Introducing a Taxonomy of Human Resource Allocation Criteria

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Abstract. Allocating the most appropriate resource to execute the activities of a business process is a key aspect within the organizational perspective. An optimal selection of the resources that are in charge of executing the activities may contribute to improve the efficiency and the performance of the business processes. Despite the existence of resource metamodels that seek to provide a better representation of resources, a detailed classification of the allocation criteria that have been used to evaluate resources has been missing. In this paper, we provide an initial proposal for a resource allocation criteria taxonomy. This taxonomy is based on an extensive literature review that yielded 2,370 articles, from which 95 articles, regarding the existing resource allocation approaches within the business process management discipline, were considered for the analysis. The proposed taxonomy points out the most frequently criteria used for assessing the resources from January 2005 to July 2016.

Keywords: human resource allocation, allocation criteria, BPM

1 Introduction

Business process management (BPM) is a discipline that combines distinct approaches that can be used for the design, execution, control, measurement and optimization of business processes [2]. According to [2], there are four business process perspectives: a) control-flow perspective; b) organizational perspective; c) case perspective; and d) time perspective. Traditionally, research efforts have been focused on the control-flow perspective [25]. Recent research has evidenced the need to provide better support to the organizational perspective [6, 20, 21], also known as resource perspective [10]. This need is motivated due to the focus that this perspective has on the analysis of resources that participate in the execution of process activities (whether they are human or not human resources [19]), and how this analysis could help to improve the process efficiency [5]. Typically, the management of resources in BPM could be separated into two task: resource assignment and resource allocation [9]. On the one hand,

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resource assignment has to do with the definition at design-time of the conditions that resources must fulfill in order to become candidates to work on the process activities. On the other hand, resource allocation refers to the designation of the actual process activities executors at run-time. Specifically, the task of human resource allocation (we focus on human resources, hereinafter referred to as 'resources') represents a key aspect within this perspective, seen as an important challenge from the BPM discipline [23, 25]. The Process-Aware Information Systems (PAISs) [1] provide several information systems that support the execution of business processes. One particular type of information systems is Business Process Management Systems (BPMSs). BPMSs focus on coordinating and automating business processes in such way that the work is executed at the right time and the allocated resources are available and authorized to perform the work [10]. For instance, Bizagi (bizagi.com) provides an organizational metamodel including properties such as: role, organizational position, and expertise criteria. Moreover, Bonita BPM (bonitasoft.com) presents an organizational metamodel considering properties such as: role, organizational position, and authorization criteria. One salient feature of Bonita BPM is the use of memberships and organizational groups to handle resource allocation.

Distinct articles have focused on supporting the organizational perspective through metamodels that perform the modeling and visualization of requirements related to the resources. Within these proposed metamodels, there has been an important interest in the relationship between resources and their competencies (e.g., expertise), and the organizational structure (e.g., role or organizational position) [8, 17, 21]. Although the proposed metamodels have sought to represent resources, they have not considered a broader set of criteria for assessing resources and determining their suitability to participate in the execution of process activities. Despite the focus on process management and the adequate selection of resources to be allocated, the currently provided support by BPMSs to the organizational perspective has room for improvement [11, 21], as a way to advance PAISs towards the concept of Process- and Resource-Aware Information System (PRAIS) [7].

In order to contribute to improve this shortfall, our work is a first step towards a taxonomy of resource allocation criteria. We conducted a Systematic Literature Review (SLR) [14] of the research area of resource allocation within BPM. Further details about the systematic review process performed can be found in [4]. From 2,370 articles, we systematically analyzed a set of 95 articles that pertain to the period between January 2005 and July 2016. This work may serve as a reference map of resource-related criteria that are commonly assessed in existing allocation approaches, a classification that has not been reported so far. This proposed classification may help those in charge of the process-oriented systems to identify what other resource-related information is relevant to capture, a frequent question from the point of view of the BPMSs [10]. This technical report is organized as follows: Section 2 provides an overview of the process followed to conduct the SLR. Section 3 presents the resource metamodels found in the reviewed literature. In Section 4 we identify and classify distinct types of

resource allocation criteria based on the 95 articles. Finally, Section 5 outlines the conclusions and future work.

2 Systematic Literature Review Protocol

There is a well-known procedure that focus on analyzing previous research called Systematic Literature Review (SLR) [14]. A SLR allows to identify, evaluate and interpret all the available research related to a specific research question. 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. In this SRL, we addressed the following objectives:

- To identify what evidence is available in the research area of human resource allocation in BPM.
- To classify the articles in the aforementioned research area, with the aim of classify the evidence according to the criteria for assessing resources and determining their suitability to participate in the execution of process activities.

Thus, we created the following research question to guide the SLR:

RQ1: *What allocation criteria have been used to perform the resource allocation?* The aim of this question is to identify and classify resource-related criteria that are commonly assessed in existing allocation approaches.

Based on these question, we performed a *Conduct Search* phase. The search for articles was undertaken using the following digital libraries: ACM Digital Library[1], IEEE Xplore Digital Library[2], ScienceDirect[3], Scopus[4], Springer Link[5], Wiley[6] and Web of Science[7]. Notice that all publishing vehicles included in this study were retrieved from the aforementioned digital libraries. Table 1 outlines the results obtained from the database searches. A total of 2,370 articles were selected as a result of the *All Papers* phase.

Subsequently, a *Screening of Papers* phase was initiated, in which all 2,370 papers were screened to evaluate whether, according to their titles and abstracts, they should be included in this SLR. Petersen et al. [18] 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

[1] http://dl.acm.org
[2] http://ieee.org/ieeexplore
[3] http://www.sciencedirect.com
[4] http://www.scopus.com
[5] http://link.springer.com
[6] http://onlinelibrary.wiley.com
[7] http://apps.webofknowledge.com

Table 1. 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**

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 study. 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. Accordingly, a final set of 94 articles was identified. The process applied is outlined in further detail in Figure 1.

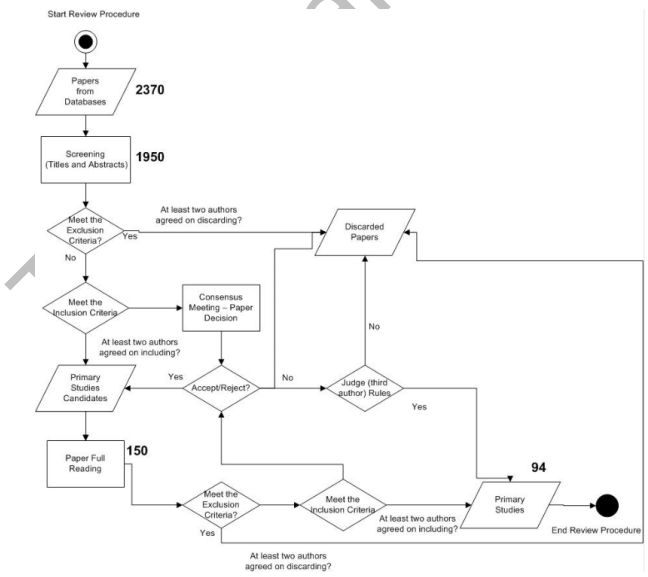

Fig. 1. Detailed Systematic Review Process Performed

Table 2 shows the breakdown of the amount of articles used. Subsequent to performing the procedure for a SLR [18], we conducted an evaluation of whether snowballing was required. A backward snowballing is the search for papers that have cited the pre-identified articles, and according to [12], is preferable when the domain area is not considered or known to be fully developed. In order to evaluate whether a snowballing for the full set of articles was required, we performed a backward snowballing with a small, 10% sample of the papers. This sample was selected by the most senior author of this work and was designed to represent the most relevant articles identified. As a result of this backward snowballing, 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 the SLR.

Table 2. Results Obtained After the Application of the Guidelines

Phase	Amount of papers
All papers	2.370
After paper screening	150
After full reading	94
Snowballing	1

3 Resource Metamodels in Human Resource Allocation

Diverse approaches have been presented to face the challenge of improving the resource allocation task. These approaches have proposed allocation methods using techniques and algorithms belonging to different fields, such as machine learning [13], dynamic programming [15], or computational optimization [24]. Within these allocation methods, different metamodels (see Table 3) have been proposed with the aim of providing a better representation of resource-related information, identifying criteria and other properties that are considered when allocating resources to activities. After reviewing these proposed metamodels, we found that they have prioritized the inclusion of criteria such as: organizational structure, roles, authorization aspects, experience, and expertise level as well as resource constraints. However, in the literature, we found that there are other criteria being used by the allocation methods to assess resources. These criteria have not been mapped to date yet, and they need to be reported in order to suggest information that should be recorded in the BPMSs to those in charge of the process-oriented systems.

4 Types of Resource Allocation Criteria

In this paper, we conducted a SLR following the guidelines proposed by Kitchenham [14] in order to identify, evaluate, and classify the resource allocation criteria

Table 3. Identified resource metamodels

Name	Description	Criteria Used
Human Resource MetaModel (HRMM) [17]	Allows the association of roles and resources. Provides a competence metamodel for the modeling of resources, considering their competences, skills and knowledge.	Role, Authorizations, Organizational position, and Expertise
Resource perspective extension to the BPMN 2.0 metamodel [21]	Supports the resource requirements modeling and visualization. It includes three main aspects: structure, authorization, and work distribution, focuses on the distribution of work corresponding to atomic activities among resources.	Role, Authorizations, Organizational position, Experience, and Expertise
Organizational metamodel [19]	Is an organizational metamodel used to define a set of workflow resource patterns.	Role, Organizational position, experience and Expertise
Resource Perspective Implementation Metamodel (RPIMet) [22]	Enables the representation of entities provided by WfMSs to implement the resource perspective aspects. Is based on the generic elements: Resource, ResourceParameter and ResourceRole defined by BPMN.	Role, Authorizations, Organizational position, Experience, and Expertise
Organisational metamodel [20]	Metalmodel used to express organisational information, which is able to cover the workflow patterns.	Identity, Roles or Groups, and Relation.
Metamodel for resource modeling [16]	Represents a hybrid meta model, which is based on a previous analysis of organizational metamodels within workflow management systems.	Role, Organizational position, Organizational unit, Privilege, and Expertise
UML organizational model [3]	Is a UML class diagram that includes it corresponding XML rendition, which can be used for the specification of workflow resources.	Roles, Organization structure, Availability, Location, and Expertise

followed to allocate resources. The guidelines include four main steps. First, the definition of the research question. In our case, we created the following research question: What allocation criteria have been used to perform the resource allocation? The second step refers to conduct the search. This step involves the definition of the keywords to perform the search. The set of selected keywords was: *resource patterns*, *resource allocation*, *resource assignment*, *staff assignment*, *task allocation*, *task assignment*, *process mining*, and *business process management*. Third, we proceed with the screening of papers. We reviewed the title, abstract and keywords of the selected papers, and evaluated them according with our predetermined inclusion or exclusion criteria. Fourth, the data extraction step focused on answering the aforementioned research question. Initially, we evaluated 2,370 articles. We excluded any duplicate papers identified. Thus, a set of 1,950 papers was obtained. Then, a total of 95 articles met our selection criteria, which were used for further analysis in the data extraction step. A

complete list of articles included in the SLR is presented in Appendix B (see Table 5). For details on the SLR protocol, we refer the reader to [14]. Our aim is to propose a classification that may serve as a reference to improve the capture of information that is currently carried out through the BPMSs. Our classification gather criteria associated with resource properties, which have been proposed by methods of resource allocation throughout the analysis period. It should be noted that we only considered resource-related information. Attributes related with activities information, activities and process time information, and process information are not part of the scope of this work, but will be studied in greater detail in order to extend the proposed taxonomy. The proposed classification is presented in Figure 2.

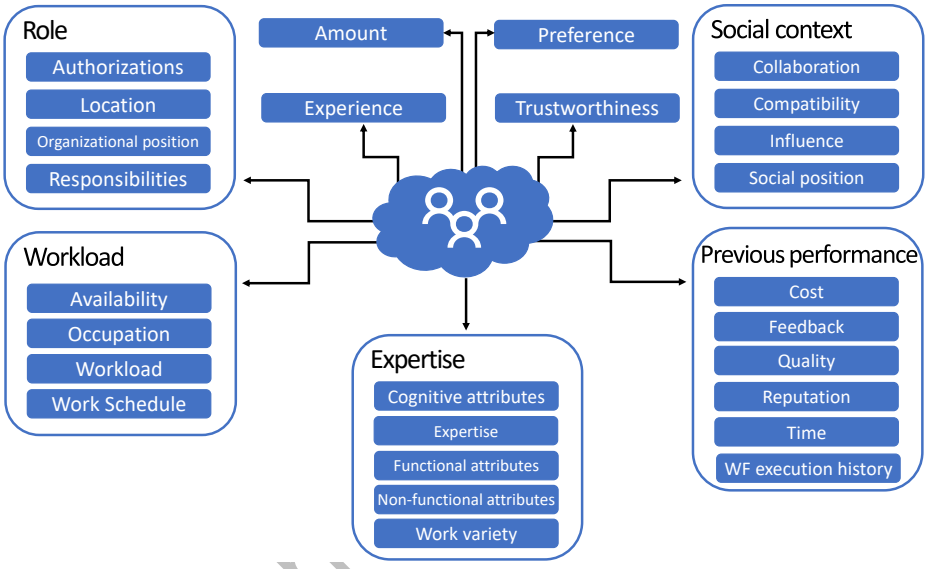

Fig. 2. Proposed taxonomy

We considered the following allocation criteria:

Amount: Number of resources required.
Experience: Resource experience executing process activities (e.g., years).
Expertise The expertise category includes the following criteria:

- *Cognitive attributes:* Cognitive characteristics a resource might possess, such as sentience, volition and causability.
- *Expertise:* Resources capabilities, competences, skills, and knowledge.
- *Functional attributes:* Resource behavior characteristics (e.g., adaptability).
- *Non-functional attributes:* Other attributes that may influence the performance of the resources (e.g., environmental factors and technical aids).

  - *Work variety:* Analyses similar and dissimilar tasks done by a resource in a day.

Preference: Resource preference for executing certain types of activities.

Previous performance: The previous performance category includes the following criteria:
  - *Cost:* Evaluates cost attributes such as resource total cost.
  - *Feedback:* resources give their feedbacks in order to accept or refuse the work done by other resources.)
  - *Quality:* Evaluates the satisfaction level of the executed process activities (e.g., customer satisfaction).
  - *Reputation:* Evaluates resource social standing within a resource network based on previous performance.
  - *Time:* Evaluates time attributes such as execution time.
  - *WF execution history:* Audit trails provided by workflow management systems.

Role: The role category includes the following criteria:
  - *Authorizations:* Constraints regarding to a specific person or role to allocate, and authorization privileges.
  - *Location:* Resources has attributes to describe its location and the structure of activities that it can perform in a workflow.
  - *Organizational position:* Constraints regarding to a specific organizational position.
  - *Responsibilities:* Set of responsibilities on a resource to perform specific activities.

Social context: The social context category includes the following criteria:
  - *Collaboration:* Measures resource collaboration and cooperation.
  - *Compatibility:* Measures resource compatibility.
  - *Influence:* Degree of the influence that on resource has on some other resources.
  - *Social position:* Resources form various social communities and take different social positions while participating in business processes.

Trustworthiness: Notion of trust degree that a resource may have to execute activities.

Workload: The workload category includes the following criteria:
  - *Availability:* An existing resource is available, busy or not available.
  - *Occupancy:* Consider the actual idle level of a resource. consider how a resource is occupied executing activities.
  - *Workload:* The capacity of resources to perform specific activities is constrained.
  - *Work Schedule:* Refers to different types of work schedules (e.g., shift plan, part time or full time).

We have classified the selected articles according to these proposed categories. Figure 3 shows the distribution of the articles according to each criterion. It should be noted that more than one criterion might have been used in a single article. We can see that eight criteria (30% of total) are the most relevant ones considering their occurrence frequency. We found that *Authorizations*,

Availability, and *Expertise* are the most frequently used criteria, which are consistent with the criteria priorities proposed by the existing metamodels (shown in Section 3). However, we found that 18 criteria (70% of total) correspond to criteria that, despite their occurrence frequency are not very high (5 times or less), represent a key insight in regard to the importance of evaluating other criteria when selecting resources.

Regarding these categories, we note that Role (68 times) and Workload (66 times) group criteria are the most often used by resource allocation approaches (59%, 134 times). Meanwhile, the remaining 7 categories represent 41% (92 times), where we can highlight *Previous performance* (36 times), *Expertise* (33 times), and *Social context* (8 times) as categories that are becoming prominent within approaches to allocate resources. Figure 4 provides a breakdown of the resource allocation categories per year. We can see that *Workload* and *Role* categories have been present in studies throughout the period of analysis. It is possible to highlight that in the period 2010 to 2016, there is a high concentration of allocation methods that used criteria regarding *Workload*, *Role*, and *Expertise* categories. This concentration confirms the preference to use criteria associated with the organizational position, availability and workload, and the resource suitability for allocation considering their expertise level. In addition, it is relevant to see how other criteria such as *Previous performance*, *Social context*, and *Preference* begin to be more popular criteria in the last 5 years of the period analysis. Specifically, we can highlight *Cost* as an emerging criterion (22 times). Some human resources are more expensive than others, and cost being used as an important property to assess within the allocation approaches, and as a major decision criteria in large companies.

We can conclude that resource allocation approaches have mainly considered criteria such as *Authorization* or *Expertise* because these criteria are commonly found in meta models and through BPMSs. However, there is a trend towards multi-criteria approaches to allocate resources, where using distinct criteria than those frequently used to assess resources is an increasingly common practice in order to select the most suitable resources for executing process activities. Evaluate *Previous performance* and consider *social context* attributes are two categories that being more popular in recent years. From our point of view, *Expertise*, *Role* and *Workload* are criteria that will continue to be used. Nonetheless, there has been a need to combine these criteria with other criteria in order to optimize the resource allocation task, due to the evolution about how resources are being evaluated in organizations. Identify other criteria associated with time, process and task information, and propose allocation mechanisms that allow prioritizing and recommending resources are challenges that require further research.

Details about the entire classification of the resource allocation criteria used are outlined in Appendix A (see Table 4.)

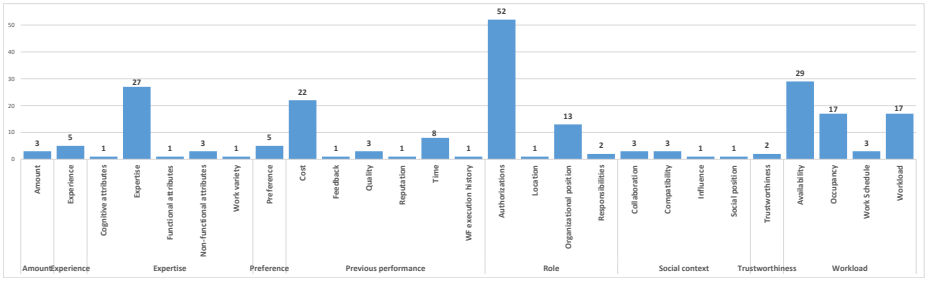

Fig. 3. Amount of articles per resource allocation criteria

Fig. 4. Breakdown of the resource allocation categories per year

5 Conclusions and Future Work

In this paper, we have identified and classified the main criteria used in resource allocation approaches in order to improve this task within organizations. We focused on considering those criteria that are related to the properties of human resources. We compiled a SLR of a set of 95 articles that proposed resource allocation approaches. We intend that the proposed classification can help those in charge of the process-oriented systems to discover common information used to evaluate resources. In addition, this classification may suggest the capture and integration of new resource-related information as part of BPMS systems, which may serve to improve the support currently given to the organizational perspective. As future work, we plan to extend the proposed classification, including other evaluation criteria, as well as formalize the allocation criteria identified in a taxonomy of resource allocation criteria.

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Appendix A: Resource allocation criteria used

Table 4. Resource allocation criteria used by the selected articles

Category	Criteria	Article ID
Amount	Amount	P2, P21, P53
Experience	Experience	P7, P67, P72, 81, P94
Expertise	Cognitive attributes	P14
	Expertise	P3, P17, P18, P19, P21, P22, P24, P26, P27, P31, P37, P39, P43, P44, P48, P49, P51, P52, P53, P63, P71, P77, P81, P82, P85, P90, P91
	Functional attributes	P92
	Non-functional attributes	P27, P71, P74
	Work variety	P82
Preference	Preference	P51, P77, P85, P91, P93
Previous performance	Cost	P10, P16, P19, P20, P23, P27, P38, P43, P46, P51, P53, P56, P57, P58, P60, P62, P63, P70, P77, P79, P81, P91
	Feedback	P53
	Quality	P12, P81, P92
	Reputation	P49
	Time	P9, P34, P57, P58, P61, P71, P77, P88
	WF execution history	P18
Role	Authorizations	P1, P3, P5, P6, P8, P9, P15, P16, P17, P18, P19, P21, P22, P23, P26, P27, P29, P32, P25, P35, P36, P39, P40, P41, P42, P43, P44, P47, P48, P49, P50, P52, P54, P59, P60, P61, P64, P63, P69, P73, P74, P75, P76, P78, P81, P83, P84, P85, P86, P89, P90, P91
	Location	P87
	Organizational position	P13, P25, P39, P47, P52, P63, P70, P76, P83, P84, P86, P89, P90,
	Responsibilities	P54, P59
Social context	Collaboration	P51, P92, P94
	Compatibility	P62, P69, P93
	Influence	P42
	Social position	P55
Trustworthy	Trustworthy	P20, P95
Workload	Availability	P8, P9, P10, P19, P21, P28, P30, P36, P37, P38, P40, P43, P44, P46, P47, P48, P51, P64, P55, P62, P65, P69, P77, P78, P79, P83, P91, P92, P93
	Occupation	P2, P9, P30, P32, P44, P45, P49, P61, P69, P71, P78, P80, P91, P92, P93, P94, P95
	Work Schedule	P43, P71, P88
	Workload	P4, P12, P19, P21, P37, P48, P54, P55, P56, P63, P66, P68, P71, P78, P80, P81, P92

Appendix B: List of Articles Included in the Review

Table 5: Articles selected

Article ID	Venue	Title	Year
P1	Workshop	Ly, Linh Thao, Stefanie Rinderle, Peter Dadam, & Manfred Reichert 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, pages 177-190.	2005
P2	Conference	van Hee, Kees M., Alexander Serebrenik, Natalia Sidorova, Marc Voorhoeve, & Jan van der Wal 2005. The Price of Coordination in Resource Management. In Business Process Management, 3rd International Conference, BPM 2005, Nancy, France, September 5-8, 2005, Proceedings, pages 96-108.	2005
P3	Journal	Bayer, K, S Kempf, H Brocks, & T Kamps 2006. A multiagent environment for the flexible enactment of knowledge-intensive processes. Cybernetics and Systems, 37(6):653-672.	2006
P4	Journal	Ha, B H a c, J b d Bae, Y T a e f Park, & S H a g Kang 2006. Development of process execution rules for workload balancing on agents. Data and Knowledge Engineering, 56(1):64-84.	2006
P5	Conference	Tan, Huixin, & Wil M. P. van der Aalst 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, pages 1184-1189.	2006
P6	Conference	Xiangpeng, Zhao, Antonio Cerone, & Padmanabhan Krishnan 2006. Verifying BPEL Work-flows Under Authorisation Constraints. In Business Process Management, 4th International Conference, BPM 2006, Vienna, Austria, September 5-7, 2006, Proceedings, pages 439-444.	2006
P7	Conference	Yingbo, Liu, Wang Jianmin, & Sun Jiaguang 2007. A Machine Learning Approach to Semiautomating Workflow Staff Assignment. In Proceedings of the 2007 ACM Symposium on Applied Computing, pages 340-345, New York, NY, USA. ACM.	2007
P8	Conference	Kress, Markus, Joachim Melcher, & Detlef Seese 2007. Introducing executable product models for the service industry. In System Sciences, 2007. HICSS 2007. 40th Annual Hawaii International Conference on, pages 46-46. IEEE.	2007
P9	Conference	Wang, J, W Tepfenhart, D Rosca, & A Tsai 2007. Resource-Constrained Workflow Modeling. In First Joint IEEE/IFIP Symposium on Theoretical Aspects of Software Engineering, TASE '07, pages 171-177. Department of Software Engineering, Monmouth University.	2007
P10	Journal	van Hee, Kees, Alexander Serebrenik, Natalia Sidorova, Marc Voorhoeve, & Jan van derWal 2007. Scheduling-free resource management. Data & Knowledge Engineering, 61(1):59-75.	2007

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