Toward an Ontology for Improving Process Flexibility

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Abstract. Process flexibility supports organisations to deal with changes, uncertainty, variations, and exceptions in business operations. Although several taxonomies of process flexibility have been proposed, the domain still lacks an ontological structure that clarifies and organises the domain. The current study fills this gap by building an ontology for improving process flexibility. Our results identify main business contexts, cases, dynamic modelling techniques, mechanisms to manage process flexibility, and their hierarchy relationships, which are structured into an ontology. The current study is significant as it provides a theoretical blueprint for improving the flexibility of organisational business processes.

Keywords: Business Process Flexibility, Design Science, Ontology.

1 Introduction

Process flexibility enables organizations to deal with change, uncertainty, variation, and evolution in their business operations. Given current disruptions to businesses, it is important for organizations to design business processes that are sufficiently flexible to cope with constantly increasing demands for change [1], including operational variations, foreseen and unforeseen events, unique cases, and exceptions [2, 3]. The demands for process flexibility are further highlighted by the Covid-19 disruption, where normal standard business processes have had to be adapted to support disrupted workflows, such as working from home, lack of suppliers, variations of work, and exceptional requests from customers.

From an organizational perspective, process flexibility enables organizations to manage standard operations and variant operations. This is particular true in cases where processes have to be dynamically adapted, for instance adapting "day to day" activities on-the-fly to carry on variant and unique cases [3]. Process flexibility further enables organizations to dynamically manage process-related information, including actors, information sources, and execution conditions, which support the relocation of skilled workers, execution under incomplete or available information, changing

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external partners, and real-time decisions [4-6]. These cases suggest the important roles of process flexibility in organisations.

From an academic perspective, process flexibility has been an important research area in Business Process Management (BPM) for the last decades [1, 7]. Recently, the research area has received momentum due to increasing variations of business processes and uncertainty caused by disruptive innovations, disruptive technologies, and disruptive business environments [2, 3, 6]. Consequently, much research has been conducted on a variety of topics related to process flexibility, including modelling flexible processes [8, 9], managing process flexibility [10], and extending information systems to support process flexibility [11, 12].

With this variety, the research area of process flexibility is characterized by diverse viewpoints, heterogenous conceptualizations and diverse research approaches, including case studies, design studies, and development studies. This is logical as process flexibility "asks to take into account different aspects from several existing disciplines including organizational science, information science, computer science, and sociology" [3]. This diversity however leads to a lack of common understanding in the research area and can prevent organizations from fully utilizing the existing scientific knowledge on process flexibility.

While researchers agree that ontologies can improve understanding and knowledge structures in the research area [13-16], there are only a few ontologies supporting process flexibility in the related literature. Prior studies aiming to increase the understanding of process flexibility have focused on developing taxonomies [17-19] and representing its main concepts [1]. These studies highlight the need to structure knowledge in the research area, i.e. taxonomies structure knowledge by classifying main concepts in the area. Further, they suggest an avenue for ontology development, as a "taxonomy may be a step toward a future ontology" [20]. Furthermore, since ontologies explicitly define and integrate key concepts and the relationships [21], including agreements and contradictions, they contribute to build a holistic view on a research area.

Therefore, the current study aims at constructing an ontology that can provide a foundation for improving process flexibility. The study sets up two objectives. First, we want to identify and analyse the main concepts and relationships concerning process flexibility. Second, based on the identified concepts and relationships, we structure an ontology to improve understanding and to support process flexibility. With these objectives, the current study conducts a scoping literature review [22] to identify and synthesize individual findings from the related literature, and then, following a design-based approach [23], constructs a preliminary ontology of process flexibility.

This study contributes to knowledge by consolidating the understanding on process flexibility, while addressing the diversity and heterogeneity of knowledge in the area. From an academic perspective, the ontology provides a theoretical foundation for understanding and managing process flexibility. From a practical perspective, our research is expected to enable organizations to understand, identify, and manage flexible processes. With the proposed ontology, organizations will have more capability to deal with uncertainty, change, emergence, and evolution [2].

2 Literature Review

Process flexibility is regarded as the capability of organizational business processes to deal with expected and unexpected changes [2, 3]. With intensified unexpected changes coming from increasingly dynamic business environments, emerging technologies, and unforeseen exceptions, there is a strong need for organizational business processes to be flexible and adaptable. Consequently, the research area of process flexibility has attracted much attention. Researchers have widely studied different aspects of process flexibility from multiples disciplines like organizational science, business process management, and information systems in order to manage, conceptualize, support, and improve process flexibility [3, 10-12, 24, 25].

While such a wide range of studies highlights the importance of the research area, it brings a variety of multifaceted concepts and heterogenous views into the research area [2, 26]. This variety can be illustrated, for instance, through diverse mechanisms to manage process flexibility, including adaptive business rules and decision tables [5, 27], context-aware adaptions [28], changed patterns [29], and process families [30]. Such multifaceted concepts and heterogenous views can also be found in other process flexibility topics, including different conceptualizations of process flexibility, different modelling languages to facilitate process flexibility, and diverse drivers for process flexibility [1, 3]. Consequently, this variety makes difficult to classify, structure, and synthesize common understanding in the research area.

Given that, the research area still needs to be consolidated. With this need, we would expect to find commonly accepted ontologies of process flexibility, for three reasons. First, ontologies can provide holistic views on process flexibility by defining the main concepts of the research area. Second, as ontologies also clarify the relationships between these concepts, they help reduce semantic ambiguity [31-33]. Finally, ontologies provide a structured means for managing knowledge on process flexibility. Corcho et al. [21] and Wong et al. [34] refer to ontologies as not only research areas' conceptualizations, but knowledge that can be inferred from the research area.

However, to the best of our knowledge, ontologies of process flexibility seem to be absent. We could only find a few taxonomies and frameworks classifying some concepts in the domain, which we will summarize in the next section.

2.1 Taxonomies and Frameworks for Process Flexibility

This section reviews the state of the art on how existing studies have structured knowledge in the research area of process flexibility. Given the heterogenous nature of the research area, a variety of unrelated taxonomies and frameworks have been proposed [6, 7, 17, 28]. However, most focus on particular aspects of process flexibility, considering in particular specific characteristics of process flexibility and factors motivating process flexibility.

Schonenberg et al. [17] propose a taxonomy characterizing the nature of process flexibility in four categories: flexibility by design, flexibility by deviation, flexibility by under specification, and flexibility by change. In a more simpler form, Kumar and Narasipuram [35] distinguish pre-designed flexibility from just-in-time, responsive

flexibility. Soffer [36] differentiates between short-term and long-term flexibility. The former refers to temporary changes to a standard workflow, while the latter refers to permanent changes which generate a new workflow.

In this group of studies characterizing the nature of process flexibility, the taxonomy proposed by Reichert and Weber [6] has been widely used. This taxonomy classifies flexibility into four categories: variability, adaptation, looseness, and evolution. Variability manages flexible processes by deriving variants from the same workflow. Adaptation manages flexible processes by handling occasional unforeseen changes at run-time without changing the standard workflow. Looseness manages flexible processes by handling run-time workflow without strict adherence to the standard workflow. Finally, evolution manages flexible processes by permanently modifying the workflow.

Moving to the next group of studies, several taxonomies analyze and classify factors motivating process flexibility. Cognini et al. [3] identify six common reasons for process flexibility, including exceptions, technology evolutions, new working methods, change in the laws, changes in the target goals, and cost savings. Snowdon et al. [37], focusing on the information support to process flexibility, classifies three factors influencing process flexibility: variety of information types, amount of information that has to be dealt with, and the need to operate in different ways.

We note that the above studies propose process flexibility taxonomies which consider specific facets, such as the nature of process and the information needs of process flexibility. Even though they define and structure elements in a specific domain, they are specific in the way they view the domain, and thus do not provide an overall picture of the research area. This leads to the need for broader ontologies that structure the diversity of knowledge in the research area. However, our literature review found no such ontologies. The closest work we found is the semantic model for Software as a service (SaaS) proposed by Hidri et al. [28]. This model embraces a diversity of concepts in three domains: business, service, and context. However, the model is restricted to SaaS processes. Consequently, there is a lack of ontologies supporting process flexibility as a whole. Fulfilling this gap, the current study aims to construct an ontology that can provide a holistic foundation for improving process flexibility.

3 Method

To build the ontology, the current study used a structured literature review [38] to gather concepts, which was then combined with a design-based method [23] to organize concepts. While the structured literature review enables us to identify key concepts and relationships and thus advances the breadth of understanding in the research area, the design-based method links and structures the identified concepts into the common frame of understanding offered by the ontology. This combination was adopted to achieve a holistic ontological coverage of meanings and relationships between the reviewed literature. To accomplish this strategy, we followed the five-stage process depicted in Fig. 1, which includes the search definition, literature search, refinement, analysis of selected papers, and presentation of findings. This process is elaborated below.

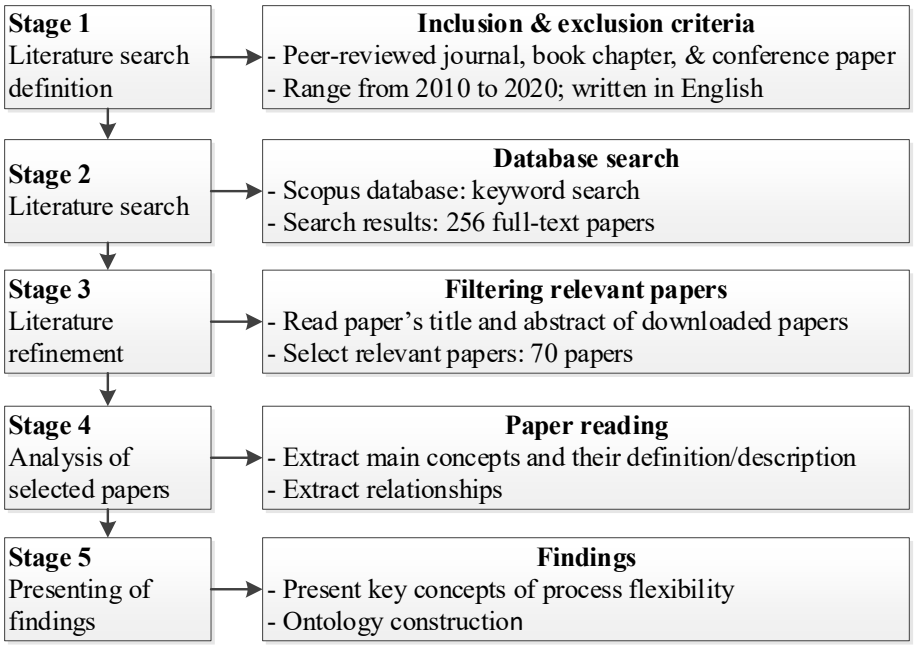

Fig. 1. Research Method

Literature search definition. To start, we set out inclusion and exclusion criteria to ensure a quality holistic review. Aligning with Webster and Watson [39], we included peered reviewed sources (e.g. academics journals, book chapters, and conference papers), and excluded dissertations, editorials, and book reviews. We also defined a review period ranging from 2010 to 2020 to ensure the review and constructed ontology is up to date.

Literature search. We used the Scopus database for the literature search to ensure a wide coverage, as Scopus indexes a wide range of academic sources. The searched keywords combined the notions of business process ("business process" OR "workflow management" OR "process concept" OR "organisational processes") and flexibility ("process flexibility" OR flexibility OR variability OR variant OR adapt OR adaptation OR adaptivity OR adaptive OR evolve OR evolution OR looseness OR dynamic OR context-ware). As a result, the search returned a total of 256 full-text sources.

The search results show some interesting points. Regarding the form of publications, the demographics show that 74% are conference papers, 4% are book chapters, and 22% are journal articles. The dominance of conference publications over journal publications confirms our assumption that the research area is still emerging and thus needs to be further established. Regarding the publication years, Fig. 2 shows the search results distributed per year from 2010 to 2020. In particular, we note an increase in the number of publications in the 2014-2016 period. Then, it seems that the number of publications decreases in 2017 and increases again in 2018 and 2019. We also note that

our search was conducted in the middle of 2020, and thus many publications of the year may not be updated and indexed yet.

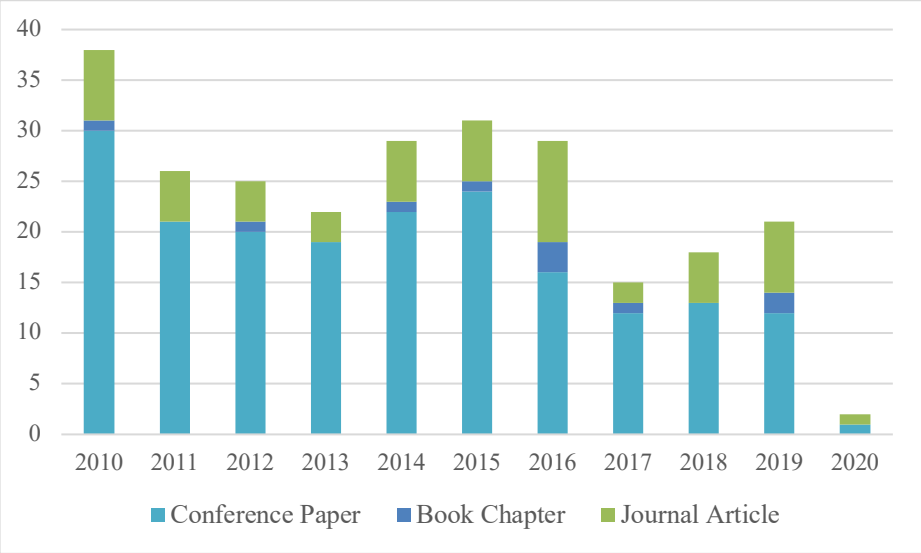

Fig. 2. Search results distribute by years and publication forms

Literature refinement. Given that the sample might include papers that contain the searching keywords yet only indirectly link to process flexibility, we conducted further refinements. Using a screening technique suggested by Okoli [38], we performed the literature refinement by reading the sources' titles, keywords, and abstracts. We filtered out papers that only broadly refer to process flexibility, or that use process flexibility as a referencing example to discuss other concepts, e.g. process mining. In this process, there were some papers on the border line. Regarding these, we made the decision to include rather than to exclude them to keep the review comprehensive. As a result of the refinement process, a total of 163 papers were selected for analysis.

Analysis of selected papers. At this stage, we analyzed the selected papers regarding their main concepts and relationships. The analysis consisted of three steps. First, we extracted concepts and relationships relevant to process flexibility. Second, we synthesized duplicated concepts, such as 'process variant', variability, and 'versioning variant'. Third, we extracted relationships among concepts, including relationships from existing taxonomies and sub-concept relationships by mapping the main concepts and their sub-concepts. The results are presented in the next section.

4 Results

4.1 Main Concepts of Process Flexibility

We now report the results from the review analysis, starting with the most popular concepts of process flexibility. We identified concepts and sub-concepts used by multiple reviewed papers. We also note that the concept definitions and suggested relationships between concepts and sub-concepts may vary across the reviewed papers. In these cases, we chose the definitions and relationships adopted by the majority of sources. As a result, Table 1 presents 48 (sub) concepts identified in the reviewed papers.

At a high level, Table 1 reveals four main groups of concepts related to process flexibility: business contexts characterizing process flexibility, case management, dynamic BPM, and mechanisms to manage process flexibility. Within these groups, Table 1 presents main concepts, sub-concepts, their (simplified) definition, and selected papers supporting them.

Table 1. Main Concepts of Process Flexibility

Main concepts	Sub-concepts/ Dimensions	Definition from Literature	Selected papers
Business context			
Aspects of flexibility		Different aspects that should be analysed from a business context in order to manage flexibility. Four aspects are identified: variability, adaptation, looseness, and evolution	[1, 3, 6, 40]
	Variability	Manage flexible processes by deriving variants from the same workflow	[3, 6, 40]
	Adaptation	Manage flexible processes by handling occasional unforeseen changes at run-time without changing the standard workflow	[3, 6]
	Looseness	Manage flexible processes by handling run-time workflow without knowing the standard workflow	[3, 6]
	Evolution	Manage flexible processes by permanently modifying the workflow	[3, 6]
Degree of flexibility		Number of changes that have to be performed, learning from a process	[11]

		model and a collection of its process variants	
Context changes		Changes captured in the business environment	[28]
Event driven BPM		Events produced by the system are processed and eventually abstracted to generate high-level information about the situational status of the system	[41]
	Real-time business events	Events originating from the real-time execution of a business process	[41]
	Real-time decision support	Real-time support that can be generated from high-level information about the situational status of the system	[42]
	Event driven process chains	Event-centric modelling language that treats events as fundamental elements of the business process	[6]
Case Management			
Adaptive case management		Case management has features that allow processes to be adapted at run time by knowledge workers	[43]
	Flexibility knowledge intensive	The status and availability of knowledge that drives decision making and influences the flow of actions and events	[3]
	Collaboration oriented	Process creation, management and execution occurs in a collaborative multi-user environment	[3]
	Goal orientation	The process evolves through a series of intermediate goals or milestones to be achieved	[3]
	Business rules	Business rules control the behaviour of business processes regarding the adaptive cases	[3]
	High skills	Adaptive cases that require incorporating personal skills, experience, and collective judgment in the processes	[44]

	Unpredictability	Case depends on situation and context-specific elements that may not be known a priori, may change during process execution, and may vary over different process cases	[44]
Emergent case management		An approach for the bottom-up managing of ad-hoc processes. The goal is to enable users to assign activities to a certain case, which can be dynamically defined by knowledge workers	[45]
	Collaborative tasks	A collaborative execution of certain process in whose execution at least two organizations/party are involved	[45]
	Communicative tasks	Tasks that at least two organizations/parties need to communicate in order to operate the tasks	[45]
Dynamic BPM			
Collaborative modelling		A process where a number of people/users actively contribute to the creation of a process model	[46]
	Participate discover	Joint learning and mutual discovery are key for building consensus	[47]
End-user changes		Letting end users tailor business processes can result in business process management that may be better tuned to users' needs and organizational changes	[48]
Model as you go		An approach to model a subject-oriented business process by enabling the process actors to record their subject communication and internal behaviour, just in time, while they execute the process instance	[49]
	Structuredness	the state of a business process being structured,	[49]

		when the way to reach the output is well defined	
	Visibility	Process workers should collaborate with each other via discussions, wikis, documents, i.e. complete visibility of the collaboration	
	Adaptation	The ability to create, store and edit model as it proceeds, enables adaptive approaches	
Adaptive modelling languages		Multiple modelling languages that enable adaptive business processes,	[3, 28]
Process stories		Process stories use a combination of textual and visual elements to model business processes	[2, 50]
Mechanisms to Manage Flexibility			
Design-time		Mechanisms to manage flexibility at design-time, which refers to the process design phase in the business process life cycle	[3, 6]
	Process-aware information systems	Information systems that support process management	[51]
	Pre-modelled	Define the expected flexibility requirements at build-time and apply them at run-time	[52]
	Well-defined adaptation - Rule-based - Case-based - Process-based	Well-defined adaptation allows self-adaptation of processes whose process model is completely known at design-time. Three main types of well-defined adaptations are rule-based, case-based, and process-based approaches	[53]
	Ill-defined adaptation - Late binding - Late modelling	Ill-defined adaptation allows adaptation of processes not known, or incompletely known, at design-time. Two main types of ill-defined adaptation are late binding and late modelling	[53]

Run-time		Mechanisms to manage flexibility at run-time, which consider the process implementation and enactment phases in the business process life cycle	[3, 6]
	Adaptive process modelling	Adaptive variant modelling enables the definition of a main process model with context-specific variants	[54]
	Ad hoc BPM (emergent process)	An unstructured process is a process that is not predictable. It depends on external factors outside the control of the process	[54]
	Exception handling	Emerging exceptions hinder a predefined business process to be executed as expected	[54]
	Fragments - Rules - Notation enhancements - Dynamic changes	A business process fragment is a connected, reusable sub-process that captures incomplete business rules and knowledge. Fragments relate to three sub-concepts: 1) Rules to avoid duplication of semantics of the patterns, 2) Notation enhance refers to BPM notation yet extended by exception handling on fragment-level, 3) Dynamic changes to insert new activities into a process instance.	[52, 55]
Flexible BPM		While the BPM objective stays the same, the BPM procedures change from time to time and from one execution to another at run-time	[1, 54]
	Change execution paths	Alternative execution paths are defined at design time and the most appropriate execution path can be selected and operated at runtime for each process instance	[56]

	Declarative approaches	Use a set of constraints, like precedence or non-coexistence, to exclude possible behaviours	[9]

Table 1 reveals a variety of concepts and sub-concepts suggested by the literature. It also provides descriptive textual definitions for these concepts, which contribute to the understanding of the research area. Here, we aligning with Mejri et al. [1] and suggest that the understanding can be further enhanced by structuring the concepts in a semantic way. This is the focus of the next section.

4.2 Preliminary Ontology of Process Flexibility

We structure the identified concepts as an ontology of process flexibility. We position our ontology as 'preliminary' as we understand that, given the same group of concepts, different structures of the ontology could be proposed. Given that, we applied a trial-and-error process to structure the concepts. We experimented with different structures (e.g. layered structure, tree structure, and radial structure) and found out that the radial structure is most suitable to represent the ontology. The radial structure enables us to center the concept of process flexibility around other related concepts, and thus it is suitable to provide a holistic view over the research area. Further, it nicely links with the four main groups of concepts (identified in Table 1), and thus reduces complexity by arranging sub-concepts into these groups. The results of the structure process are presented in Fig. 3.

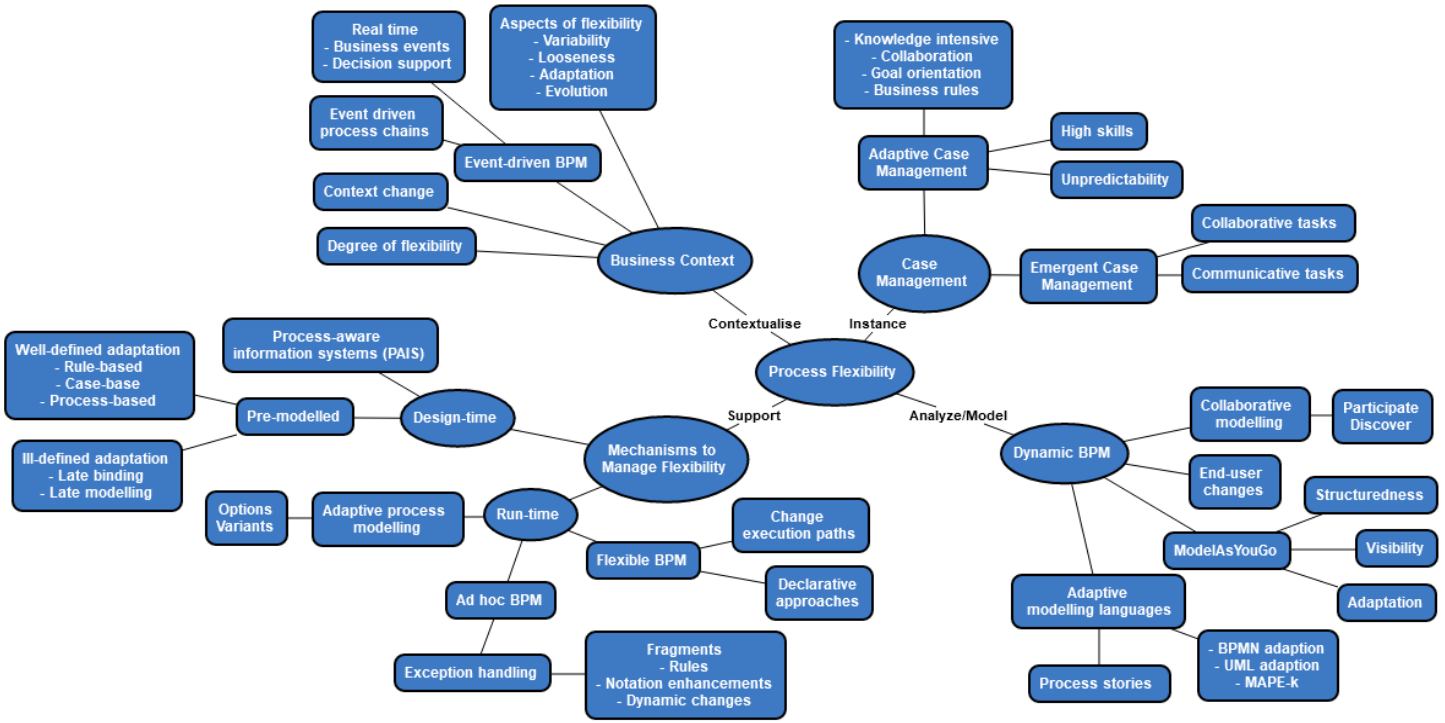

Fig. 3. Preliminary Ontology of Process Flexibility

Fig. 3 represents a preliminary ontology of process flexibility, which is structured into four groups of concepts. Overall, the ontology should be viewed from-inner-to-outer, which highlights four key concepts: business context, case management, mechanisms to manage flexibility, and dynamic BPM. Business context refers to the contextualization of business practice, where unexpected and unforeseeable changes in business contexts increase the needs for flexible processes. Analyzing business contexts enables us to understand aspects of flexibility, degree of flexibility, context changes, and event-driven changes in business processes (upper left-hand side of Fig. 3). We note that in analyzing business contexts, Reichert and Weber [6] highlight four flexibility aspects: variability, looseness, adaptation, and evolution (see Table 1 for definitions of these aspects).

Case management forms another important group of concepts in the ontology (upper right-hand side of Fig. 3). It represents different instances of adaptive and emergent cases that are executed for specific goals [57]. Adaptive cases are standard cases with certain features that enable them to be adapted by knowledge workers [43]. Emerging cases are new ad-hoc cases, which can be dynamically defined and re-defined by the knowledge workers [45]. Through the adaptive and emergent instances, case management captures process knowledge that may be subsequently reused.

The ontology also identifies several mechanisms to manage flexibility (lower left-hand side of Fig. 3). By and large, the mechanisms to manage flexibility can be classified into two main categories: design-time and run-time [3, 6, 17]. Mechanisms to manage flexibility at design time aim to identify process deviations in the process model, which can then be applied at run-time. Examples include pre-modelled mechanisms like rule-based, case-based, and process-based approaches [52], which can be supported by process-aware information systems [51]. Mechanisms to manage flexibility at run time manage flexibility at implementation and operation times. Examples include exception handling, ad-hoc process management [54], and using business process fragments [52, 55].

Finally, the ontology presents concepts related to dynamic BPM (lower right-hand side of Fig. 3), which highlight modelling techniques used to analyze, model, and operate flexible processes. Common techniques include collaborative modelling, end-user ad hoc changes, model as you go, and adaptive modeling languages [48, 49]. Adaptive modelling languages can be further classified into two categories: prescriptive languages and process stories. Prescriptive languages define a structured set of essential process elements (e.g. events, activities, actors, and their interdependencies). Exemplars include BPMN adaptation, UML adaptation, and UML MAPE-k [3, 28]. Process stories combines textual and visual elements to model business processes [2, 50].

5 Discussion and Conclusion

There has been an ongoing research interest on process flexibility to deal with rapidly changing business contexts. Researchers have studied different aspects of process flexibility from a variety of viewpoints, which challenges common understanding on the research area [2, 26]. In this study, we review and structure knowledge reported in

individual studies to identify the main concepts and relationships involved in process flexibility (Table 1). The identified concepts and relationships are then structured into a preliminary ontology (Fig. 3).

Considering the need to structure knowledge in the research area, several process flexibility taxonomies have already been proposed [3, 6, 7, 17, 28]. However, our ontology extends the scope of existing taxonomies. On the one hand, our ontology captures many concepts and relationships found in other taxonomies, in particular Reichert and Weber's [6] and Cognini's et al. [3]. This increases the confidence in our results and at the same time extends the existing works. On the other hand, our ontology reveals additional (sub) concepts and relationships, which enable a more systematic and comprehensive understanding of the research area.

Our study is also useful from a practical perspective. In particular, our ontology structures concepts in groups (Fig. 3). To some extent, these groups enable organizations to better understand and manage process flexibility considering four facets: why, where, what, and how. In particular, the business context group highlights aspects justifying why organizations should manage process flexibility. The case management group suggests instances where process flexibility can be applied. The group of mechanisms to approach process flexibility highlights how to manage process flexibility. And finally, the dynamic BPM highlights what mechanisms can be used to analyze, model, design, and manage process flexibility.

We believe that these four facets help organizations to better understand and thus improve process flexibility. For instance, organizations may realize that they can manage process flexibility using design-time and run-time mechanisms (lower left-hand side of Fig. 3). They can further identify and choose different BPM mechanisms to analyze, model, and manage process flexibility (lower right-hand side of Fig. 3). In short, the ontology provides a blueprint for organizations to improve process flexibility.

We note certain limitations of this study and suggest some directions for future research. First, we understand the risk of synthesizing ontological elements from different studies conducted in diverse contexts and using diverse viewpoints. Addressing this risk, future work should further explore multi and trans-disciplinary viewpoints on process flexibility. Second, we position our ontology as 'preliminary'. Future work is required to empirically evaluate the ontology. Third and finally, we also plan to apply the ontology in the field, e.g. in decision-making support, and case studies to assess its practical utility.

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