Research Challenges in Adaptive Case Mangement: A Literature Review

Matheus Hauder, Simon Pigat, Florian Matthes
Technische Universität München (TUM)
Chair for Informatics 19 (sebis)
Boltzmannstr. 3, 85748 Garching bei München, Germany
Email: {matheus.hauder, simon.pigat, matthes}@tum.de

***Abstract*—Non-traditional scenarios for Business Process Management (BPM) are often knowledge-intensive and driven by user decisions making it difficult to specify them into a set of activities with precedence relations at design-time. Adaptive Case Management (ACM) is gaining interest among researchers and practitioners as an emerging paradigm to master situations in which adaptions have to be made at run-time by so called knowledge workers. In contrast to workflow management the ACM paradigm is not dictating knowledge workers a predefined course of action, but provides them with the required information at the right time and authorizes them to make decisions on their own. Understanding current research challenges imposed by ACM is of utmost importance for the future evolution of this discipline as well as for the maturity of the BPM field. In this paper we present 77 codes referring to research challenges in ACM that have been revealed from an extensive literature review with scientific publications and books. We aggregated these codes to 13 concepts and categorized them into five distinct areas for data integration, theoretical foundation, authorization and role management, knowledge worker empowerment as well as knowledge storage and extraction. Main goal of this paper is to provide a thorough basis for the discussion of future research activities in the community which are indispensable for ACM.**

I. Introduction

Increasing usage of information technology solutions in organizations has significantly changed the work environment over the past decades. Workplaces which require less skilled workers have been automated and replaced by software solutions in many situations [1]. At the same time the ability to develop innovations and continuously adapt to new market requirements becomes more important. As a result prevalent work in organizations now requires highly trained and specialized experts that perform much more complex tasks autonomously. These experts are often referred to as knowledge workers and their processes take place in people's head or through collaboration making it difficult to analyze and structure them with existing Business Process Management (BPM) solutions [2].

Highly important processes in organizations that have a tremendous impact on the success and add the most value involve a high degree of knowledge work. Davenport describes this development as follows: "*I've come to the conclusion that the most important processes for organizations today involve knowledge work. In the past, these haven't really been the focus of most organizations - improving administrative and operational processes has been easier - but they must be in the future*" [3]. Typical examples for these knowledge-intensive processes in which people "think for a living" appear in e.g. software engineering, innovation management, science, and healthcare.

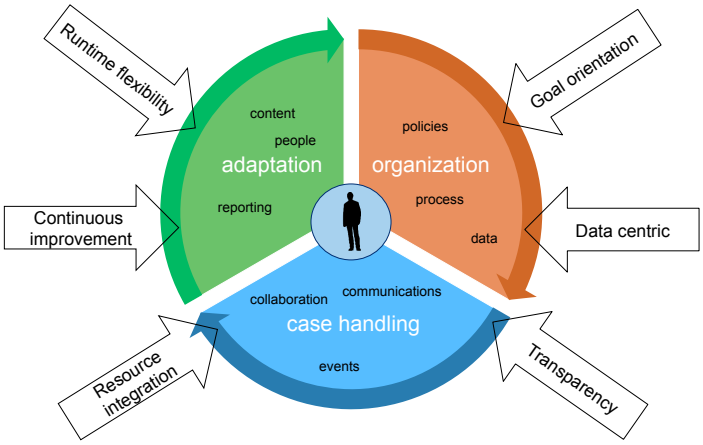

Fig. 1. Aspects and requirements that are relevant for ACM (adapted from [4])

Traditional workflow management solutions are not able to support these knowledge-intensive processes sufficiently [5]. Due to frequent exceptions in knowledge-intensive processes, traditional workflow management models would get to complex to manage and maintain [6]. A solution that aims to support knowledge workers needs to balance between structured processes for repetitive aspects of knowledge work and unstructured processes to facilitate creative aspects which are indispensable for complex problems. Case management is increasingly promoted as a means to overcome these issues to support knowledge-intensive processes, e.g., [5], [7], [8], [9], [10], [11].

Case management can be divided in the two categories production case management (PCM) and adaptive case management (ACM). PCM supports processes that are defined at design-time by software engineers for a particular domain or problem. ACM additionally empowers knowledge workers without programming and modeling expertise to modify processes on their own. The ability to adapt processes at run-time enables a quicker response to changes in order to facilitate an innovative and learning organization [12]. In the following we will focus on ACM which is recently gaining attention as an approach to master unpredictable situations in processes [13].

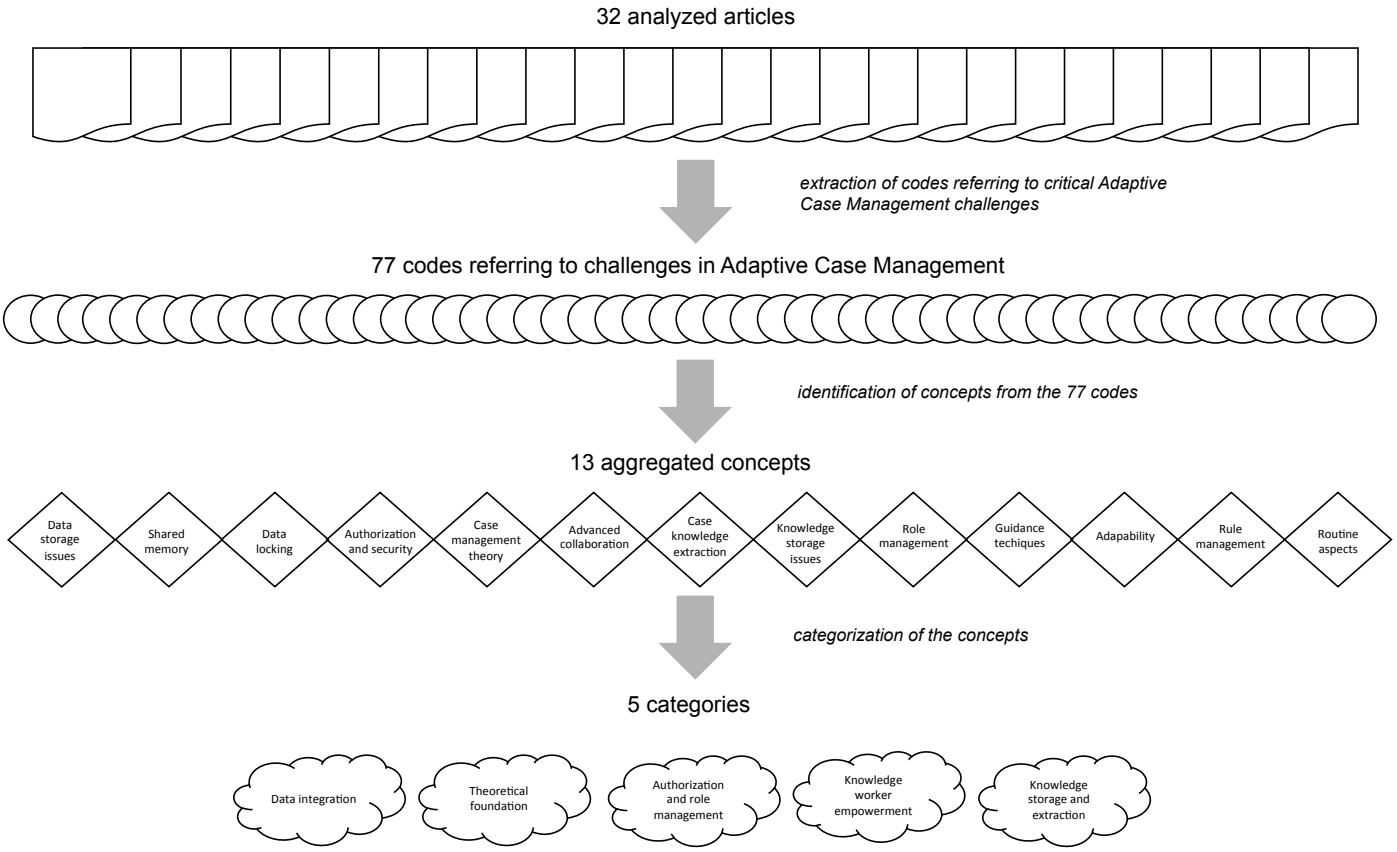

Fig. 2. Overview of the steps conducted within this paper to identify codes, concepts, and categories for ACM research challenges from current literature

Figure 1 illustrates the core aspects and requirements that are relevant for ACM. A lot of research in workflow management was conducted in the past to improve the flexibility of workflows, e.g., [14], [15], [16]. Main difference between this research on flexibility in workflow management and ACM is the assumption that it is possible to define a structured process in advance. A more detailed description on the differences between workflow and case management in general can be found in [5].

The *adaption* aspect consists of content, people, and reporting capabilities which are necessary to make changes on the process. In ACM the processes are designed to master unpredictable situations that require the adaption of the process at run-time. In contrast to workflow management these adaptions are also performed by end users that might have no programming or modeling expertise. In addition to the adaption of currently executed instances, ACM also requires a continuous improvement of process templates. With every execution of a process the case template might be improved with the feedback and the adaptions performed by end users.

Within the *organization* aspect goal orientation and data-centric processes are important requirements for ACM. While certain tasks might change frequently during execution of a task, goals remain rather stable in knowledge-intensive processes [17]. Workflow management separates between processes and data. Knowledge work in turn requires an integration of data in the execution of processes. The data records in the processes are always visible for the user and the progress of the process is driven by the values of these data records.

The *case handling* aspect is concerned with collaboration, events, and communication. Complex problems in knowledge work are typically solved collaboratively with several involved roles [18]. As a result processes for knowledge work emerge through the individual contributions and involvement of these different roles. Collaboration requires transparency of the processes with a shared understanding of the responsibilities. Integration of resources is another requirement for case handling since knowledge workers use various tools like messaging, mail, collaboration, and special purpose software to complete their tasks.

In this paper we will present research challenges imposed by ACM that we retrieved from an extensive literature review. To the best of our knowledge this is the first paper that provides are comprehensive summary on ACM research challenges. About five years after initial ideas on ACM have been published [13], we were able to identify over thirty scientific publications and book chapters addressing challenges in case management. In order to provide a solid basis and common terminology for future research in ACM these challenges are grouped into five distinct categories.

Following the introduction the paper continues with an explanation of the research methodology which we applied in order to reveal ACM challenges from literature. In Section III the identified research challenges from our literature review are presented with their references to ensure the traceability. Based

on the research challenges five distinct categories that aggregate these research challenges are presented in Section IV. In Section V the paper concludes with a discussion on possible limitations of this paper and future work.

II. Research Methodology

The research methodology applied in this paper is a database-driven literature review [19], [20]. The search was conducted in February and repeated in June 2014 with conference proceedings, journals, and books with IEEExplore, CiteSeerX, Google Scholar, Google search and the library of our research institution. We also included book chapters as well as white papers in our literature review. Main reason for this was that we also wanted to incorporate practical findings and discussions in our literature review. Furthermore, at the current stage there is only a limited amount of scientific publications on ACM available and many contributions in this field are not published at conferences or journals.

We performed a full text search with the term "Adaptive Case Management" in the previously mentioned sources without using any filters resulting in 41 references. Before we started our content analysis approach, only articles referring to ACM challenges were selected from the identified results. The filtered articles consist of 32 publications and book chapters which were all published between 2003 and 2014. These papers already indicate an increasing interest on the topic since 16 of these articles were published in 2012 or later. The majority of these publications were published in dedicated workshops.

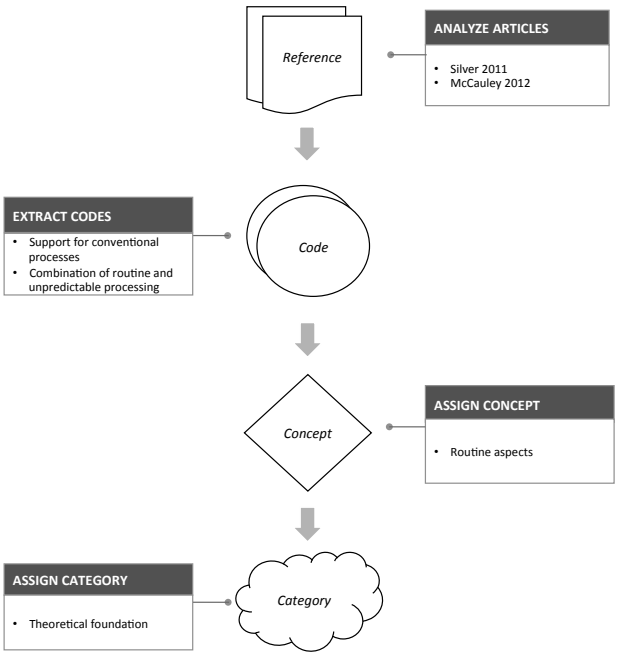

Fig. 3. Example of the content analysis approach to retrieve ACM challenges

The content analysis approach with the individual steps and deliverables is presented in Figure 2. We applied a content analysis approach in line with grounded theory literature [21]. In the first step we extracted 77 codes from the selected 32 articles which describe or address one or more ACM challenges. Similar codes in these articles were grouped by inductive reasoning to identify generalized concepts. We identified 13 concepts in total and aggregated these in the final step to five distinct categories for data integration, theoretical foundation, authorization and role management, knowledge worker empowerment, as well as knowledge storage and extraction.

In order to briefly illustrate this approach we provide a simple example in Figure 3 that is applied for all references. Silver describes in [22] the code *support for conventional processes* and the code *combination of routine and unpredictable processing* is described by McCauley in [23]. These two codes are grouped to the concept for *routine aspects* in ACM. Both codes describe related challenges that are generalized to an overall concept. In the next step this concept for routine aspects in ACM is assigned to the category *theoretical foundation*. Similarly, the category also consists of four other concepts that are related.

III. ACM Research Challenges

Gaining an understanding of current research challenges in ACM is a key for the future development of the discipline. In this section 13 concepts that we revealed from our literature review as ACM research challenges are summarized and briefly explained in the following. An overview of these concepts with their mapping to the 77 codes with their references are illustrated in Table I. We provide the reference for every code to ensure traceability. Despite inferior research activities compared to traditional BPM and workflow management it was still possible to get a comprehensive overview of challenges.

A. Data Storage Issues

In his reference McCauley describes how Microsoft products, e.g. exchange, sharepoint, lync, provide some of the essential components of an ACM platform in agile organizations [24]. Regarding the most common challenges for ACM these components require more advanced capabilities. Among these capabilities is the version management of cases including the in-flight upgrading to new versions of a case as mentioned in [24]. Within the concept of data storage issues the handling of big data is another challenge in ACM. The term big data is not only related to large data sets but also to the complexity or breadth of information [25]. In particular event data from social interactions and unstructured information present in the cases contain valuable information that need to be stored appropriately.

B. Case Management Theory

Despite the increasing interest by researchers and practitioners case management still lacks a proper theory and model. As a result a clear understanding of ACM is missing and an analysis, comparison, and development of such systems becomes infeasible [26]. Future research needs to address this challenge and investigate case management theory. Main weakness of workflow management technology is that it requires a complete specification before a process can be executed. ACM promises that through its goal oriented approach it might enable a much quicker execution [17].

ACM needs to balance between process descriptions that are too high-level for execution on the one hand and provide enough flexibility to be adapted at run-time at the other

hand. This depth of the process model definition is another challenge related to case management theory [5]. Changes on cases instance that are executed might lead to deadlocks and errors. In order to avoid these problems verification techniques are necessary [27]. Comparing and assessing case management tools is only possible with a capability and maturity model [28]. Case management theory is also related to the use of a process modeling notation for cases. In contrast to BPMN that requires much effort for the complete specification of the process, knowledge workers in an ACM solution require much less complicated mechanisms. Templates could represent the middle ground between blank slates and a completely specified process [29].

C. Shared Memory

In traditional workflow management applications only information required to execute a certain task is visible for the user. As a result information that could be valuable for the entire case and not the task is moved to the background. This behavior is not desired in ACM and a shared memory is required so that all important information for the case should be provided to the users [7]. A missing shared memory can originate from context tunneling which is also described in detail by Reijers et al. [8]. Traditional workflow management systems lack insight into earlier and yet to performed work. As a result individuals are forced to stay within limits that are given by the workflow system and it becomes more difficult to facilitate creativity which is essential to solve complex problems.

D. Data Locking

Another problem in ACM arises when dealing with concurrent situations and multiple workers changing the data objects of a case at the same time [8]. Since values of case data drive the progress of the case, it is important that no inconsistent situations due to concurrent editing arise during case execution. As a result a data locking system is required to prohibit simultaneous handling of case data by different workers. This problem is also identified within a comparison of case handling and adaptive processes by Guenther et al. [9]. As a major limitation it is mentioned that handling a case concurrently is impossible since it has to be exclusively locked as long as it is handled in a concurrent situation.

E. Advanced Collaboration

Advanced collaboration in ACM is challenging for many different reasons according to literature. Synchronization between different case handling tools and the development of a case interchange protocol is mentioned by Motahari-Nezhad et al. [30]. This synchronization will be inevitable in future because case participants are increasingly collaborating across multiple organizations and might use tools from various different vendors. Supporting case management applications in a social network environment is studied by Motahari-Nezhad et al. [31]. Main goal of this reference is to enable the exploitation of relationships between people and entities, sharing knowledge about cases, and the ability to use notifications. Allocating work according to some criteria is challenging in ACM according to McCauley [24]. Possible criteria for the allocation could be skills, competencies, availability of persons and priorities. During collaboration it might also become necessary to have multi-repository and document management for case management [24].

Knowledge-intensive processes typically deal with complex problems that require an emergent and collaborative development of processes [34]. The case management templates for these processes have to be improved in a dedicated lifecycle [33]. Participating roles in a case might also have to be added during execution of the case. It might be necessary to find an expert that is able to solve a goal that is added during case execution [35].

Increasing use of mobile devices in organizations and much more connected individuals have led to another challenge for ACM [23]. Nowadays it is possible to communicate almost anywhere and at anytime. As a result the number of channels for enterprises has increased and traditional communication, e.g., paper-based mail, email, fax, are supplemented through these new channels. Similarly, Moore [36] mentions mobile work collaboration as a challenge due to a large number of information workers working at least part of the time remotely. In the domain of court case management judges often require certain expertise that is provided by experts [38]. In order to support judges with the knowledge of these experts it is necessary that a court case management solution provides them with personal relationships. Another challenge in the court case management domain is mobile collaboration since judges increasingly use electronic documents [38].

While ACM manages adaptive processes that follow some certain steps, particular situations also require incorporation of personal skills, experience, and collective judgment in the processes. Harrison [32] describes this abilities as human interaction management which is currently missing in ACM. Knowledge workers can also quickly become to bottlenecks in different processes because their expertise might be needed in many work streams. Sharing this living knowledge of experts and making it explicit through ACM are important capabilities for organizations to constantly improve [37]. One successful pattern to share living knowledge is to apply in case mentoring and reproduce knowledge in different ways. Finding the right expert during the execution of a case might be necessary to fulfill some goal [35].

F. Guidance Techniques

The development of an adequate data model for ACM applications is addressed by Motahariz-Nezhad et al. in [31]. In this reference the required data model to support task execution order for a sample sales process in an organization is presented. The solution includes data model concepts for e.g., processes, tasks, artifacts, and templates. Recommending next steps in a case management system for IT service management is initially presented in [40]. In this solution tasks can be collaboratively defined for each particular case. Capturing and sharing the knowledge how similar cases have been resolved in the past through recommendations would help knowledge workers to handle new cases more effectively. In order to recommend the best next step two additional challenges need to be solved [40]. The first challenge deals with the automated detection of similar cases in the system that are the basis for the recommendation. The second challenge comes from

TABLE I. RESEARCH CHALLENGES FOR ADAPTIVE CASE MANAGEMENT DERIVED FROM THE LITERATURE REVIEW

Concept	Code	Reference
Data storage issues	Version management	[24]
	Handling big data	[25]
Case management theory	Build a theory/model of ACM	[26]
	Setup and maintenance challenges of an ACM system	[17]
	Depth of process model definition	[5]
	Verification of changes during execution of process instances	[27]
	Capability and maturity model for IT-based case management	[28]
	Process modeling notation	[29]
Shared memory	Data storage and access problem	[7]
	Danger of context tunneling	[8]
Data locking	Data locking	[8]
	Data locking system (multiple access)	[9]
Advanced collaboration	Synchronization between case tools	[30]
	Social framework around case execution	[31]
	Work allocation	[24]
	Multi-repository content and document management	[24]
	HR based management (skill, competence, availability)	[32]
	Multichannel engagement	[23]
	Support for collaborative knowledge work	[33]
	Collaborative case management	[34]
	Expert finding	[35]
	Mobile work collaboration	[36]
	Human interaction management	[32]
	Sharing ”living knowledge” through in case mentoring	[37]
	Personal relationships	[38]
Guidance techniques	Overview of task execution order	[39]
	Data model for task execution order	[31]
	Detect redundant activities	[40]
	Case similarity detection	[40]
	Step rating to identify best next step	[40]
	Intelligent user assistance through recommendations	[41]
	Graphical modeling environment	[42]
	Case worker guidance	[24]
	Case alerts and notifications	[24]
	Pre-emptive escalation management	[24]
	”What if?” case simulations	[24]
	Case templates	[22]
	Determination and visualization of the case progress	[11]
	Change management for templates	[11]
	Event-triggered automation	[22]
	Process simulation	[43]
	Self-organization in ACM	[44]
Authorization and security	Action-related authorization	[8]
	Handling data views (with forms)	[5]
	Avoiding authorization and distribution coincidation	[7]
	Case data and case role relationship	[45]
	Unique person identifiers	[46]
	Authorization and digital signatures	[46]
	Dynamic access control	[38]

Role management	Advanced role management	[5]
	Multiple and changing roles for one person	[24]
Adaptability	Modify case types on the fly	[9]
	Process definition configurability	[31]
	Process configurability	[24]
	Ability to change case management in-flight	[24]
	In-flight solution configuration	[38]
Routine aspects	Support for conventional processes	[22]
	Automation of recurring elements and patterns	[11]
	Combination of routine and unpredictable processing	[23]
	Flexibility versus business roles and rules	[11]
Rule management	Advanced workflow rules	[24]
	Link between data objects and processes	[5]
	Rule definition, execution, and enforcement	[24]
Knowledge storage issues	Impact of process knowledge	[39]
	Ad-hoc tasks and documents	[22]
	Document-awareness (integrated ECM-System)	[22]
	Cloud integration	[36]
	Cloud case management	[25]
	Wide range of possible data types	[11]
Case knowledge extraction	Tool knowledge and usability	[39]
	Capturing contextual information from conversations	[40]
	"Case health monitor" (Time- and effort-tracking)	[24]
	Data capturing and exporting	[38]
	Combination of process observation and navigation	[47]
	Integration of external resources	[11]
	Danger of information overload	[11]
	Process mining	[38]

the step rating to identify the next best step in the cases. A similar challenge with the history based recommendation to support flexible processes has been addressed by Schonenberg et al. [41].

Guiding knowledge workers with the definition and adaption is one of the key challenges in ACM. One possibility to simplify and guide the implementation of a case are graphical modeling environments. Main advantages of graphical modeling environments are that they facilitate common understanding and provide a common language among all business people involved [42]. The Object Management Group (OMG) has recently announced a final version of the Case Management Model and Notation (CMMN)[1]. This specification proposes a visual notation for case management, whereas the definition of rules and the linkage between data and process are out of the scope for this specification.

Guidance techniques for ACM consists of four more codes that are mentioned in [24]. This includes the guidance of the case worker e.g., easy access policy to documents, visibility of who else is participating in the case, and who relevant experts are. Case alerts and notifications as well as preemptive escalation management are also assigned to this concept. Finally, analysis of process improvement ideas need to be considered for ACM. While traditional BPM knows events in particular for the initiation of a process, the role of events is much different in ACM [22].

In case management a collection of independent tasks interact via events. These events can be triggered from external resources, e.g., phone calls, letters, faxes, or they can be internal through business rules that automatically trigger some task or case worker who manually assigns new tasks. Case templates as a guidance technique are used for a particular type of case [22]. Templates contain a list of tasks and documents that are typically required as a starting point. These templates can be public and visible for all users if they have sufficient maturity and relevance. Since a high number of templates might overwhelm users some templates that are less mature could be private. The change management of public templates also needs to be ensured in some way [11].

Similar to the process simulation of highly flexible business processes, a similar approach could be required for case management [43]. The characteristics of ACM systems, e.g., exceptions, changes at run-time, missing of a predefined course of action, make the simulation of processes in this domain especially challenging. The ability for adaption in ACM raises the interesting capability for self-organization due to knowledge workers that are empowered to perform changes on the cases [44].

[1]http://www.omg.org/spec/CMMN/, last accessed on: 2014-06-20

G. Authorization and Security

Authorization defines what a person is allowed to do within an application. ACM with its implicit modeling requires an action-related authorization [8]. In addition to traditional BPM that only has an execution role, case management also introduces redo and skip roles that leverages a higher level of flexibility. These new roles require new action-related authorization mechanisms for the case designer. Handling of data views and forms is also related to the authorization since users should only see forms that they are allowed to execute [5]. In traditional BPM an in-tray or work-list is used to capture work-items that need to be executed. In ACM it is necessary that this authorization and work distribution should not coincide with each other [7]. Knowledge workers should be able to query for cases in which they are allowed to participate.

Another relationship between case data and case role relationships has also been mentioned in [45]. Case management requires flexible definition of roles which give the users access to functions related to their jobs. Some roles might be very restricted when dealing with confidential data, while other roles are fairly open. Configuring these security levels also needs to balance between appropriate access and ease of maintenance [38]. Digital signatures are becoming legally validated to electronically sign digital resources [46]. ACM systems might deal with other partners that require this digital signatures to perform transactions.

H. Role Management

Next to the execution role known from workflow management, ACM requires more advanced role management capabilities [5]. These capabilities include skip and redo roles that can be defined for tasks. The skip role can be used to pass over tasks if a knowledge workers considers them not to be required for this case and continue with the defined process. The redo role can undo already finished tasks to return to a previous case state. Using these three roles provides a very powerful mechanism to model a wide range of exceptions. Users working in an ACM system might also have multiple and changing roles. Depending on the context changing roles might even occur within the lifetime of a case [24].

I. Adaptability

Although the data-driven nature of case management prevents the need for change in many situations, adaptions of the process definition are very important. This makes adaption of cases at run-time through knowledge workers a critical research challenge for ACM. One of the problems in this context is the inability to modify case types on the fly and migrate running cases to an updated case type [9]. Some authors, e.g., [31], [24], [38], mention the need for process definition configuration. This configuration is required to enable the process to be adapted for the case as more contextual information becomes available during execution [31].

J. Routine Aspects

In practice cases often contain paths with a stricter order of tasks in the processes that should also be supported through, e.g. adequate workflow management technologies or other means [22]. ACM is not meant to replace workflow management solutions for routine work, but some rigid and well established processes might contain less structured parts and vice versa. A similar point with the combined routine and unpredictable processing is raised in [23], [11]. Ideally, there should be an approach which is capable to integrate both approaches in one coherent solution. Some parts or roles of a process might have to be enforced due to some business rules [11]. In these parts flexibility is not desired and has to be prevented.

K. Rule Management

The progress of a case is driven by data in the case folder and user decisions, which make rules to a major component of an ACM solution. Rules can also be used to express temporal and logical dependencies between tasks. Tasks in a case can have defined pre- and postconditions. Only tasks with a fulfilled precondition are activated and users don't see tasks that are not applicable. They have to be defined, executed and enforced in an intuitive manner [24]. Knowledge workers without expert knowledge in programming or modeling should be able to work with these rules and the definition of rules should be very specific to the particular language of the domain.

Linking data objects, processes, and tasks is mentioned by van der Aalst et al. in [5], whereas the reference delineates between free data objects and mandatory or restricted data objects. Free data objects can be changed while the case is handled without any side effects or implications on the execution of the case. Mandatory or restricted data objects are explicitly linked to one or more tasks in order to determine the progress of the case. Mandatory data objects are required before a task can be completed. Restricted data objects of a task have to be defined in a particular order and cannot be entered in preceding or subsequent activities.

L. Knowledge Storage Issues

Knowledge storage issues are challenging in ACM for several different reasons according to our literature review. A study presented by Mutschler et al. [39] evaluated case handling and workflow management using a controlled software experiment. Compared to workflow management the effort to implement a process using a case handling solution is larger. This effort was reduced and productivity improved in subsequent runs through increased process knowledge.

Simplifying implementation effort for case handling is crucial in order to empower business user with limited or no programming expertise. Storing knowledge must be possible at almost any time to facilitate ad-hoc tasks and documents [22]. These elements could be defined on the fly or selected from a defined menu. Documents play also a very crucial role in ACM and they can be reused through many cases [22]. This requires sophisticated Enterprise Content Management functions e.g., versioning, searching, retention management, and role management. Increasing procuring of technology directly from vendors leads to cloud-based and software as a service solutions for some situations [36], [25]. Users might also be overwhelmed with the wide range of possible data types in a system and this has to be prevented [11].

Data integration	Data storage issues	In contrast to traditional workflow management ACM relies on a stronger integration of data in the process. The data integration leads to a number of challenges. Data objects and processes need to be integrated with each other. These data objects need to be stored which can be challenging due to large volume of necessary data and handling of different versions. Integration of data leads to challenges from concurrent access. This requires mechanism to avoid conflicts or inconsistent states of the data objects in the system.
	Shared memory	
	Data locking	
Knowledge worker empowerment	Advanced collaboration	Empowering knowledge workers in ACM deals with collaboration and guidance that are required around the cases. Successful implementation of ACM will heavily rely on the active involvement of knowledge workers in the system.
	Guidance techniques	
Authorization and role management	Authorization and security	Similar to the adaption of tasks in the case, roles in ACM systems need to provide enough flexibility to support changing roles during execution and possibilities to redo and skip tasks in the case.
	Role management	
Theoretical foundation	Case management theory	The ACM approach raises some challenges that require a solid theoretical foundation. A common theory or model for ACM is still missing at the moment. The ability for adaption of cases requires the configuration of process definitions as soon as they are required in the system. ACM solutions will require means to define stricter order on some paths since unpredictable processing might contain some routine processing steps. Relationship between tasks and data objects in an ACM solution need to be described through rules.
	Adaptability	
	Routine aspects	
	Rule management	
Knowledge storage and extraction	Knowledge storage issues	ACM needs to be able to store and extract information that can be highly unstructured or only available through experts. Capturing this knowledge in the ACM system and making it accessible to other knowledge workers is challenging.
	Case knowledge extraction	

Fig. 4. Mapping of the concepts from the literature review to categories for ACM research challenges with a description for every category

M. Case Knowledge Extraction

Similar to the storage of knowledge required during storage or implementation of a case, the opposite direction requires an extraction of knowledge by end users to facilitate an efficient use of an ACM solution. Mutschler et al. [39] evaluated and compared in their software experiment usability of a workflow management and case handling solution. The study revealed that usability for case handling solutions needs to be improved for the knowledge extraction. Extracting the knowledge in cases comprises the recommendation of successful solutions that were applied by other colleagues for the case. These recommendations need to consider contextual information of informal conversations and the flow of other similar cases [40].

Measuring the performance of a case might reveal interesting findings across multiple organizational units and case types. Using a case health monitor could provide this functionality through time, effort, cost, milestone tracking and reporting [24]. Technical solutions to automatically capture and export data should be supported by an ACM solution [38]. Collecting and analyzing event information could provide insights, e.g., how many times was a case addressed and who was involved how long, using process mining techniques [38]. These insights could be used to optimize work methods and constantly look for improvements. ACM solutions might also overwhelm users with too much information that is not relevant for them [11]. Knowledge workers also use a variety of different specialized tools which have to be integrated [11].

IV. Categorization of ACM Research Challenges

During our literature review we identified 77 codes that we grouped to 13 concepts which describe current research challenges in ACM. These concepts are grouped to five categories that aggregate ACM challenges which belong to a related topic. While we assume that the research challenges on concept level might be rather volatile and changing over time, we expect the more coarse-grained categories to be rather stable in future. Nevertheless, more empirical evaluation and practical case studies are necessary in future to validate these categories.

Figure 4 shows an overview of the research categories in the first column, individual concepts that are mapped to these categories in the second column as well as a brief description for every category in the third column. The research categories are data integration, knowledge worker empowerment, authorization and role management, theoretical foundation as well as knowledge storage and extraction. Next to the structured approach to identify research categories for ACM from existing literature, we also provide a discussion of these categories and an outlook on the implication of our findings for future research. In the following we discuss implications for every research category.

A. Data integration

Seven codes in our literature review address the integration of data in ACM. These codes deal with the linking of data

objects and processes, a shared memory as well as the locking of data objects in order to avoid inconsistent states due to concurrent editing of several users. Data is the primary element in ACM and processes are executed in the context of this data. While processes can be defined and adapted due to changes or exceptions, data in ACM tends to remain stable for a much longer time. This ability makes data integration in ACM to one of the core capabilities which will require further research. Previous research on artefact-centric business process models already provides some approaches that could be applied for this research category [48], [49].

B. Knowledge worker empowerment

Empowering knowledge workers in ACM contains the largest of references and consists of 30 codes. This is not much surprising since empowering knowledge workers and providing them with more autonomy in the process is the key characteristic of ACM. References related to knowledge worker empowerment deal with advanced collaboration topics and guidance techniques. Incorporating knowledge from experts during execution of the case is essential to leverage the emergent design of templates through ACM systems. One of the most challenging parts could be to support knowledge workers with possible next steps through recommendations. These recommendations could be derived from previously executed cases and solutions that were applied by colleagues for related problems.

C. Authorization and role management

Seven codes investigate authorization and role management in ACM. Due to the integration of data in the process, authorization and role management is required on a much more detailed level in the data structures. Depending on the current role and the state of the case some attributes in the forms of the case might not be accessible to the user. Although changing a process instance in ACM during execution through end users is desired, an ACM system might also need to retain certain constrains and rules that prohibit changes on the template by certain roles.

D. Theoretical foundation

Topics related to a theoretical foundation of ACM can be found in 17 codes. These topics cover a theory for case management, adaptability, conversation with traditional approaches, and rule management. Despite the increasing interest on ACM a profound theoretical model that could be used for the development of such systems is still missing. Business processes in organizations can vary in their structure from designed to emergent, i.e. knowledge work might also consist of some routine aspects. As a result ACM systems also needs to be able to support routine paths and patterns in a process through an integration with traditional workflow management or other means. The adaption of process instances during their execution might also create inconsistent states or deadlocks in the system. Verification of process models in case management could provide new solutions for this problem.

E. Knowledge storage and extraction

Storage and extraction of knowledge from information and data in ACM is mentioned in 14 codes. Similar to the variable structure of processes in cases, i.e. from designed to emergent, data can also be primarily unstructured in ACM. This includes contextual information from conversations as well as implicit knowledge from execution traces of process instances. At the same time users should not be overwhelmed with too much unimportant information. Leveraging the potential of ACM to support knowledge-intensive processes requires the efficient storage and extraction of relevant knowledge in a way that is suitable for the end user.

V. Conclusion

Many processes in organizations cannot be completely specified at design-time due to complexity or exceptions. These processes are typically very knowledge-intensive, e.g., medical treatment, research and development, agile software development. Traditional workflow management solutions do not provide the right means to support them adequately. Case management is promoted as an approach for knowledge-intensive processes, whereas in particular ACM is gaining attention in research, standardization organizations, and industry recently. Understanding research challenges imposed by this approach is of prime importance for the future evolution of the discipline.

In this paper we conducted an extensive literature review with books, conference proceedings as well as workshop papers to identify 77 codes from 32 analyzed articles with occurrences of research challenges for ACM. We aggregated these codes to 13 concepts and categorized into five distinct areas for data integration, knowledge worker empowerment, authorization and role management, theoretical foundation as well as knowledge storage and extraction research challenges. To the best of the authors knowledge this is the first thorough review of ACM challenges based on a literature review. Due to the missing maturity of the field it is unlikely that our research approach is able to provide a complete list of all ACM challenges. Future work needs to validate our findings on a larger empirical basis or through practical case studies.

Acknowledgment

This research has been sponsored in part by the German Federal Ministry of Education and Research (BMBF) with grant number TUM: 01IS12057.

References

[1] E. Brynjolfsson and A. McAfee, *Race Against The Machine: How the Digital Revolution is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy*. Digital Frontier Press, Oct. 2011.

[2] M. White, "Case management: Combining knowledge with process," *BPTrends, July*, 2009.

[3] T. H. Davenport, *Thinking for a living: how to get better performances and results from knowledge workers*. Harvard Business Press, 2005.

[4] L. Fischer, *Taming the Unpredictable: Real World Adaptive Case Management: Case Studies and Practical Guidance*. Future Strategies Inc., 2011.

[5] W. Van der Aalst, M. Stoffele, and J. Wamelink, "Case handling in construction," *Automation in Construction*, vol. 12, no. 3, pp. 303–320, 2003.

[6] D. M. Strong and S. M. Miller, "Exceptions and exception handling in computerized information processes," *ACM Transactions on Information Systems (TOIS)*, vol. 13, no. 2, pp. 206–233, 1995.

[7] W. M. Van der Aalst, M. Weske, and D. Grünbauer, "Case handling: a new paradigm for business process support," *Data & Knowledge Engineering*, vol. 53, no. 2, pp. 129–162, 2005.

[8] H. A. Reijers, J. Rigter, and W. M. van der Aalst, "The case handling case," *International Journal of Cooperative Information Systems*, vol. 12, no. 03, pp. 365–391, 2003.

[9] C. W. Guenther, M. Reichert, and W. M. van der Aalst, "Supporting flexible processes with adaptive workflow and case handling," in *Workshop on Enabling Technologies: Infrastructure for Collaborative Enterprises*. IEEE, 2008, pp. 229–234.

[10] M. Hauder, D. Münch, F. Michel, A. Utz, and F. Matthes, "Examining adaptive case management to support processes for enterprise architecture management," in *Enterprise Distributed Object Computing Conference Workshops (EDOCW)*. IEEE, 2014.

[11] S. Huber, A. Hauptmann, M. Lederer, and M. Kurz, "Managing complexity in adaptive case management," in *S-BPM ONE-Running Processes*. Springer, 2013, pp. 209–226.

[12] N. Taleb, *Anti-fragile: How to Live in a World We Don't Understand*. Allen Lane, 2012.

[13] K. D. Swenson *et al.*, "Mastering the unpredictable," *How Adaptive Case Management Will Revolutionize The Way That Knowledge Workers Get Things Done. Meghan-Kiffer Press, Tampa*, 2010.

[14] M. Reichert, S. Rinderle, and P. Dadam, "Adept workflow management system," in *Business Process Management*. Springer, 2003, pp. 370–379.

[15] M. Reichert and B. Weber, *Enabling flexibility in process-aware information systems: challenges, methods, technologies*. Springer, 2012.

[16] V. Liptchinsky, R. Khazankin, H.-L. Truong, and S. Dustdar, "A novel approach to modeling context-aware and social collaboration processes," in *Advanced Information Systems Engineering*. Springer, 2012, pp. 565–580.

[17] T. T. K. Tran, M. J. Pucher, J. Mendling, and C. Ruhsam, "Setup and maintenance factors of acm systems," in *On the Move to Meaningful Internet Systems: OTM 2013 Workshops*. Springer, 2013, pp. 172–177.

[18] W. Reinhardt, B. Schmidt, P. Sloep, and H. Drachsler, "Knowledge worker roles and actions - results of two empirical studies," *Knowledge and Process Management*, vol. 18, no. 3, pp. 150–174, 2011.

[19] J. Vom Brocke, A. Simons, B. Niehaves, K. Riemer, R. Plattfaut, and A. Cleven, "Reconstructing the giant: On the importance of rigour in documenting the literature search process." in *ECIS*, vol. 2009, 2009, pp. 2206–2217.

[20] J. Webster and R. T. Watson, "Analyzing the past to prepare," *MIS quarterly*, vol. 26, no. 2, pp. 13–23, 2002.

[21] B. G. Glaser and A. L. Strauss, *The discovery of grounded theory: Strategies for qualitative research*. Transaction Publishers, 2009.

[22] B. Silver, "Case management: Addressing unique bpm requirements," *Taming the Unpredictable: Real World Adaptive Case Management: Case Studies and Practical Guidance*, 2011.

[23] D. McCauley, *How ACM Drives Better Customer Engangement*. Future Strategies Inc., 2012.

[24] ——, "Acm and business agility for the microsoft-aligned organization," *Taming the Unpredictable: Real World Adaptive Case Management: Case Studies and Practical Guidance*, 2011.

[25] N. P. Thomas M. Koulopoulous, "Case management megatrends," *Whitepaper*, 2012.

[26] I. Bider, A. Jalali, and J. Ohlsson, "Adaptive case management as a process of construction of and movement in a state space," in *On the Move to Meaningful Internet Systems: OTM 2013 Workshops*. Springer, 2013, pp. 155–165.

[27] R. R. Mukkamala, T. Hildebrandt, and T. Slaats, "Towards trustworthy adaptive case management with dynamic condition response graphs," in *Enterprise Distributed Object Computing Conference (EDOC)*. IEEE, 2013, pp. 127–136.

[28] J. Koehler, J. Hofstetter, and R. Woodtly, "Capabilities and levels of maturity in it-based case management," in *Business Process Management*. Springer, 2012, pp. 49–64.

[29] D. Khoyi, "Templates, not programs," *Mastering the unpredictable: How Adaptive Case Management Will Revolutionize The Way That Knowledge Workers Get Things Done*, 2010.

[30] H. R. Motahari-Nezhad and K. D. Swenson, "Adaptive case management: Overview and research challenges," in *Business Informatics (CBI), 2013 IEEE 15th Conference on*. IEEE, 2013, pp. 264–269.

[31] H. R. Motahari-Nezhad, C. Bartolini, S. Graupner, and S. Spence, "Adaptive case management in the social enterprise," in *Service-Oriented Computing*. Springer, 2012, pp. 550–557.

[32] K. Harrision-Broninski, "Types of business process," *How Knowledge Workers get Things Done: Real-World Adaptive Case Management*, 2012.

[33] N. Mundbrod, J. Kolb, and M. Reichert, "Towards a system support of collaborative knowledge work," in *Business Process Management Workshops*. Springer, 2013, pp. 31–42.

[34] S. Huber, M. Lederer, and F. Bodendorf, "It-enabled collaborative case management - principles and tools," in *Proceedings of the 2014 International Conference on Collaboration Technologies and Systems*. IEEE by The Printing House, Inc., Stoughton, 2014.

[35] S. Heil, S. Wild, and M. Gaedke, "Collaborative adaptive case management with linked data," in *Proceedings of the companion publication of the 23rd international conference on World wide web companion*. International World Wide Web Conferences Steering Committee, 2014, pp. 99–102.

[36] C. Moore, *The Process-Driven Business Of 2020*. Future Strategies Inc., 2012.

[37] F. M. Kraft and H. Normann, "Distribute process knowledge in acm through mentoring," *How Knowledge Workers get Things Done: Real-World Adaptive Case Management*, 2012.

[38] J. T. Matthias, "Case management forecast: Mostly pcm with a chance of acm," *How Knowledge Workers get Things Done: Real-World Adaptive Case Management*, 2012.

[39] B. Mutschler, B. Weber, and M. Reichert, "Workflow management versus case handling: results from a controlled software experiment," in *Proceedings of the 2008 ACM symposium on Applied computing*. ACM, 2008, pp. 82–89.

[40] H. R. Motahari-Nezhad and C. Bartolini, "Next best step and expert recommendation for collaborative processes in it service management," in *Business Process Management*. Springer, 2011, pp. 50–61.

[41] H. Schonenberg, B. Weber, B. van Dongen, and W. van der Aalst, "Supporting flexible processes through recommendations based on history," in *Business Process Management*. Springer, 2008, pp. 51–66.

[42] H. De Man, S. Prasad, and T. Van Donge, "Innovation management," *Mastering the unpredictable: How Adaptive Case Management Will Revolutionize The Way That Knowledge Workers Get Things Done*, 2010.

[43] K. Mühlbauer and D. Bartmann, "Effizienzsteigerung hochflexibler geschäftsprozesse mittels simulation," 2011.

[44] M. Kurz and C. Herrmann, "Adaptive case management–anwendung des business process management 2.0-konzepts auf schwach strukturierte geschäftsprozesse," *Schriften aus der Fakultät Wirtschaftsinformatik und Angewandte Informatik der Otto-Friedrich-Universität Bamberg*, 2012.

[45] H. de Man, "Case management: A review of modeling approaches," *BPTrends, January*, pp. 1–17, 2009.

[46] M. J. Pucher, "The elements of adaptive case management," *Mastering the unpredictable: How Adaptive Case Management Will Revolutionize The Way That Knowledge Workers Get Things Done*, 2010.

[47] S. Schönig, M. Zeising, and S. Jablonski, "Comprehensive business process management through observation and navigation." *PoEM (Short Papers)*, vol. 1023, pp. 59–69, 2013.

[48] D. Cohn and R. Hull, "Business artifacts: A data-centric approach to modeling business operations and processes," *Bulletin of the IEEE Computer Society Technical Committee on Data Engineering*, vol. 32, no. 3, pp. 3–9, 2009.

[49] K. Bhattacharya, C. Gerede, R. Hull, R. Liu, and J. Su, "Towards formal analysis of artifact-centric business process models," in *Business Process Management*. Springer, 2007, pp. 288–304.