Comparing Modelling Techniques For Knowledge Intensive Company Acquisition Processes

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Abstract. Modelling knowledge-intensive processes currently incorporates the challenge to select an appropriate modelling technique. Thereby, we neither lack on the existence of modelling techniques, specifically invented for the universe of knowledge-intensive processes, nor criteria- or modelling-based comparisons. However, an examination that combines both comparison methodologies is missing. We provide a process perspective on the company acquisition process and build our analysis upon. Thereby, we discuss to which extent the modelling techniques "fragment-based Case Management" and "Guard-Stage-Milestone" can support knowledge-intensive processes. We finally prioritize future work topics about both modelling techniques.

Keywords: Business Process Management · Knowledge-intensive Processes · Modelling Techniques · Guard-Stage-Milestone · fragment-based Case Management

1 Introduction

Organisations' processes increasingly rely on the experience and knowledge of the involved process participants [5]. Such processes represent *knowledge-intensive processes* (KiPs), if their executions require so-called knowledge workers. Knowledge workers collaborate to achieve process goals by taking informed decisions for driving the actual trace of activities. Thus, the execution of KiPs requires flexibility at design- and run-time [22]. Di Ciccio et al. [5] characterise KiPs within eight dimensions and postulate requirements for a new generation of process-aware support systems. As such systems derive automation semantics from explicit process descriptions, the expressiveness of the underlying modelling technique limits the potential support, they can provide. In recent years, various research developed different techniques, like PHILharmonic Flows, ArchiMate, YAWL, Declare, SmartPM, fragment-based Case Management or Guard-Stage-Milestone, for modelling KiPs [5][10][13].

Although different publications [5][13] compare these new modelling techniques, it remains a challenge to select an appropriate modelling technique for a specific use case. We introduce a yet missing [23] process perspective on company acquisitions. Therefore, we source our experiences from a mid-size M&A company and verify our findings following mature research in the area of acquisitions [6][17][23]. As we argue for the knowledge-intensive nature of company acquisition processes, they serve as a suitable, coherent, real-world use case.

In this paper, we compare *fragment-based Case Management* (fCM) and *Guard-Stage-Milestone* (GSM). For each of the two modelling techniques, we provide a prototype model of the company acquisition process and examine in-depth to which extent the requirements, postulated by Di Ciccio et al. [5], are implemented. Thereby, we combine modelling- and criteria-based analysis methods. As we will identify certain limitations, we guide where further focus on improving both modelling techniques is required.

The paper is structured as follows. We review related work in section 2 and provide a process perspective on the company acquisition process in section 3. Afterwards, section 4 summarizes Di Ciccio et al.'s characteristics on KiPs as well as the mechanics of fCM and GSM. Our analysis of the two modelling techniques is presented in section 5. Finally, we conclude our findings and motivate future work in section 6.

2 Related Work

Vaculin et al. [22] define KiPs as processes, in which knowledge workers undertake knowledge-intensive decision-making tasks, wherefore KiPs require flexibility at design- and runtime. Di Ciccio et al. [5] characterize KiPs and derive requirements on process-aware support systems from these characteristics. Unger et al. [21] pick up Di Ciccio et al.'s characteristics and explain why the execution of KiPs is complex. Furthermore, they compare how long and how often KiPs are executed compared to non-KiPs. Generally, the execution of a KiP takes longer, but less KiP instances exist.

KiPs base on the fulfilment of knowledge requirements, wherefore knowledge-worker communicate informally and formally. Thereby, human behaviour constitute a major cause of the unpredictability property of KiPs. Recently, de Almeida Rodrigues Gonçalves et al. [1] propose a theory for analysing and predicting socio-psychological aspects during the execution of KiPs. They map out a relationship between intentions which the individual knowledge-workers carry, actions which are triggered by these intentions and the goals which should be achieved by these actions.

Following the characteristics of KiPs, we require specialized modelling techniques [7]. In 2011, Hull et al. [16] introduce the Guard-Stage-Milestone approach. Vaculin et al. [22], Hull et al. [14] as well as Damagio et al. [4] enhance the modelling technique and define formal execution semantics. Supplementary work defines process mining on top of GSM [18] or proposes GSM as a tool for monitoring compliance in BPMN models [3].

In 2016, Hewelt and Weske [12] introduce the fragment-based Case Management approach. Later, Haarmann [10] defines formal execution semantics on fCM by using Petri nets. He also increases the model quality by providing a framework for automatically checking the consistency and correctness of fCM models [9]. Supplementary work considers supporting knowledge workers in planning next activities [19], a formal framework for compliance checking [11] or an improved exception handling [2].

Although various work on modelling KiPs is spent, it remains a challenge to select an appropriate one [5][13]. Di Ciccio et al. prove to which extent existing process-aware support systems implement their requirements, but they do not analyse underlying modelling techniques. However, they relate their analysis to real-world use cases. Steinau et al. [20] conduct a literature review to identify existing research directions in the area of data-centric process modelling and develop the formal framework *DALEC* to compare modelling techniques. They illustrate their framework by comparing the Guard-Stage-Milestone approach, PHILharmonic Flows and the Custom Case Handling approach. However, Steinau et al. do not incorporate real-world use cases in their comparison, although they emphasize the relevance to create a connection between theoretical criteria and practical use cases. Holz [13] reviews which comparisons of modelling techniques for KiPs exist and outlines their limitations. She compares CMMN, fCM and PHILharmonic Flows by using a comprehensibility study but also a set of theoretical criteria.

3 Use Case

Our comparison examines theoretical criteria along a real-world use case. Combining our own experiences from a mid-size M&A company with Very et al.'s [23] and Jemison et al.'s [17] mature theoretical perspectives, we provide a process perspective on the company acquisition process in the following section.

We consider two companies, a consultant agency that advices its customer in optimizing business processes, as well as a start-up company which developed a new modelling technique. The CEO of the consultant agency recognizes a business opportunity, if they would own the patent for the new modelling technique. Thus, she decides on acquiring the start-up and defines an acquisition strategy.

Based on the acquisition strategy, sales experts analyse the market environment and examine the feasibility of the strategy. If their results do not reveal the assumed business opportunity, the CEO refines the acquisition strategy or cancels the acquisition process.

After the market environment analysis classified the start-up company as an acquisition candidate and may also identify further candidates, different experts conduct a set of analyses for each candidate. For instance, accounting experts check the trustworthiness of the accounting principles, cultural experts examine whether the candidate's organization and culture match to internal practices, financial experts calculate a purchase price range, and sales experts forecast the order book. Some analyses are only applicable for specific candidates. For instance, involved experts decide to identify differences in national accounting policies or general legal regulations only for cross-border acquisitions.

A candidate overview, often also referred to as *due diligence*, summarizes the key findings. The different experts jointly contribute their findings and repeat analyses for clarification reasons. The results of an analysis may negate the fit of the candidate, wherefore, the experts filter it out. Furthermore, time constraints often exert pressure on the acquisition process, as a candidate is in demand, or it is to expect that the seller starts the bidding [23]. Thus, the experts plan the parallelization of the analysis activities.

As some analyses require internal information, negotiation experts establish a contact to the shareholders of the candidate. Thereby, they start to negotiate and close a letter of intent and a term sheet. Both documents contain binding and non-binding agreements, whereby the term sheet shows more the structure of a contract. A successful negotiation leads finally to a deal which contains how shares will be exchanged and for which price. Corporate lawyers check the deal and request approvals from external supervisory authorities, like national antitrust authorities. After receiving the approvals, the CEO of the consultant agency finally evaluates the deal and accepts or rejects it.

During the whole execution of the process, the involved experts recognize different happenings from the environment, like negative press releases or events at the stock exchange, and react appropriately on them.

4 Preliminaries

In this section, we argue for the knowledge-intensity of the company acquisition process following Di Ciccio et al.'s [5] characteristics on KiPs, explain the requirements on modelling techniques and indicate why these requirements own relevance for the company acquisition process. Furthermore, we introduce the key concepts of fCM and GSM. Due to place limitations, we refer to other publications for getting in-depth insights about both modelling techniques and provide a repository[1] with prototype models of the company acquisition process.

4.1 Characteristics of KiPs

For evaluating an acquisition candidate, various experts from different domains, like finance or sales, contribute to the acquisition overview. Thus, the acquisition process is *collaboration-oriented.* As analyses may reveal contrary information, the knowledge workers plan the execution based upon upcoming insights, wherefore we identify *emergent* and *unpredictable* traits. The decision to contact an acquisition candidate requires analysis results as well as experience [6], and consequently, constitutes a *knowledge-driven* activity. Simultaneously, only negotiation experts are allowed to establish a contact to an acquisition candidate, wherefore, the execution of the acquisition process is bound within a framework of *rules and constraints.* Furthermore, the acquisition process is *event-driven* and *non-repeatable* because press releases may influence the success of an acquisition, but not for each acquisition relevant press releases occur. Following

[1] https://github.com/florian-papsdorf/kip-company-acquisition

De Almeida Rodrigues Gonçalves et al. [1], the involved experts decompose the goal to acquire the start-up into intermediate milestones, like collecting detailed information about the candidate or negotiating a satisfactory deal. As negotiations can fail, the goal to close the process neatly substitutes the goal to sign a deal. After we argued for the *goal-orientation* in acquisition processes, we finally concluded that an acquisition process represent a KiP.

4.2 Requirements On Modelling Techniques

Knowledge workers organize information in data objects and modify them in collaboration. Thus, we can (R1) *model data* classes, their relationships and whether they allow parallel access. For instance, we need to model the purchase price range report or the deal. Furthermore, we can (R2) *model data-driven actions*. Thereby, the modelling technique allows the specification of (R3) *flexible process executions* so that knowledge-workers can compose a trace during runtime. As this planning happens aligned to goals and rules, the modelling technique supports the (R4) *formalization of goals* based on states of data objects as well as the (R5) *formalization of rules and constraints*. Especially, only negotiation experts are allowed to establish a contact to an acquisition candidate. Furthermore, we can (R6) *capture knowledge workers' decisions* and (R7) *handle anticipated as well as unanticipated events* from the environment. To cope with the different roles, which are involved in KiPs, the modelling technique allows the (R8) *modelling of roles* with associations to responsibilities for data objects, decisions, and actions as well as access privileges on data objects. As information asymmetry constitutes a main driver of the acquisition process, knowledge workers should only access information they really require for their tasks to avoid information leaks.

Due to the in KiPs inherent complexity, the modelling technique (R9) *provides learning tools* which allow the definition of overviews about the whole process to make the process knowledge visible. Simultaneously, process mining illustrates benefits of learning from past process instances, wherefore, we can formalize how we extract event logs and insights from data objects.

As KiPs are emergent, knowledge-workers must adapt the process to changing requirements during runtime. Thus, the modelling technique (R10) *allows late changes*. For instance, a new law requires further reports. The modelling technique contains concepts to capture different versions of the data, goals, actions, rules and constraints, roles, privileges, events as well as control flow models. Additionally, we can define a metamodel to specify how and to which extent late changes are allowed. As the modelling technique provides formalizations for migration strategies, we are able to migrate process instances.

4.3 Fragment-based Case Management (fCM)

Based on Hewelt and Weske [12], Haarmann [10] specifies fCM as a modelling technique that combines data-centric and activity-centric views. We refer to Haarmann's dissertation [10] for a holistic view on fCM. In essence, a fCM model

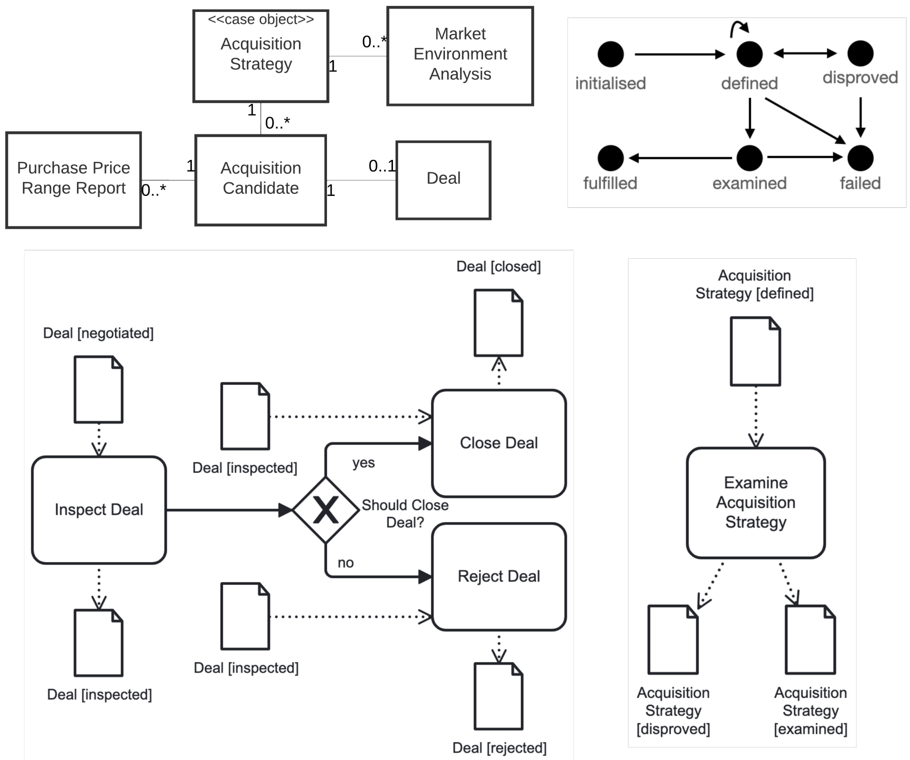

Fig. 1. Excerpt of a fCM diagram with a domain model (top left), the object lifecycle of an acquisition strategy (top right) and two process fragments (bottom row).

consists of four components: A UML class digram expresses the *domain model*. For each data class in the domain model, an *object behaviour model* defines possible states of the instantiated data objects and legal state transitions. Based on the data objects' states, a *termination condition* indicates when the knowledge workers can close the process instance, here referred to as a case. Finally, *process fragments* define sets of activities and a-cyclic control flows. When data conditions hold, a fragment becomes enabled and knowledge-workers can select and execute it. Thereby, they can decide on concurrent and repetitive executions of fragments. For illustration, we provide figure 4.3. As soon as the acquisition strategy is present in state "defined", knowledge workers can examine the strategy as the respective fragment becomes enabled. The object behaviour model restricts that knowledge workers are not allowed to change an acquisition strategy as soon as it is examined because there is no directed edge from the state "examined" back to the state "defined".

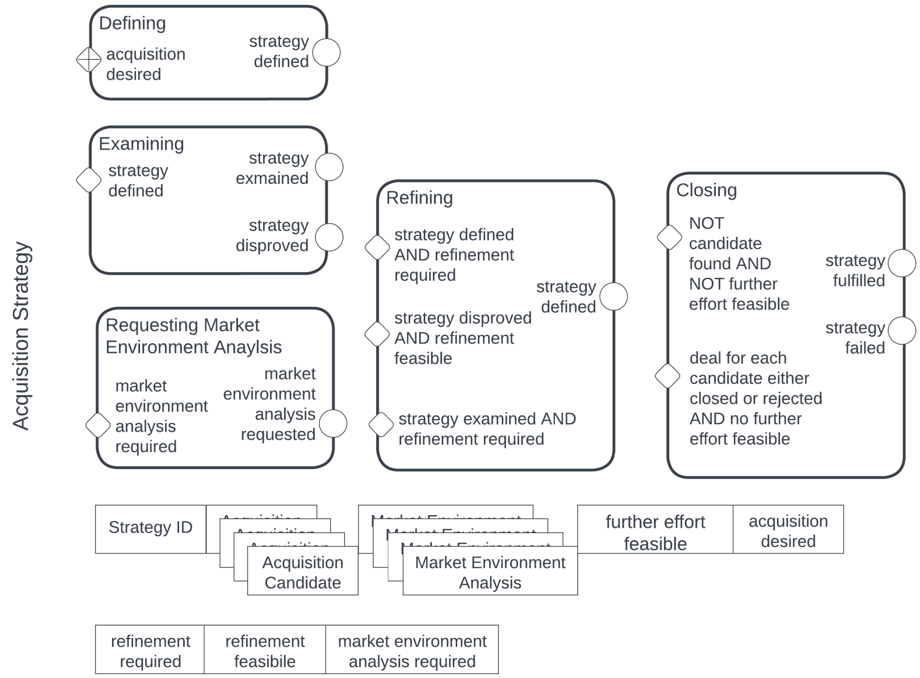

Fig. 2. Modelling the acquisition strategy as a GSM business artefact.

4.4 Guard-Stage-Milestone (GSM)

We refer to Hull et al. [14] for a holistic introduction to GSM. In contrast to fCM, GSM is a purely data-driven modelling technique. Thereby, a GSM model consists of a set of *business artefacts*. A business artefact represents a key conceptual entity in the business, and consists of an *information* and a *lifecycle model*. For instance, the acquisition strategy constitutes a business artefact as shown in figure 2. The information model holds in an attribute-based data structure all relevant data in form of single values or lists of values. Thereby, GSM also allows a reference to another business artefact as a value. For instance, we can store an identifier of the strategy or a list of conducted market environment analyses. The lifecycle model consists of a set of *stages*. For each stage, *guards* define when a stage is instantiated and entered. Equally, *milestones* define when a stage is closed. Guards and milestones are logical conditions based on values in the information model and the occurrence of events. For instance, as soon as an acquisition is desired, we enter the "Defining" stage, which represents the running activity of defining an acquisition strategy. Eventually, the strategy is defined, and the respective milestone is reached, wherefore, we leave the "Defining" stage.

Table 1. Evaluating fCM and GSM against the requirements described in section4.2.

Requirement	**fCM**	**GSM**
R1 Data Modelling	+	+
R2 Model Data-Driven Actions	+	+
R3 Flexible Process Execution	+	~
R4 Formalise Goals	~	+
R5 Formalise Rules and Constraints	~	~
R6 Capture Knowledge Workers' Decisions	~	+
R7 Handle Anticipated and Unanticipated Events	~	+
R8 Knowledge Workers' Modelling	-	-
R9 Provide Learning Tools	~	+
R10 Allow Late Changes	~	-

5 Analysis of Modelling Techniques

Based on the prototype models for the company acquisition process and the criteria, which we summarize in section 4, the following paragraphs examine in-depth to which extent the requirements are implemented by GSM and fCM. Table 1 summarizes our results, whether GSM or fCM provide full (+), partial ($\sim$) or no support ($-$) for a given requirement.

5.1 Fragment-based Case Management

Using a UML class diagram as the domain model, fCM allows holistic data modelling (R1). A set of input sets constraints when an activity becomes enabled. In our use case, the activity "Examine Acquisition Strategy" becomes enabled as soon as the data object "Acquisition Strategy" is present in state "defined". The process fragments model activities and their control flow, wherefore, fCM supports the modelling of data-driven actions (R2). Furthermore, the manner on how knowledge workers can compose fragments during runtime enables a flexible process execution (R3).

Expressed as the termination condition, we can model goals. However, the goal modelling is limited because we cannot specify under which conditions a goal may become invalid (R4). Successfully closing a deal represents a goal in the company acquisition process, which may become invalid if a disastrous press release occurs. Additionally, the semantics on relationships between domain model, process fragments and object life cycle models support the formalisation of rules and constraints (R5). For instance, as soon as an acquisition strategy enters the state "examined", no activity can translate it into the state "disproved" as no directed edge from "examined" to "disproved" exists in the object lifecycle model. Haarmann et al. [11] also establish a formal framework for compliance checking.

Within process fragments, we can introduce decision points as XOR gateways. As the selection of a fragment represents a decision, further effort is required to fully capture knowledge workers' decisions (R6).

Haarmann [10] allows events only for case instantiation. Thus, his formal semantics on fCM cannot cope with events. In contrast, Hewelt and Weske [12] allow events if they are not the start node of a fragment. As shown in our prototype model for handling press releases, we can cope with events, but further research should define proper semantics on handling events (R7).

The absence of a notion for modelling roles and, consequently, for specifying privileges and interactions between roles, constitute a major weakness of fCM. Thus, we cannot express the rule that only negotiation experts are allowed to establish a contact to an acquisition candidate (R8).

Gonzalez-Lopez et al. [8] present an extension to fCM which allows the definition of process overviews. However, mining process fragments is still an open research challenge (R9).

Knowledge workers are allowed to modify goals and add process fragments during runtime. However, fCM neither contain any notion to capture versions of model elements nor to formalise migration strategies to transfer running process instances into instances which properly implement the new process model. Equally, we cannot express change processes about who can make which change at which time. Further work is also required to define formal semantics on changing the domain or object life cycle models (R10).

5.2 Guard-Stage-Milestone

GSM is a purely data-centric modelling technique and allows with the key-value based data structure holistic data modelling. In contrast to fCM, GSM include natively consistency guarantees for concurrently accessing values in the information model (R1). If we interpret an active stage as the ongoing execution of an activity, we can use stages, their guards and milestones to model data-driven activities (R2). Thereby, GSM limits flexible process executions, as it does not allow the concurrent execution of two instances of the same stage (R3).

Using milestones and nested stages, we can extensively model goals. Furthermore, Hull et al. [14] introduce invalidators for guards and milestones, wherefore, we can also model when goals should become invalid (R4).

Equally, Hull et al. [15] also provide a formal framework for compliance checking on GSM models (R5).

As the instantiation of a stage directly and exclusively follows when a guard from a non-overlapping set of guards holds, GSM captures decisions completely (R6). For instance, we explicitly express the assessment that a strategy refinement is required for entering the refining stage of the acquisition strategy business entity.

Furthermore, guards and milestones can check for the occurrence or not occurrence of events. Thus, GSM natively provide mechanism to handle events (R7).

Analogous to fCM, GSM does not provide any notion to incorporate role perspectives into the model (R8).

However, with the help of derived attributes, GSM allows natively the definition of abstractions. Additionally, a business artefact intrinsically maintains a log of occurred events, stage instantiations and stage closings. Popova et al. [18] also introduce a concept for translating Petri nets into GSM models and consequently define process mining on GSM (R9).

In contrast, GSM completely lacks on semantics for handling late changes. There are neither semantics yet defined about changing model elements during runtime, nor notions to capture versions or change conditions (R10).

6 Conclusion

In recent years, knowledge-intensive processes received strong research attention in the area of business process management because an increasing number of organisations rely on the knowledge of the process participants rather than explicit process descriptions [5]. Simultaneously, various work developed modelling techniques for supporting such KiPs. However, the challenge to select an appropriate modelling technique for a given use case remains, although criteria- as well as modelling-based comparisons [13] exist.

To cope with this challenge, we provide an examination of fCM and GSM by conducting a criteria-based comparison based on a real-world use case. As decades ago, economic sciences and economic psychology [23] [17] identified a lack of a process perspective on company acquisitions, we introduce the company acquisition process as a KiP. Therefore, we incorporate our experiences from a mid-size M&A company and verify our findings with mature research on company acquisitions [6][17][23]. Following Di Ciccio et al.'s [5] characteristics on KiPs, we prove the intuition about the knowledge-intensive nature of the company acquisition process.

Furthermore, we provide prototype models of the company acquisition process for fCM and GSM. Using these models in combination with the requirements postulated by Di Ciccio et al. [5], we identify strengths of both techniques in modelling data, activities with their dependencies to data, rules and constraints, as well as goals. As fCM allows the concurrent execution of multiple instances of the same fragment, and already includes early concepts for enabling late changes, fCM beats GSM in terms of these two requirements. However, both modelling techniques require further work on enabling late changes. In contrast, considering the handling of decisions and events as well as the existence of learning tools, GSM outperforms fCM. Especially, fCM requires future work on inventing a fragment miner.

Both modelling techniques share a lack of knowledge workers' modelling. GSM and fCM do not incorporate any perspectives on roles and their privileges, yet. These perspectives own high relevance for our use case, because sales, financial and other experts collaborate to achieve an acquisition and any information leak is disastrous [6]. Thus, both modelling techniques are currently not suitable to assist the company acquisition process. Future work should focus on introducing role perspectives.

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