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EcoKnow: Engineering Effective, Co-created and Compliant Adaptive Case Management Systems for Knowledge Workers

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ABSTRACT

We report on a new approach to co-creating adaptive case management systems jointly with end-users, developed in the context of the *Effective co-created and compliant adaptive case Management Systems for Knowledge Workers* (EcoKnow.org) research project. The approach is based on knowledge from prior ethnographic field studies and research in the declarative Dynamic Condition Response (DCR) technology for model-driven design of case management systems. The approach was tested in an operational environment jointly with the danish municipality of Syddjurs by conducting a service-design project and implementing an open source case manager tool and a new highlighter tool for mapping between textual specifications and the DCR notation. The design method and technologies were evaluated by understandability studies with end-users. The study showed that the development could be done in just 6 months, and that the new highlighter tool in combination with the traditional design and simulation tools, supports domain experts formalise and provide traceability between their interpretations of textual specifications and the formal models.

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CCS CONCEPTS

• **Software and its engineering → Constraint and logic languages**; **Software prototyping**; **Agile software development**; **Traceability**.

KEYWORDS

agile, adaptive case management, regulatory compliance, traceability, service design, co-creation, local government, declarative models, understandability, prototyping, case study

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1 INTRODUCTION

The public sector has during the past decade in many countries gone through a radical transformation from paper-based to computer-supported case management. This is often pushed by the belief that digitalisation can make the public sector become more effective and able to provide services of higher quality.

The present paper describes a case study of co-creating an open source, adaptable case management system in the Danish municipality of Syddjurs. The system provides flexible process support for regulatory compliance on top of an existing document management system. The study is part of the research project *Effective, co-created and compliant adaptive case management for knowledge workers*

(EcoKnow.org) initiated in the Fall 2017. The overall aim of the EcoKnow project is to develop solutions for the effective digitalisation of knowledge work processes governed by legal regulations, that empower case workers and citizens to make evidence-based plans for individual cases, while improving both efficiency and compliance with the law. The focus is on case management processes in local government, in particular processes involving services and benefits offered to young persons with special needs and unemployed citizens, regulated by the Danish Consolidation Act for Social Services (CASS) [58] and the Danish law on Active Employment Effort [10] respectively. These processes are characterised by having deep consequences for the lives of citizens, having high and unpredictable costs and being subject to complex, changing legal regulations. Moreover, it has been documented in several studies that problems with efficiency and compliance are found in practice in these areas (e.g. [40],[19],[7]). Similar challenges are however also found in other domains, as for instance the healthcare sector [37] and the financial sector [8, 30].

The EcoKnow project brings together researchers, municipalities, representatives for case workers, key industrial partners, digitalisation consultants and lawyers, collaborating in research and development of methods for co-creation and technologies for analysis of process logs and adaptive case management. The development is based on previous research in case management work practices [28] based on ethnographic studies, and adaptive case management technologies based on Dynamic Condition Response (DCR) Graphs (see e.g. [13–16, 25, 26, 36, 38, 52, 56]). The DCR technology has been developed during the last decade as a collaboration between research groups and industry in Copenhagen. The new technologies will through a multi-disciplinary situated design process be continuously informed and evaluated by ethnographic studies of the case management work practices and understandability studies.

One finding of the ethnographic studies is that there is a difference to the classes of public service systems that are digitalised and how they transform the citizen-government interaction [28]: One class of systems is where civic services and interfaces are moved into digital forms and often take on the characterisation of policy implementation and enforcement (e.g. enabling public departments as they set policy and govern). Another class of systems and activities aligns with practices in, for example, social welfare, where citizens' records are used in the instrumental role of tending to the individual and informing the activities of the care professionals. The role of the individual citizen greatly differs in each of these systems. In the first instance, the citizen is acting on information about their activities – e.g. reviewing public documents. In the second case, the citizen is acted upon as professionals assess the effects of different programs (or treatments), and choose services based on the collected evidence of progress toward some resolution to the underlying condition (*Ibid*). What we learn from the study in [28] is that the different logics of systems for support of public services differ and in order to achieve the benefits of digitalisation, it is critical that we consider this difference, as we move forward to develop case management systems.

A survey [11] carried out in the Danish public sector in 2016 showed that the governmental institutions today use a plethora of information systems for supporting the case management. Two major categories are the so-called *Electronic Document and Case Managment systems* (in danish: *Elektronisk Sags- og Dokumenthåndteringssystem*, abbreviated ESDH) and *Domain-specific systems* (in danish: Fagsystemer).

ESDH systems support the digital recording of all documents related to a case in one place and provide role based access control, but they are oblivious to which activities, e.g. according to the law, are actually carried out. This means that ESDH systems provide no support for the ordering of activities related to the case and thus very little support for regulatory compliance. Consequently, whether a case is carried out in compliance with the law can be highly dependent on the case worker. It also means, that there is no standardised way of recording a structured event-log containing the activities carried out in a particular case. In situations like this, caseworkers tend to make their own, more or less, idiosyncratic structures. In other words, they use their discretion to fill in the gap by creating their own rules [53]. A standardised event-log would enable using artificial intelligence technologies such as process mining [62] and predictive process monitoring [35, 47] for gaining knowledge of how cases were carried out historically and predicting for instance delays of on-going cases. It would furthermore contribute to the cooperation and coordination of work [53].

The domain-specific systems do have specific tasks that are particular to the domain. Yet, they normally have little support for ordering of tasks and ensuring compliance with the law. One reason for this is, that it is a slow, error prone and expensive process to update the system when the politicians make a change to the law. Indeed, the respondents of [11] indicated that the most important factors for getting full value in return of an investment in a digital case management system in the future were: 1) Support for easy continuous adaptation, 2) User-friendliness, 3) Automatisation, and 4) Local anchoring of the digitalisation in the organisation.

The efforts in the development of the business process management model and notation (BPMN) [41] as well as notations such as Little-JIL [1] and so-called business process management and process-aware information systems [54] have been strongly driven by wish for supporting and automating business processes by software systems in a way that allows the business and domain experts to configure and re-configure the processes. However, it was already pointed out in the 1980s [43, 55], that while the traditional imperative notations are suitable for stable processes such as election processes [44] and highly critical, surgical sub-processes [9], they are unsuitable for describing more frequently changing or unpredictable processes. Moreover, imperative procedures describe *possible* ways to fulfil requirements of the law, but not the law itself. This means, that the process designer make choices and interpretations that may be too restrictive or even turn out to be illegal in practice and is very difficult to trace back to the law. It also means that it is a manual and difficult task to update a process diagram if the law changes. A line of work that attempts to address the latter problem by providing automated verification of process diagrams against declarative specifications of the law (e.g. [23]). But this approach does not remedy the first problem: That imperative notations are often too rigid and restrictive in practice.

An approach to provide both flexible process support and improve compliance with the law is to employ declarative process specifications not only for the formalisation of rules but also for the support of processes [18, 26, 42, 60, 61]. The declarative approach

can be seen as a continuation of the so-called 5th generation programming languages approach based on constraints and constraint solving. The uptake of such systems has however been limited. One possible reason for this is, that the logical formalisms have been too difficult to use and understand by domain experts [65], thus, the coding of rules has been too difficult to maintain and validate. Another possible reason, also pointed out already in [43], is that many processes are combinations of stable, predicable sub processes and unpredictable events and changing rules. Therefore, neither imperative nor declarative process notations may be the answer. Instead, researchers have been considering hybrid notations and combinations of views, supported by end-user tools [14, 43, 50, 57].

As mentioned above, the present work is based on the Dynamic Condition Response (DCR) graphs notation and tools. The DCR graphs notation has similarities with other declarative notations, notably the GSM model [18], the Case Management Model and Notation (CMMN) from OMG [42], and the Declare notation [60, 61]. The DCR technology is however rather unique among the declarative notations in being supported in commercial case management and workflow tools already used widely in local and central government institutions in Denmark[1]. A central hypothesis of the EcoKnow research project is that the DCR technology can

(1) serve as the basis for locally anchored and co-created digitalisation of case management in municipalities,
(2) contribute to higher degree of legal compliance,
(3) enable systematic gathering of event logs that can be used for AI-based decision support, and
(4) lead to better experience for both case workers and citizens.

The goal of this paper is to describe our progress towards proving the two first items in the hypothesis, namely the development of technologies enabling locally anchored and co-created digitalisation based on the DCR technology, that can contribute to achieve higher degree of compliance with legal regulations. To summarise, we will in the rest of the paper overview the following accomplishments:

- The DCR graphs design and simulation tools (Sec. 2).
- A systematic literature review of research in formal methods for regulatory compliance and a text highlighter tool supporting traceability between textual requirements and formal models (Sec. 3).
- A service-design project developing and deploying an Open Case Manager tool in the Municipality (Sec. 4).
- Evaluation of the understandability of the hybrid DCR design tools (Sec. 5).

Before the development and deployment of the case management system in the municipality, ethnographic field studies were carried out to understand the case management practices and the interplay between discretionary decisions and decisions that can be formulated by rules and automated (see [46]). Having the case management system in operational use, it is now possible to focus on the last two items of the hypothesis, i.e. the systematic gathering of event logs used for AI-based decision support and improving the experience for case workers and citizens. We briefly conclude and discuss future work in 6.

[1]https://www.kmd.dk/indsigter/fleksibilitet-og-dynamisk-sagsbehandling-i-staten

2 THE DCR TECHNOLOGY STACK

The DCR method is supported by a full technology stack[2] covering *design*, *simulation*, *analysis*, *documentation* and *execution* of declarative processes. We first briefly recall the DCR graph notation and use of the design tool.

2.1 DCR Graphs and the DCR Design tool

A DCR graph consists of *nodes*, representing *events* or *activities*, and *directed edges* between the nodes, referred to as *relations* and representing rules. Events/activities may be *standard*, *data* and *computations*. A standard activity can just be executed. A data activity is assigned a value (i.e. given as input) when executed. A computation activity holds and expression, which is computed when the activity is executed and the result is assigned as the value of the activity. Values of activities can be referenced in guards of rules and expressions of computation events. Activities can be assigned *roles*, indicating that an actor assigned this role can execute the activity.

As example we consider Section 155 b from Part 27, Duty of notification in the CASS:

> 155 b.–(1) Within six (6) business days after receiving a notification under sections 152-154 above, the municipal council shall acknowledge receipt of the notification to the notifier.
> (2) The municipal council shall inform the notifier under section 153 above whether it has initiated an investigation or measures pertaining to the child or young person to whom the notification relates. Notwithstanding the aforesaid, this shall not apply where special circumstances exist.

Fig. 1 shows a DCR graph in the design tool (dcrgraphs.net/Tool?id=15491) formalising the rules considered to be needed for case management to be compliant with the law text above.

We see five activities drawn as boxes. Each activity is assigned the role municipal council, written in the bar at the top of each box. The activity labelled special circumstances exist is a data activity (indicated by a folded ear in the upper right corner) and is selected in the editor (indicated by the highlighted, blue border). In the Options panel shown to the right it can be seen that the activity has id special and data type Choice, which in this case is defined as a choice between Yes (represented by the value 1) and No (represented by the value 0).

Between the activities one can see the five most common types of relations of DCR graphs. The (orange) relation with the dot at the target is the *condition* relation and the (blue) relation with a dot at the source is the *response* relation. These two relations are also present in the early work on patterns in property specifications by Dwyer [17] and in the DECLARE [61] notation. The condition relation denotes, that the activity at the source must have been executed before the activity at the target can be executed. Dually, the response relation denotes, that the activity at the destination must eventually be executed if the activity at the source has been executed. Condition/response relations can further be given a delay/deadline, indicated next to the relation. A delay of 7 on a

[2]available via dcrsolutions.net

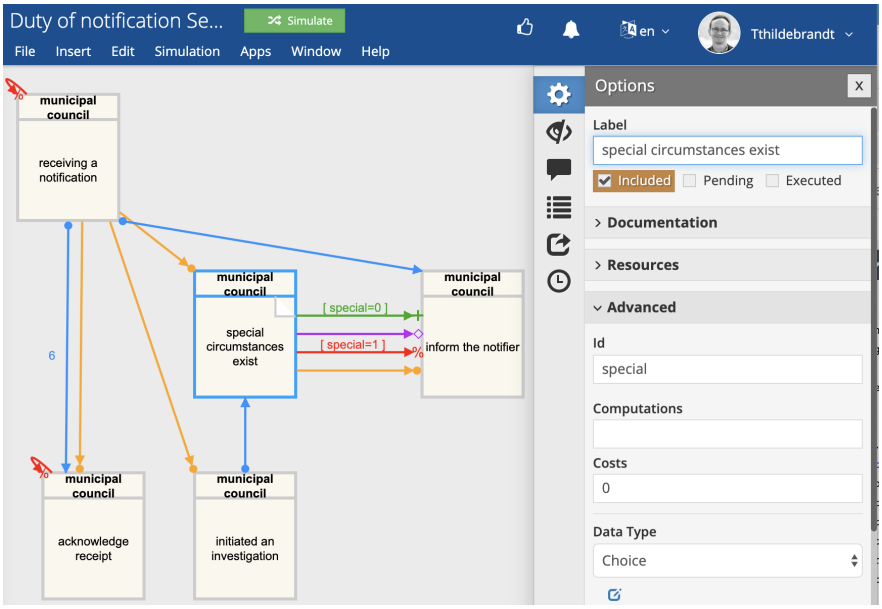


Figure 1: Section 155 b from Part 27 viewed in the DCR Design tool.

condition denotes that at least 7 days most have passed after the last execution of the activity at the source before the activity at the target can be executed. A deadline of 7 on a response denotes that at most 7 days may pass before the activity at the destination must be executed, after the last execution of the activity at the source was last executed.

In the example graph, the condition and response relations from the activity labelled receiving a notification to the activity labelled acknowledge receipt means respectively, that the acknowledgement can only be executed after the notification has been received (which is only implicit in the law text), and that the acknowledge must be executed within 6 days of receiving the notification as declared explicitly in section 155 b (1). The (red) relation with the % sign at the target and the (green) relation with the + sign at the target are special to DCR Graphs and are referred to as the *exclusion* and the *inclusion* relations respectively. The exclusion relation means that the activity at the target is excluded from the graph whenever the activity at the source is executed. The inclusion relation dually means, that the activity at the target is included in the graph whenever the activity at the source is executed. An excluded activity is ignored when evaluating constraints and can not be executed. In the example, the exclusion relation from the activity labelled receive notification to itself thus means that when receive notification is executed it will be excluded and can no longer be executed.

All relations can be guarded by a Boolean expression with the meaning, that the relation is to be ignored if (and only if) the Boolean expression evaluates to false. In the example, the exclusion relation from the activity labelled special circumstances exist to inform the notifier only takes effect if the value of the choice activity with id special is 1 (representing the choice Yes). If the value is 0, instead the include relation takes effect. In this way, the activity inform the notifier is included if and only if the municipal council record that special circumstances exist, and this choice can be executed any number of times if the municipality changes its mind. Finally, the (purple) relation with the diamond at the end shown from special circumstances exist to inform the notifier is the milestone relation.

All activities in the example are initially included, but one may define initially excluded activities, which are shown in the tool with dashed borders. A key feature of DCR graphs is that the state of an executed process can be represented as a *marking* of the graph that assign a state to each activity.

Formally, the state of a standard activity is given by three Boolean values **Ex**, **In**, **Re** and two date (possibly null) values **t** and **d** with the meaning:

Ex: Indicates if the activity has been executed at least once. If so, the time of execution is also recorded as the date value **t**.
In: Indicates if the activity is currently included in the graph.
Re: Indicates if the activity is pending and required to be carried out in the future. If so, a deadline for execution may be also recorded as a date value **d**.

If the activity is defined as a data activity, it further receives a value during execution, also recorded in the state. If the activity is defined as a computation activity, the result of computing the expression assigned is recorded in the state of the activity. Values of activities may be referenced by other computation activities (like cells in a spreadsheet) or guards on relations as in the example above, where the guards on the include and exclude relations refer to the data of the special circumstances exist activity.

2.2 DCR Execution Semantics and Simulation

We will explain the semantics of DCR Graphs informally by describing a simulation carried out using the DCR Simulator. [3] The simulator can be started at any time directly from the DCR designer

[3] For a formal semantics of timed DCR graphs see e.g. [27].

by pressing the green Simulate button at the top of the Design tool window shown in Fig. 1. Simulation is an essential ingredient of the DCR scenario-driven modelling methodology described in [25]. Models are validated by doing frequent simulations during the design and can be recorded as required and forbidden scenarios. After the graph has been modified, all recorded scenarios can be re-run and checked automatically to see if required scenarios are still possible and forbidden scenarios have been ruled out. Execution is carried out by a state-less, DCR execution engine that is available as a service that can be integrated with 3rd party systems for process support and analysis.

Fig. 2a shows the graph introduced above in the simulator after having started the simulation. Enabled activities are marked with a highlighted (green) border and also shown in the right side of the window in a task list. Initially, only the activity receive notification is enabled. All other activities have included conditions that have not yet been executed. The activities can be executed by pressing the green Execute button next to the task in the task list.

The result of executing receive notification is an updated marking and task list as shown in Fig. 2b. The activity receive notification activity has been marked with a check mark, indicating that it has been executed. The dashed border of the shows that it has been excluded, which is a consequence of the exclude relation from the activity to itself. For this reason, it is also removed from the task list. The (blue) exclamation mark on the activities acknowledge receipt and inform the notifier show that these activities are now pending. A pending activity is required to be executed in the future. This is also indicated in the task list by an exclamation mark to the left of the activity. The activity acknowledge receipt has also been given a deadline 6 days in the future. Note that the activity inform the notifier is pending, i.e. required to be executed, but it can not be executed yet due to the condition activity special circumstances exist has not yet been executed. Finally, the swimlane window shows the sequence of executed activities so far. Since special circumstances exist is a data activity, a form window as shown in Fig. 2c opens when it is executed. In this case, the data type has been defined by two key value pairs (Yes,1) and (No,0) to be a choice between two values, Yes and No. The value corresponding to the chosen key is after execution recorded as the value of the activity. This value can be accessed in expressions by referring to the event id (special) of the activity. The resulting graph, task list and swimlane after executing special circumstances exist and choosing Yes is shown in Fig. 2d. Since Yes is recorded as the value 1, the exclude relation guarded by the expression [special=1] causes the activity inform the notifier to be excluded and removed from the task list. This models the last sentence of Sec 155 b (2) stating that the requirement to inform the notifier "shall not apply where special circumstances exist".

3 DIGITALISING REGULATIONS

A paramount goal for a municipal government is to be in compliance with laws, such as the CASS exemplified in the previous section. Each Danish municipality processed on average 9.337,33 CASS cases in the last 3 years [39]. Many of these decisions are later revisited (e.g., on appeal): 887 cases (9.5% of the total cases) were revised just in the first half of 2018. Such revisions led to changes in the outcome: 483 cases (5.1% of the total cases) were reversed [40]. An earlier analysis of municipal practice [7] showed that in more than half of the analysed cases, the rules described in the law were not followed correctly.

However, the law is frequently not operational (or even practical), and must be interpreted and operationalised. Even though the practice is not perfect, municipal governments embody expertise in both what is required by law, and how to operationalise those requirements. It-support for a municipal government, must therefore be founded on the one hand in the law, on the other in the operational experience of that government.

To collect experience from the state of the art in formal models used for regulatory compliance, we performed a Systematic Literature Review (SLR) following Kitchenham's guidelines [29]. The review protocol can be accessed at [31]. The final set of hits included 5.018 entries, that after duplicate removal, screening and two rounds of filtering at abstract and full-text level, returned 46 primary studies that were analysed.

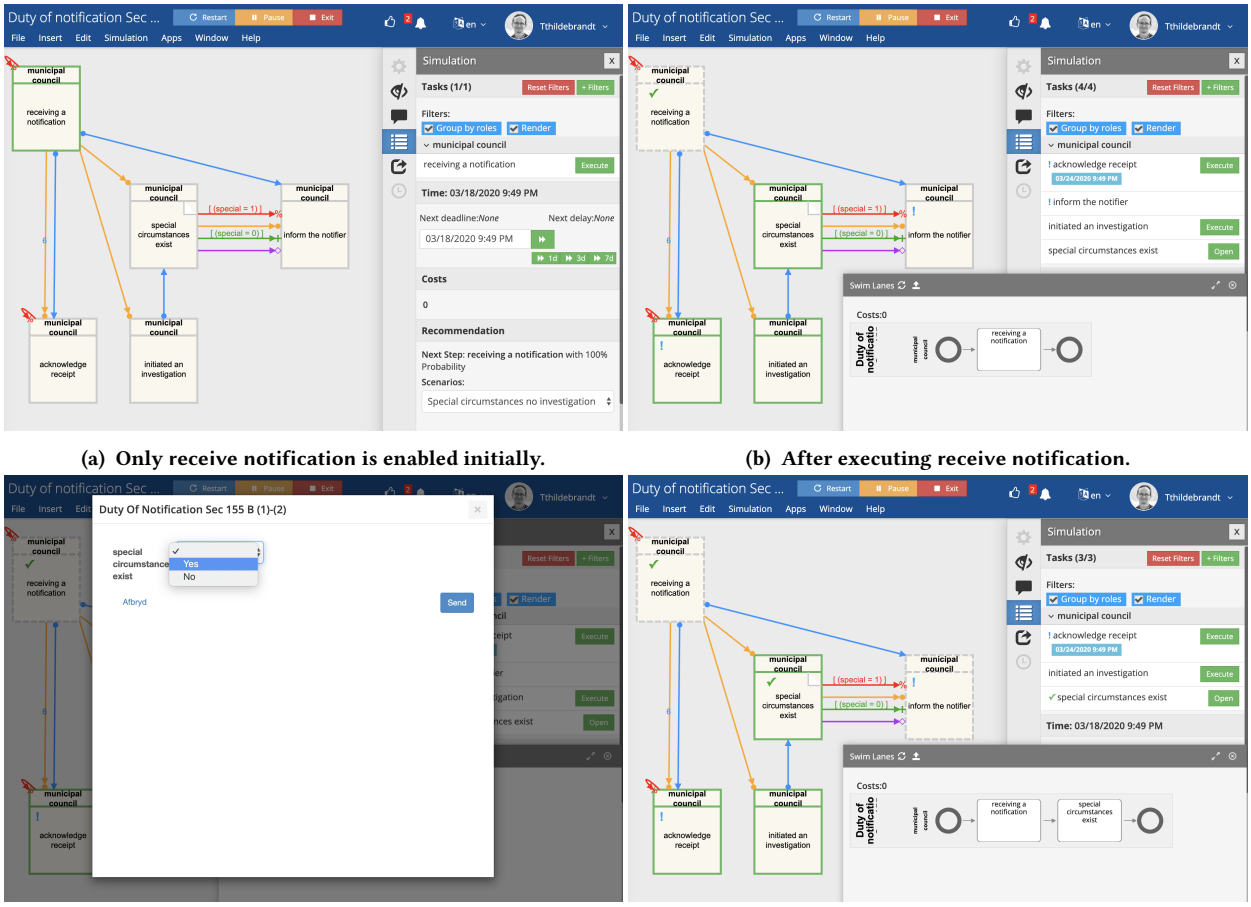
Part of the research questions included in the SLR looked at what are the current trends to formalise regulatory compliance for process oriented technologies, the specification languages used to capture processes and laws, the compliance techniques applied, and whether there existed evidence on the application of the compliance frameworks into the digitalisation of real laws.

The primary studies collected provided the alignment between the legal and the process dimensions. At processes level, the defacto languages used were imperative process specifications, such as BPMN [41] and Petri Nets [59]. On the side of regulations, laws were mostly encoded in logical languages such as Linear and Branching Temporal Logics [49], and variants of defeasible and deontic logics such as FCL and PCL [22, 23]. Moreover, some of these languages might not be completely suited for expressing laws, as it is the case of LTL (and therefore of DECLARE [61], whose semantics is based on LTL) [20, 21]. Others might require extensive training in logics, limiting the adoption of compliance languages by users without a background in mathematical logic, or requiring of external consultants that does the formalisation, limiting the transparency in the formalisation of the law.

The present research distinguishes itself from the literature on formalising law by considering a law that was always meant to be operationalised into casework (as opposed to, e.g., contract or criminal law), and by having access to case workers in a municipality, whose professional life is dedicated to understanding and carrying out that operationalisation of the law.

A service design project was initiated and led by the municipality, focusing on understanding case processes from the perspective of social workers and citizens, and how these could be supported better with the DCR Graphs technology. The project was initiated in spring 2018 and involved interviews and co-creation workshops with 5 social workers and 3 citizens and follow up session with the social workers. The focus of these studies included the role of the law in this context, as well as other factors influencing or directly impacting the process.

The studies suggested a need for improving current processes and that DCR Graphs could help with that. Based on the findings derived from this work, it was decided to move ahead with the digitalisation of a selected set of articles of the CASS and to test the use of such digital models in the so-called "family division" of the



(a) Only receive notification is enabled initially.

(b) After executing receive notification.

(c) Executing special circumstances exist with value 1 (yes)

(d) After executing special circumstances exist with value 1 (yes)

Figure 2: Simulation of the DCR Graph formalizing Section 155 b from Part 27.

municipality, who work with cases concerning children and young people below 18 years with general and special needs for support.

The effort of digitalising the articles from CASS confirmed well-known requirements from works on process compliance [23, 24, 33, 51]: it must describe what can be done (*rights*), what must be done (*obligations*), and what should not happen (*violations*).

The collaboration with Syddjurs exposes both challenges and opportunities for the DCR model and the vision of co-creation. For instance, the CASS changes roughly every 6 months and the changes need to be operatialised in the context of the local policies in the municipality. For a traditional software development, this is a major challenge. However, for user-driven co-creation and model-driven software development, this is an opportunity: end-user domain experts are *excellently* positioned to update models when the law changes. The technical challenge for DCR then becomes how to enable such user-updates.

As an answer to this challenge, we developed the highlighter [32] tool that supports identification of activities, roles and rules in law texts and traceability between textual descriptions and declarative process specifications. Fig. 3 show the highlighter view of the example graph from the previous section. The five activities are overlined (and highlighted blue) in the text and the role municipal

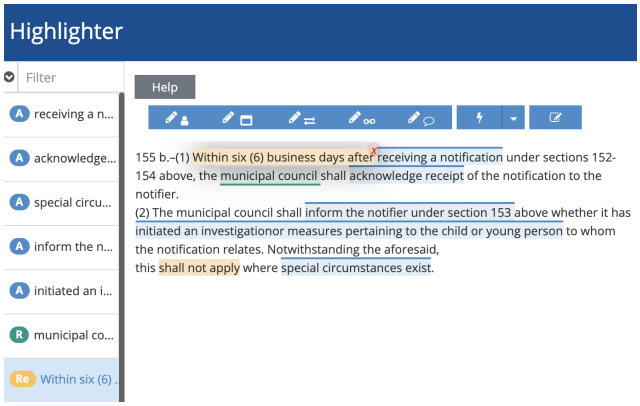


Figure 3: Highlighter view of CASS Sec 155b (1)-(2).

council is underlined (and highlighted green). Two relations have also been highlighted (light orange) in the text. In the left hand side all activities, roles.

The ideas behind the highlighter stem back to Paivio's dual code theory [45]: while process models are visual representations with a



Figure 4: Customised screen presenting overview of cases for the case workers (names and CPR numbers deleted).

defined execution semantics, they lack in many ways the context (e.g.: *why is this activity necessary?*) and are unnatural to the law practitioner. Adding the verbal information allows to include the legal context on why certain activities are necessary. Moreover, visual and verbal information are linked *together*: elements in the process model can be traced back to their requirements in the law by looking at their highlights. To help case workers streamlining their process elicitation activities, we embedded into the highlighter NLP techniques such as named-entity recognition and part-of-speech tagging [34], as well as developing visualisation methods so the alignments between the process model and the legal text become evident for the case worker.

4 THE OPEN CASE MANAGER

In this section we briefly describe the Open Case Manager (OCM) system developed to support case workers in their daily case work.

The OCM is provided as a web application hosted in Microsoft Azure, using a Microsoft IIS and SQL infrastructure. It is integrated with the DCR Process engine to support the logic of dynamic task lists, robotic automated activities and web forms defined as DCR graphs, and integrated with the existing ESDH system used in the municipality to support storage of data.

The OCM was implemented and deployed in the municipality in a half year, agile development process during the spring 2018. The process involved 1) the vendor of the DCR technology stack (DCR Solutions), 2) A digitalisation worker and domain experts in Syddjurs Municipality, and 3) A group of university students working on a User Interaction project. The CEO of DCR Solutions acted as product owner, coordinating the project and prioritising backlog items in collaboration with a member of the digitalisation unit in Syddjurs municipality. In 7 sprints during the first 3 months the students had 4 Skype meetings and a single physical meeting. The work of the students was central for the customisation of the OCM to the wishes and requirements of the case and digitalisation workers at the municipality. A working prototype solution was presented for the case workers after the three month period, after which the integration of the OCM with the customised code made by the students and the existing local ESDH was carried out. The system has been used actively for case management in the municipality since the release in the summer 2018.

The user-interface of the OCM provides an overview of all ongoing cases as shown in Fig. 4, and a time-line showing the past activities of a particular case. It also provides a task-list like in the simulator described in Sec. 2, in which the user can execute activities in a particular case. Just as in the simulator, standard activities are presented to the user as a simple button for execution and data activities such as the special circumstances exist choice activity described in Sec. 2, are shown as a dynamic web-form. Computation activities are assigned to a specific Robot-role, which means that they will be executed automatically by the OCM whenever they are enabled and pending. Typical uses of such automatic activities is the creation or addition of documents to the external ESDH system.

Several data activities can be combined in transactional subprocess of the DCR graph marked as a form. During execution or simulation, the form can be opened and the data activities nested within the form are presented as fields of the form. The form can only be submitted if no pending activities are included. After submission, the sequence of executed activities is replayed in the context of the entire graph, and if possible, this is the effect of submitting the form. If it is not possible to carry out the sequence of activities, no activities are carried out, i.e. the transaction is aborted. This may happen if the activities in the form have relations to activities in the graph outside the form that have been executed while the form was open. Similarly, if the user closes the form without submitting, the transaction is aborted. Forms have the exact same logic when executed in the OCM (or other case management tools with forms based on the DCR technology) as when executed in the simulator. This makes it possible to simulate the entire case logic, including forms and input of data, in the simulation tool before the process is used in practice on real cases [36, 52]. This is in particular useful for more complex forms that need validation of end-users. Fig. 5 shows an example of such a form in the implementation of Sec 155 of the CASS in the municipality. The form shows the many standard categories of reasons for notification used in the municipality.

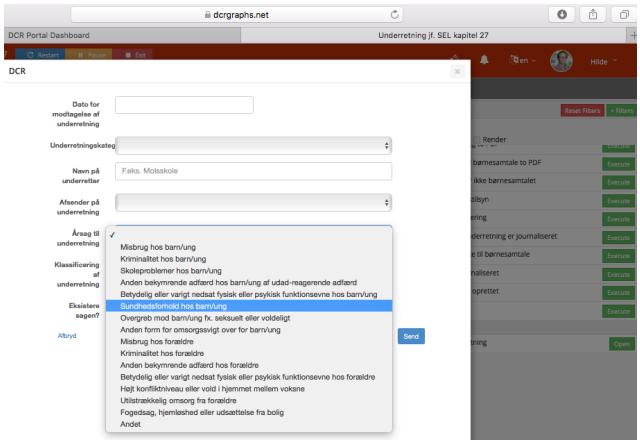


Figure 5: A complex form with many categories explaining the cause of notification in Sec 155 of the CASS.

The OCM is shared in Github[4] under an AGPLv3 open source license. This allows organisations or companies using the OCM to make their own customisation, such as integration of robotic events with existing systems used in the organisation. A more detailed description of the OCM can be found at the DCR Graphs wiki[5].

[4] github.com/DCRGraphsNet/DCROpenCaseManager
[5] https://wiki.dcrgraphs.net/wiki/108

5 UNDERSTANDABILITY STUDIES

We evaluated the DCR technology stack as part of a larger investigation of the usability and understandability of hybrid process design artifacts.

We started by conducting a systematic literature review (SLR) about hybrid business process representations [5], in which we identified the existing hybrid process artifacts and investigated the studies where they have been evaluated. For instance, De Smedt et al. [12] propose a hybrid process artifact combining a declarative model with a set of textual annotations revealing the implicit constraints in the model. The evaluation shows that this reduces the perceived difficulty of declarative models and improves their understandability. Zugal et al. propose a test driven approach [66], where a declarative model is combined with a set of test cases showing the intended behaviour of the model. The evaluation [65] shows that the test-driven approach for maintainability tasks reduces end-users' mental effort and increases the perceived quality of declarative models.

After the SLR, we set out to assess if end-users (i.e., case workers, process consultants, lawyers) can understand and use DCR Graphs as a tool for describing and modelling processes and compliance rules when assisted by hybrid artifacts that extend the declarative notation with additional process representations. In particular, we first studied the potential benefits of using law texts as process annotations combined with guided simulation of the process and then studied the use of the highlighter tools for process construction.

Combining declarative models with law texts and simulations. The first exploratory study investigated the understandability of a hybrid process artifact combining a process model in DCR graphs with textual annotations depicting the law and an interactive simulation tool [3, 4] similar to what is possible in the design tool described in Sec. 2. The participants were asked to solve different understandability tasks. The results show that each task type is associated with a different reading pattern, suggesting that the end-users followed different strategies characterised by the use of different combinations of process artifacts to solve different types of tasks.

In more detail, three research questions were investigated, following a qualitative research approach supported by verbal utterances and eye-tracking data [6]:

- RQ1: What are the benefits and challenges associated with the use of the different artifacts?.
- RQ2: How do end-users with different backgrounds engage with the artifacts?
- RQ3: How can the different artifacts be used to fulfil different tasks?

Unlike previous studies investigating the understandability of hybrid process artifacts (e.g., [64]), which were limited to students, the present study covered both academics at two danish universities and employees at Syddjurs municipality. The disparity in the participants backgrounds provided important insights into the proposed hybrid representations: Although the majority of the municipal employees relied on the law text as a primary source of knowledge, some of them referred to the DCR activities to orient themselves in the process and used the simulation as a means for validation. Academics on the other hand interacted mainly with the DCR graph and the simulation, while only few of them used or could understand the law text. The difference in the reading patterns of academics and municipal employees can be linked to the disparity in their backgrounds, which reflects the real-world scenario where domain experts and IT specialists have difficulties to make sense of process artifacts they are not familiar with [48]. The declarative DCR graphs process model generally helped the participants to familiarise with the scope of the process and provided insights into the interplay between the different activities of the process. However, some participants reported challenges w.r.t understanding the semantics of the DCR relations. One group of participants used the interactive simulation to clarify the implications of the different DCR relations and to track the dependencies between the activities of the model. Still, the use of the simulation was seen as being time consuming and inefficient for some participants. The law text, in turn, was used by some participants to complement their understanding of the DCR graph and to provide contextual information about the activities of the model. However, most of the academics were unable to make sense of the linguistic patterns and the legal terms in the law text. Overall, these insights suggest that no single artifact has the ability to provide a clear understanding of the business process. A hypothesis to be explored in future work is if the use of a hybrid process artifact can help to make up for weakness of the individual process artifacts and serve to facilitate collaboration between different types of users.

Understandable Modelling of Declarative Processes Using the Highlighter. The second study investigated the modelling of DCR graphs using the highlighter [2]. The highlighter provides a hybrid modelling approach to support end-users during the process modelling. By interlinking the constructs of the model (activities, roles and constraints) with their corresponding textual fragments in the process description, the highlighter aims at clarifying the semantics of DCR graphs and providing a better alignment between the process model and the process specifications [32]. In this study, the highlighter was embedded in the default DCR modelling tool and an interactive simulation.

The study was motivated by *(1)* the challenges associated with the understandability of declarative languages, in addition to *(2)* the need for concrete means to maintain the alignment between process models and process specifications.

Following a qualitative research approach supported by verbal data and user interactions collected throughout the modelling session, this study addressed two main research questions. Namely, the first research question looked into the way end-users engage with a modelling task using the highlighter, while the second research question investigated the aspects in which the highlighter could potentially improve the quality of process models. In order to have a global understanding about the modelling of DCR graphs using the highlighter, the study has covered both university students and municipal employees.

The results of the analysis showed that most participants used the highlighter as a kick-start and then progressively increased their interactions with the modeller. When investigating this observation, it has been shown that the highlighter was mostly used to identify and append activities and roles to the DCR graph, while the modeller

was used to directly add relations to the DCR graph. The insights provided by the participants justify to a large extent the reasons why the highlighter was primarily used to identify roles and activities but not relations. These insights are associated with the facility to highlight activities from the text and the implied cognitive support obtained when doing so. This support can be associated with the isolation effect [63] resulting from highlighting different parts of the text, which has been shown to increase the attention of the readers and help them memorise the highlighted textual fragments. Nevertheless, the implicit complexity of some constraints in the process description increased the complexity of identifying the DCR relations in the process specifications and mapping them with the process model using the highlighter. Hence, the deployment of the highlighter can be more effective with process specifications including explicit constraints.

With respect to the quality of process models, the insights obtained from the participants indicated the potential benefits associated with the use of the highlighter. In particular, participants mentioned that the highlighter can support the traceability of the process specifications and enhance their coverage. Moreover, the highlighter can provide better alignment between the process model and the corresponding process description. The use of the highlighter can also help to document process models which in turn facilitate their maintainability. These insights motivate the use of the highlighter as a means to map the specifications in the process description with the different parts of the model.

6 CONCLUSIONS AND FUTURE WORK

The paper has presented a case study of co-creating an adaptive case management system in a municipality based on the DCR technology stack for declarative adaptive case management and carried out as part of the EcoKnow.org research project. The development is grounded in ethnographical field studies of practice carried out before the case study and reported elsewhere [46]. The development was initiated by systematic literature reviews on formal methods for regulatory compliance and understandability of process modelling, followed by a service design study with case workers and citizens in the municipality. The service design study helped identify the areas in which to test the case management system, refine its user-interface and define the requirements of a new highlighter design tool, providing traceability between formal DCR models and natural language text. The design tools were evaluated in understandability studies with end-users.

The case study showed, that the DCR technology stack including the new highlighter design tool and case management system in this case supported an agile, prototyping based development together with local domain experts. The system has been used for case management in the municipality since the summer 2018.

Future work will focus on further evaluation of the approach and the use of the OCM system in practice. Hereto comes the development of methods and technologies for the responsible use of artificial intelligence for decision support in case management. Another challenge for future work is to support modular specification of laws, as well as intra- and inter- dependencies between articles.

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