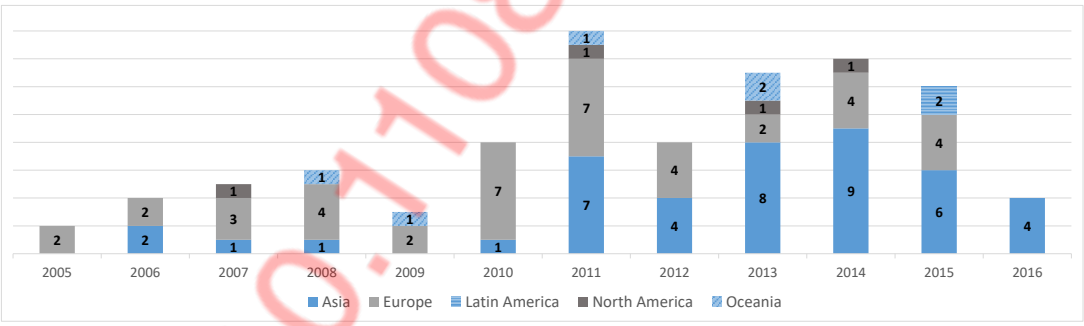

Figure 10.: Region studies per year

Among the research groups that are working in the human resource allocation research area, we can highlight the Vienna University of Economics and Business (WU), Austria, with 6 studies; the Tsinghua University and the Zhejiang University, China, with 4 studies each; and the University of Karlsruhe, Germany, with 3 studies.

6. Threats to validity

Construct validity reflects the extent to which the phenomenon under study genuinely represents the area conceived by researchers and the subject being investigated, in line with the relevant research questions. The number of articles found herein indicates that

the search terms used were well defined and reported. To reiterate, only data available between January 2005 and July 2016 were considered.

Reliability relates to data collected and the analysis thereof, in order to gauge whether it was conducted in such a way that can be repeated by others. The search terms were defined according to a standard procedure, while mapping was undertaken by following a detailed guideline which is described herein, in order to facilitate its replication by third parties. The extracted information could also be a source of reliability concern since different keyword searching mechanisms exist for articles in each of the online digital libraries. We adapted the search strings as described in the methodology outlined in the *Conduct search strategy* (Subsection 4.2), according to each online digital library. To mitigate the reliability threat in relation to the keywords and article-reading selection processes, two authors performed the data extraction. If no consensus was reached among the authors, a discussion meeting was held. If consensus was still lacking, a third author was required to read the article in question and pass final judgement. The results obtained could be the subject of distinct limitations relating to the automated search engines used in this paper. There is a possibility that some primary studies might have been omitted. The studies considered herein were those that met the inclusion criteria and were not rejected on the basis of the exclusion criteria.

Internal validity is related to the classification of each article according to the data collected by the authors. External validity, on the other hand, is concerned with the generalization of results. Overall, a mapping study does not generate any particular conclusion (does not go into further details), it presents the data collected from the primary studies, as well as their results. The obtained results are generalized and limited to the researched period and the approaches published in the research area of human resource allocation with only BPM and Process Mining disciplines. We included only peer-reviewed articles, therefore other publishing vehicles (e.g., master thesis) were not considered.

7. Conclusions and future work

This paper have presented the results of an SMS of existing articles in the research area of human resource allocation in BPM and Process Mining. The results obtained reflect a growing interest in working in this particular research area over the last decade. To compile this work, we have followed a protocol of conducting mapping studies to create an initial classification of the research published in this research area; something that was previously lacking. The work undertaken help us answer four questions that aim to generate greater understanding in relation to: (i) common publishing vehicles; (ii) research types used; (iii) evaluation methods utilized; and (iv) geographic distribution. The scope of this SMS covers 95 primary studies that have been published across different publishing vehicles.

The results confirm that the task of allocating resources is an emerging research area in BPM and Process Mining. Results also demonstrate that a large number of researchers have dedicated their time and effort to identifying ways to enhance the efficiency of resource allocation in these two disciplines. With regard to the first research question, *Journals* represent the most commonly used venue (44%), followed by *Conferences* (41%), *Workshop* (13%), and *Book parts* (2%). There is no clear preference for a specific publishing method. In some research areas, journals are more relevant than conferences, or vice versa. However, in the human resource allocation research area, both venues are equally relevant. In relation to the second research question,

the most frequently used research types are *Validation Research* and *Evaluation Research*. This demonstrates that there is a trend whereby human resource allocation approaches are not only validated by means of experiments that use synthetic data and the implementation of prototypes and/or tools, but also via the application of case studies. In the third research question, we identified that the categories of *Simulation* (54%) and *Case Study* (30%) are the most commonly used evaluation methods in the primary studies. The increasing use of case studies as evaluation method promotes the maturity level of the research area. This greater maturity level in turn will require researchers in the future to assess their proposals in real environments. Finally, the geographic analysis shows that Asia (46%) and Europe (43%) are the regions with the highest concentration of studies in the human resource allocation research area, compared to a limited number of articles in Oceania (5%), North America (4%), and Latin America (2%).

This SMS can now serve as a reference guide about articles that have been published in this research area, enabling researchers to classify the proposed studies and ensuring the provision of an overview of the work compiled in this discipline over the course of the last decade.

We plan to extend this work further to produce a more in-depth analysis, introducing additional elements into the systematic evaluation. We plan to identify the main business drivers that are considered by resource allocation approaches, the algorithms and tools, the criteria for assessing the resources, and the process domains that are frequently used to evaluate the proposed approaches. This will help to determine current challenges, identify opportunities for future research, and the key aspects that need to be considered when allocating human resources in business processes.

Appendix A: List of primary studies included in the SMS

Table 12.: Primary studies selected

Article ID	Venue	Title	Year	Region
P1	Workshop	Ly, L. T., Rinderle, S., Dadam, P., & Reichert, M. (2005). Mining staff assignment rules from event-based data. In Business Process Management Workshops, BPM 2005 International Workshops, BPI, BPD, ENEI, BPRM, WSCOBPM, BPS, Nancy, France, September 5, 2005, Revised Selected Papers (pp. 177-190).	2005	Europe
P2	Conference	van Hee, K. M., Serebrenik, A., Sidorova, N., Voorhoeve, M., & van der Wal, J. (2005). The price of coordination in resource management. In Business Process Management, 3rd International Conference, BPM 2005, Nancy, France, September 5-8, 2005, proceedings (pp.96-108).	2005	Europe
P3	Journal	Bayer, K., Kempf, S., Brocks, H., & Kamps, T. (2006). A multiagent environment for the flexible enactment of knowledge-intensive processes. Cybernetics and Systems, 37 (6), 653-672.	2006	Europe
P4	Journal	Ha, B. H. a. c., Bae, J. b. d., Park, Y. T. a. e. f., & Kang, S. H. a. g. (2006). Development of process execution rules for workload balancing on agents. Data & Knowledge Engineering, 56 (1), 64-84.	2006	Asia
P5	Conference	Tan, H., & van der Aalst, W. M. P. (2006). Implementation of a YAWL work-list handler based on the resource patterns. In Proceedings of the 10th international conference on CSCW in design, CSCWD 2006, May 3-5, 2006, Southeast University, Nanjing, China (pp.1184-1189).	2006	Europe
P6	Conference	Xiangpeng, Z., Cerone, A., & Krishnan, P. (2006). Verifying BPEL workflows under authorisation constraints. In Business Process Management, 4th International Conference, BPM 2006, Vienna, Austria, September 5-7, 2006, proceedings (pp. 439-444).	2006	Asia
P7	Conference	Yingbo, L., Jianmin, W., & Jiaguang, S. (2007). A machine learning approach to semiautomating workflow staff assignment. In Proceedings of the 2007 ACM Symposium on Applied Computing (pp. 340-345). New York, NY, USA: ACM.	2007	Asia
P8	Conference	Kress, M., Melcher, J., & Seese, D. (2007). Introducing executable product models for the service industry. In System sciences, 2007. HICSS 2007. 40th Annual Hawaii International Conference on (pp. 46-46).	2007	Europe
P9	Conference	Wang, J., Tepfenhart, W., Rosca, D., & Tsai, A. (2007). Resource-constrained workflow modeling. In First joint IEEE/IFIP Symposium on Theoretical Aspects of Software Engineering, TASE '07 (pp. 171-177).	2007	North America
P10	Journal	van Hee, Kees, Alexander Serebrenik, Natalia Sidorova, Marc Voorhoeve, & Jan van der Wal. (2007). Scheduling-free resource management. Data & Knowledge Engineering, 61(1):59-75.	2007	Europe

P11	Conference	Reijers, H. A., Jansen-Vullers, M. H., zur Muehlen, M., & Appl, W. (2007). Workflow Management Systems + Swarm Intelligence = Dynamic task assignment for emergency management applications. In Business Process Management, 5th International Conference, BPM 2007, Brisbane, Australia, September 24-28, 2007, proceedings (pp. 125-140).	2007	Europe
P12	Conference	Delias, P., Doulamis, A., & Matsatsinis, N. (2008, jan). A joint optimization algorithm for dispatching tasks in agent-based workflow management systems. In ICEIS 2008 - proceedings of the 10th International Conference on Enterprise Information Systems (Vol. AIDSS, pp.199-206).	2008	Europe
P13	Journal	Liu, Y., Wang, J., Yang, Y., & Sun, J. (2008). A semi-automatic approach for workflow staff assignment. Computers in Industry, 59 (5), 463-476.	2008	Asia
P14	Journal	Overbeek, S. J., van Bommel, P., & Proper, H. A. E. (2008). Matching cognitive characteristics of actors and tasks in information systems engineering. Knowledge-Based Systems, 21 (8), 764-785.	2008	Europe
P15	Conference	Link, S., Hoyer, P., Schuster, T., & Abeck, S. (2008). Model-driven development of human tasks for workflows. In Proceedings - the 3rd International Conference on Software Engineering Advances, ICSEA 2008, International Workshop on Enterprise Information Systems (pp. 329-335).	2008	Europe
P16	Conference	Xu, J., Liu, C., & Zhao, X. (2008a). Resource allocation vs. business process improvement: How they impact on each other. In Business Process Management, 6th International Conference, BPM 2008, Milan, Italy, September 2-4, 2008. proceedings (pp. 228-243).	2008	Oceania
P17	Conference	Stefansen, C., Rajamani, S., & Seshan, P. (2008). Softalloc: A work allocation language with soft constraints. In Web Services, 2008. iICWS'08. IEEE International Conference on (pp. 441-448).	2008	Europe
P18	Workshop	Jablonski, S., & Talib, R. (2009). Agent assignment for process management: Pattern based agent performance evaluation. In Agents and data mining interaction, 4th International Workshop, ADMI 2009, Budapest, Hungary, May 10-15, 2009, Revised Selected Papers (pp.155-169).	2009	Europe
P19	Conference	Xu, J., Liu, C., & Zhao, X. (2009). Resource planning for massive number of process instances. In On the Move to Meaningful Internet Dystems: OTM 2009, Confederated International Conferences, Coopis, DOA, IS, and ODBASE 2009, Vilamoura, Portugal, November 1-6, 2009, proceedings, part I (pp. 219-236).	2009	Oceania
P20	Journal	Ramchurn, S. D., Mezzetti, C., Giovannucci, A., Rodriguez-Aguilar, J. A., Dash, R. K., & Jennings, N. R. (2009, jan). Trust-based mechanisms for robust and efficient task allocation in the presence of execution uncertainty. Journal of Artificial Intelligence Research, 35, 119-159.	2009	Europe
P21	Conference	Oberweis, A., & Schuster, T. (2010). A meta-model based approach to the description of resources and skills. In AMCIS (p. 383).	2010	Europe

P22	Workshop	Talib, R., Volz, B., & Jablonski, S. (2010). Agent assignment for process management: Agent performance evaluation framework. In ICDMW 2010, the 10th IEEE International Conference on Data Mining Workshops, Sydney, Australia, 13 December 2010 (pp. 1005-1012).	2010	Europe
P23	Journal	Huang, Z., Van Der Aalst, W. M. P., Lu, X., & Duan, H. (2010). An adaptive work distribution mechanism based on reinforcement learning. Expert Systems with Applications, 37 (12), 7533-7541.	2010	Europe
P24	Conference	Suzuki, Y., Jin, Y., Koyama, H., & Kang, G. (2010). In New World Situation: New Directions in Concurrent Engineering (pp. 73-81). Springer London.	2010	Asia
P25	Workshop	Unger, T., & Wagner, S. (2010, September). Collaboration aspects of human tasks. In International Conference on Business Process Management (pp. 579-590). Springer Berlin Heidelberg.	2010	Europe
P26	Workshop	Chrzastowski-Wachtel, P., & Rauch, J. (2010). IRS-MT: Tool for Intelligent Resource Allocation. In Susanna Donatelli, Jetty Kleijn, Ricardo J. Machado, Joao M. Fernandes (eds.) CEUR Workshop Proceedings, vol. 827 urn: nbn: de: 0074-827-8 ISSN 1613-0073 (p. 235).	2010	Europe
P27	Workshop	Kamrani, F., Ayani, R., & Karimson, A. (2010, May). Optimizing a business process model by using simulation. In Proceedings of the 2010 IEEE Workshop on Principles of Advanced and Distributed Simulation (pp. 40-47). IEEE Computer Society.	2010	Europe
P28	Conference	Tjoa, S., Jakoubi, S., Goluch, S., & Kitzler, G. (2010, February). Planning dynamic activity and resource allocations using a risk-aware business process management approach. In Availability, Reliability, and Security, 2010. ARES'10 International Conference on (pp. 268-274). IEEE.	2010	Europe
P29	Journal	Yahya, B. N., & Bae, H. (2011). Adaptive RBAC in Complex Event-Driven BPM Systems. In Dynamics in Logistics (pp. 203-212). Springer Berlin Heidelberg.	2011	Asia
P30	Journal	Suresh, M., Dutta, P., & Jain, K. (2011). Analysis of an EPC project: a solution to the resource constrained project scheduling problem using genetic algorithms. International Journal of Industrial and Systems Engineering, 8(2), 251-269.	2011	Asia
P31	Journal	Colucci, S., Tinelli, E., Di Sciascio, E., & Donini, F. M. (2011). Automating competence management through non-standard reasoning. Engineering Applications of Artificial Intelligence, 24(8), 1368-1384.	2011	Europe
P32	Workshop	Niedermann, F., Pavel, A., & Mitschang, B. (2011, June). Beyond roles: Prediction model-based process resource management. In International Conference on Business Information Systems Workshops. (pp. 5-17). Springer Berlin Heidelberg.	2011	Europe
P33	Journal	Huang, Z., Lu, X., & Duan, H. (2011). Mining association rules to support resource allocation in business process management. Expert Systems with Applications, 38(8), 9483-9490.	2011	Asia
P34	Journal	Yingbo, L., Li, Z., & Jianmin, W. (2011). Mining workflow event log to facilitate parallel work item sharing among human resources. International Journal of Computer Integrated Manufacturing, 24(9), 864-877.	2011	Asia

P35	Journal	Strembeck, M., & Mendling, J. (2011). Modeling process-related RBAC models with extended UML activity models. Information and Software Technology, 53(5), 456-483.	2011	Europe
P36	Journal	Delias, P., Doulamis, A., Doulamis, N., & Matsatsinis, N. (2011). Optimizing resource conflicts in workflow management systems. IEEE Transactions on Knowledge and Data Engineering, 23(3), 417-432.	2011	Europe
P37	Conference	Khazankin, R., Psaier, H., Schall, D., & Dustdar, S. (2011, December). Qos-based task scheduling in crowdsourcing environments. In International Conference on Service-Oriented Computing (pp. 297-311). Springer Berlin Heidelberg.	2011	Europe
P38	Journal	Huang, Z., van der Aalst, W. M., Lu, X., & Duan, H. (2011). Reinforcement learning based resource allocation in business process management. Data & Knowledge Engineering, 70(1), 127-145.	2011	Asia
P39	Workshop	Koschmider, A., Yingbo, L., & Schuster, T. (2011). Role assignment in business process models. In Business Process Management Workshops (pp. 37-49). Springer Berlin Heidelberg.	2011	Europe
P40	Workshop	Barba, I., Weber, B., & Valle, C. (2011). Supporting the optimized execution of business processes through recommendations. In Business Process Management Workshops (pp. 135-140). Springer Berlin Heidelberg.	2011	Europe
P41	Journal	Yu, Y., Pan, M., Li, X., & Jiang, H. (2011). Tabu search heuristics for workflow resource allocation simulation optimization. Concurrency and Computation: Practice and Experience, 23(16), 2020-2033.	2011	Asia
P42	Journal	Li, L. J., Gao, J. M., Chen, K., & Jiang, H. Q. (2011). The identification of irrationally allocated resources in business process based on network centrality analysis. International Journal of Computer Integrated Manufacturing, 24(8), 748-755.	2011	Asia
P43	Conference	Liu, R., Nigam, A., Shan, Z., & Wu, F. (2011, July). Uniform modeling of resources and business processes using business entities. In Services Computing (SCC), 2011 IEEE International Conference on (pp. 693-700). IEEE.	2011	North America
P44	Conference	Ouyang, C., Wynn, M. T., Kuhr, J. C., Adams, M. J., Becker, T., ter Hofstede, A. H., & Fidge, C. J. (2011). Workflow support for scheduling in surgical care processes. In ECIS 2011 Proceedings.	2011	Oceania
P45	Conference	Xu, J., Huang, Z., Yu, Y., & Pan, M. (2012, November). A performance analysis on task allocation using social context. In Cloud and Green Computing (CGC), 2012 Second International Conference on (pp. 637-644). IEEE.	2012	Asia
P46	Journal	Huang, Z., Lu, X., & Duan, H. (2012). A task operation model for resource allocation optimization in business process management. IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, 42(5), 1256-1270.	2012	Asia
P47	Conference	Lawall, A., Schaller, T., & Reichelt, D. (2012, April). An approach towards subject-oriented access control. In International Conference on Subject-Oriented Business Process Management (pp. 33-42). Springer Berlin Heidelberg.	2012	Europe
P48	Conference	Schuster, T. (2012). Balanced resource allocation. In 18th Americas Conference on Information Systems, AMCIS.	2012	Europe

P49	Book parts	Schall, D. (2012). Crowdsourcing Tasks in BPEL4People. In Service-Oriented Crowdsourcing (pp. 59-92). Springer New York.	2012	Europe
P50	Journal	Liu, T., Cheng, Y., & Ni, Z. (2012). Mining event logs to support workflow resource allocation. Knowledge-Based Systems, 35, 320-331.	2012	Asia
P51	Journal	Huang, Z., Lu, X., & Duan, H. (2012). Resource behavior measure and application in business process management. Expert Systems with Applications, 39(7), 6458-6468.	2012	Asia
P52	Conference	Schuster, T., Dietz, G., & Juhrisch, M. (2012). The Impact of Conceptual Modeling on Allocation of Human Resources in Collaborative Networks. In 18th Americas Conference on Information Systems 2012, AMCIS 2012, volume 4, pages 2778-2789.	2012	Europe
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P56	Journal	Genquan, R., Rui, H., Yingbo, L., Jiong, Z., Tao, J., Li, Z., & Jianmin, W. (2013). Applying genetic algorithm to optimise personal worklist management in workflow systems. International Journal of Production Research, 51(17), 5158-5179.	2013	Asia
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P58	Conference	Obregon, J., Kim, A., & Jung, J. Y. (2013, August). Dtminer: a tool for decision making based on historical process data. In Asia-Pacific Conference on Business Process Management (pp. 81-91). Springer International Publishing.	2013	Asia
P59	Conference	Guo, H., Brown, R., & Rasmussen, R. (2013). Human resource behaviour simulation in business processes. In Information Systems Development (pp. 167-178). Springer New York.	2013	Oceania
P60	Journal	Xu, J., Liu, C., Zhao, X., & Ding, Z. (2013). Incorporating structural improvement into resource allocation for business process execution planning. Concurrency and Computation: Practice and Experience, 25(3), 427-442.	2013	Oceania
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P63	Conference	Cabanillas, C., García, J. M., Resinas, M., Ruiz, D., Mendling, J., & Ruiz-Cortés, A. (2013, December). Priority-based human resource allocation in business processes. In International Conference on Service-Oriented Computing (pp. 374-388). Springer Berlin Heidelberg.	2013	Europe
P64	Journal	Barba, I., Weber, B., Del Valle, C., & Jiménez-Ramírez, A. (2013). User recommendations for the optimized execution of business processes. Data & Knowledge Engineering, 86, 61-84.	2013	Europe
P65	Journal	Gao, X., Xu, L., Wang, X., Li, Y., Yang, M., & Liu, Y. (2013). Workflow process modelling and resource allocation based on polychromatic sets theory. Enterprise Information Systems, 7(2), 198-226.	2013	Asia
P66	Journal	Hsieh, F. S., & Lin, J. B. (2014). A dynamic scheme for scheduling complex tasks in manufacturing systems based on collaboration of agents. Applied Intelligence, 41(2), 366-382.	2014	Asia
P67	Conference	Xu, R., Liu, X., Xie, Y., Yuan, D., & Yang, Y. (2014, May). A gaussian fields based mining method for semi-automating staff assignment in workflow application. In International Conference on Software and Systems Process 2014, ICSSP'14 (pp. 178–182).	2014	Asia
P68	Conference	Hsieh, F. S., & Lin, J. B. (2014, May). A multiagent approach for managing collaborative workflows in supply chains. In Computer Supported Cooperative Work in Design (CSCWD), Proceedings of the 2014 IEEE 18th International Conference on (pp. 71-76). IEEE.	2014	Asia
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P72	Journal	Son, M. J., & Kim, T. W. (2014). Business process management-based job assignment in ship hull production design. Ocean Engineering, 88, 12-26.	2014	Asia
P73	Journal	Hsieh, F. S., & Lin, J. B. (2014). Context-aware workflow management for virtual enterprises based on coordination of agents. Journal of Intelligent Manufacturing, 25(3), 393-412.	2014	Asia
P74	Journal	Schall, D., Satzger, B., & Psaier, H. (2014). Crowdsourcing tasks to social networks in BPEL4People. World Wide Web, 17(1), 1-32.	2014	Europe
P75	Journal	Hsieh, F. S., & Lin, J. B. (2014). Development of context-aware workflow systems based on Petri Net Markup Language. Computer Standards & Interfaces, 36(3), 672-685.	2014	Asia

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P77	Conference	Florez, L., & Castro-Lacouture, D. (2014). Optimal Crew Design for Masonry Construction Projects Considering Contractors' Requirements and Workers' Needs. In Construction Research Congress 2014: Construction in a Global Network (pp. 1149-1158).	2014	North America
P78	Journal	Linden, I. (2014). Proposals for the integration of interactive dashboards in business process monitoring to support resources allocation decisions. Journal of Decision Systems, 23(3), 318-332.	2014	Europe
P79	Conference	Lopez, B., Ghose, A., Savarimuthu, T., Nowostawski, M., Winikoff, M., & Cranefield, S. (2014). Towards energy-aware optimisation of business processes. In SMARTGREENS 2014 - Proceedings of the 3rd International Conference on Smart Grids and Green IT Systems, pages 68-75.	2014	Europe
P80	Journal	Xie, Y., Chien, C. F., & Tang, R. Z. (2015). A dynamic task assignment approach based on individual worklists for minimizing the cycle time of business processes. Computers & Industrial Engineering, 99, 401-414.	2015	Asia
P81	Workshop	Arias, M., Rojas, E., Munoz-Gama, J., & Sepúlveda, M. (2015, August). A framework for recommending resource allocation based on process mining. In International Conference on Business Process Management Workshops (pp. 458-470). Springer International Publishing.	2015	Latin America
P82	Conference	Sindhgatta, R., Ghose, A., & Dasgupta, G. B. (2015, November). Analyzing Resource Behavior to Aid Task Assignment in Service Systems. In International Conference on Service-Oriented Computing (pp. 412-426). Springer Berlin Heidelberg.	2015	Asia
P83	Workshop	Havur, G., Cabanillas, C., Mendling, J., & Polleres, A. (2015, August). Automated resource allocation in business processes with answer set programming. In International Conference on Business Process Management Workshops (pp. 191-203). Springer International Publishing.	2015	Europe
P84	Conference	Cabanillas, C., Resinas, M., Mendling, J., & Ruiz-Cortés, A. (2015, August). Automated team selection and compliance checking in business processes. In Proceedings of the 2015 International Conference on Software and System Process (pp. 42-51). ACM.	2015	Europe
P85	Conference	Sohail, A., & Dominic, P. D. D. (2015, August). Business process improvement: A process warehouse based resource management method. In Technology Management and Emerging Technologies (ISTMET), 2015 International Symposium on (pp. 291-296). IEEE.	2015	Asia
P86	Journal	Stroppi, L. J. R., Chiotti, O., & Villarreal, P. D. (2015). Defining the resource perspective in the development of processes-aware information systems. Information and Software Technology, 59, 86-108.	2015	Latin America
P87	Conference	Hsieh, F. S. (2015, November). Location-aware workflow scheduling in supply chains based on multi-agent systems. In Technologies and Applications of Artificial Intelligence (TAAI), 2015 Conference on (pp. 441-448). IEEE.	2015	Asia

P88	Conference	Wibisono, A., Nisafani, A. S., Bae, H., & Park, Y. J. (2015, June). On-the-Fly Performance-Aware Human Resource Allocation in the Business Process Management Systems Environment Using Naïve Bayes. In Asia-Pacific Conference on Business Process Management (pp. 70-80). Springer International Publishing.	2015	Asia
P89	Book parts	Lawall, A., Schaller, T., & Reichelt, D. (2015). Role and Rights Management. In S-BPM in the Wild (pp. 171-185). Springer International Publishing.	2015	Europe
P90	Journal	Cabanillas, C., Resinas, M., del-Río-Ortega, A., & Ruiz-Cortés, A. (2015). Specification and automated design-time analysis of the business process human resource perspective. Information Systems, 52, 55-82.	2015	Europe
P91	Conference	Zhao, W., Yang, L., Liu, H., & Wu, R. (2015, August). The optimization of resource allocation based on process mining. In International Conference on Intelligent Computing (pp. 341-353). Springer International Publishing.	2015	Asia
P92	Journal	Zhao, W., Liu, H., Dai, W., & Ma, J. (2016). An entropy-based clustering ensemble method to support resource allocation in business process management. Knowledge and Information Systems, 48(2), 305-330.	2016	Asia
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P94	Conference	Sindhgatta, R., Ghose, A., & Dam, H. K. (2016, June). Context-aware analysis of past process executions to aid resource allocation decisions. In International Conference on Advanced Information Systems Engineering (pp. 575-589). Springer International Publishing.	2016	Asia
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