A Verification Framework for Business Rules Management in the Dutch Government Context

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***Abstract*—Since an increasing amount of business decision/logic management solutions are utilized, organizations search for guidance to design such solutions. An important aspect of such a solution is the ability to guard the quality of the specified or modified business decisions and underlying business logic to ensure logical soundness. This particular capability is referred to as verification. As an increasing amount of organizations adopt the new Decision Management and Notation (DMN) standard, introduced in September 2015, it is essential that organizations are able to guard the logical soundness of their business decisions and business logic with the help of certain verification capabilities. However, the current knowledge base regarding verification as a capability is not yet researched in relation to the new DMN standard. In this paper, we re-address and - present our earlier work on the identification of 28 verification capabilities applied by the Dutch government [1]. Yet, we extended the previous research with more detailed descriptions of the related literature, findings, and results, which provide a grounded basis from which further, empirical, research on verification capabilities with regards to business decisions and business logic can be explored.**

Keywords-Business Rules; Business Rules Management; Verification; Capabilities; Dutch Government

I. INTRODUCTION

Business rules (BR's), as part of business logic, are increasingly being utilized in enterprises as building blocks for (automated) decision making, for example, supporting execution of various types of e-services like applying for an insurance product and applying for social benefits and automated fraud detection at financial organisations. As a result, organizations employ various methods and processes to manage these BR's, often referred to as Business Rules Management (BRM) [2]. An important part of BRM comprises quality control, which focuses on reducing errors in the syntax and intended behavior of the business rules. Thereby improving the quality of the defined and executed BR's [3]. This particular capability is referred to as verification. A capability in this paper is defined as an ability that an organization, person, or system, possesses. It, therefore, defines what an organization, person or system does or can do but not how it accomplishes it. In practice, a capability can be implemented in different ways, for example manually, partly- or fully automated.

In September 2015, the Object Management Group (OMG) released a new standard for modelling decisions and underlying business logic, the Decision Model and Notation (DMN) [4]. As the adoption of the DMN standard increases, the need for verification of BR's, which are a significant component of the decision logic layer in DMN, increases as well. Therefore, in this paper, we adhere to the DMN 1.1 standard [5] and aim to explore which verification capabilities are relevant in the verification process of decisions and underlying BR's.

Verification, as a capability in general software development, is an established research field and has received a lot of attention from researchers in the previous decades (Ackerman, Buchwald, & Lewski, 1989; Van der Aalst, 1999; Vermesan & Coenen, 2013). In literature, verification of business rules is a capability, executed by a specific component, of expert systems, knowledge management systems, knowledge engineering systems, or knowledge based systems. Regarding these research domains, different scholars and practitioners identify different types of verification capabilities, for example, the work [9] on verification capabilities for expert systems, in the work of [10], [11] and [8] on verification capabilities for business process models, and in the work of [12] and [7] on verification capabilities for Knowledge Based Systems. Another contribution within the research domain of business logic is the work of Von Halle and Goldberg [13], which presents multiple principles that refer to capabilities that are applicable when performing verification of business logic, containing business rules. An example included in their work is the normalization and integrity verification capability.

However, in current literature on business logic, no uniform overview exists. Additionally, the current knowledge base predominantly focuses on theory forming by means of deductive research methods, while inductive research methods to explore the spectrum of the verification capability seem almost non-existent to the knowledge of the authors.

This paper aims to define, from practice, the spectrum of capabilities required for the verification of business logic which can be designed and specified with DMN. To be able to do so, we addressed the following research question: "*Which verification capabilities are useful to take into account when designing a business rules management solution?*" Five large Dutch government institutions participated in a three-round focus group to derive verification capabilities applied in practice. The results form a framework of capabilities regarding the verification of business rules.

The remainder of this paper proceeds as follows. First, we provide, in short, insights into what verification comprises in the context of BRM and how it relates to the other BRM capabilities. This is followed by the research method utilized to identify the verification capabilities applied in the Dutch governmental context. Furthermore, the collection and analysis of our research data are described. Subsequently, our results, which led to our framework containing 28 verification capabilities are presented. Finally, we discuss which conclusions can be drawn from our results, followed by a critical view of the research method and techniques utilized and propose possible directions for future results.

II. Background and Related Work

With increasing investments in BRM, organizations are searching for ways to guide the design of business rules management solutions. A business rule is defined as "*a statement that defines or constrains some aspect of the business intending to assert business structure or to control the behavior of the business*" [14]. A business rules management solution enables organizations to elicitate, design, specify, verify, validate, deploy, execute, evaluate and govern business rules, see Figure 1 [15], [16]. When a business rules management solution is designed, each of the nine previously mentioned capabilities need to be designed, implemented and governed. The manner in which way these capabilities are realized depends on the actual situation in a specific organization. This paper is part of a research project in which the focus was to evaluate all nine capabilities of five government institutions. In this paper, we focus on the verification capability as other studies (i.e., [17]–[20]) already focused on the exploration and definition of the other BRM capabilities.

As stated in the introduction section, no uniform overview exists with regards to verification capabilities in the context of BRM, and more specific, in relation to DMN. Literature in neighboring fields often define one or more verification capabilities, however, they do not present a uniform overview. Furthermore, the verification capabilities described in neighboring fields are often based on or related to a specific language and therefore less generalizable. For example, regarding software development verification, [21] and [6] describe several verification capabilities, but do not aim to be complete as their work define the boundaries of verification in general and a process to execute verification. Furthermore, for example, with regards to Business Process Management and process modeling. The work of [22] and [23], describe verification as a capability for process model checking. However, they do so in a technical and non-uniform manner. From the literature we find that verification capabilities, in a general sense, are often mentioned or described as part, thus often a sub-goal, of a research study, to evaluate the conformance with certain guidelines. To contribute to the current knowledge base, we aim to define the verification capability with regards to BRM utilizing an inductive approach.

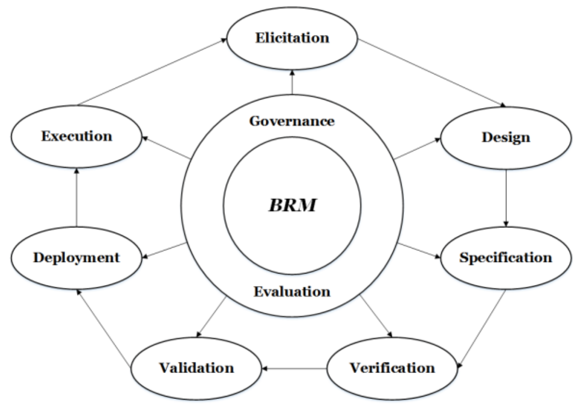

Figure 1. BRM Capability Framework

A detailed explanation of each capability can be found in [24]. However, to ground our research, a summary of the elicitation, design, specification and verification capabilities is provided here. The purpose of the elicitation capability is twofold. On the one hand, the purpose is to determine the knowledge that needs to be captured from various legal sources to realize the value proposition of the business rules. Many possible legal sources from which this knowledge can be derived exist, for example, laws, policies, guidelines, regulations, expert hearings, research outcomes, case law, and internal documentation. Depending on the type of knowledge source(s), different methods, processes, techniques and tools to extract the knowledge are applied [25]. The output of the elicitation capability is the collection of knowledge that is required to design the Decision Requirements Diagram (DRD), which is the highest level of abstraction with respect to decision modelling in DMN. The DRD layer recognizes four concepts: 1) a decision, 2) business knowledge, 3) input data, and 4) a knowledge source. When no DRD exists, elicitation information is collected to specify the four. On the other hand, when a DRD is already in place, an impact analysis is performed to identify the modifications that need to be processed to the existing structure and underlying business logic in the design and specification capabilities. The DRD consists of a combination of business decisions. A DRD is a collection of business logic, in terms of business rules and fact types. The relationship between different decisions is depicted in a derivation structure. The DRD is the high-level output which the design capability needs to realize. After the DRD is created, the content (business rules and fact types) of each individual decision need to be specified in the specification capability. The purpose of the specification capability is to create the business rules and fact types needed to make the decision, the Decision Logic Level (DLL). The decision logic level has multiple key concepts which are described in two languages the Friendly Enough Expression Language (FEEL) and the Simple FEEL variant (SFEEL). SFEEL is a subset of FEEL, tailored for simple expressions in conjunction to be utilized in decision tables. However, the same concepts of SFEEL and FEEL can be expressed in multiple other languages. For example, Camunda also supports the use of other languages to define business logic with, such as Javascript, Groovy, Python, Jruby, and Juel [26]. The language selected to represent the decision logic does not influence the decision requirements level. The output of the specification capability is a specified context design that contains decisions, business rules, and fact types. After the DRD and DLL are created, they are verified, comprising the evaluation to eliminate syntax errors in both abstraction levels. This is defined as the verification capability. The purpose of the verification capability is to determine if the decisions, business rules, and fact types adhere to predefined criteria, for example, conformance to language guidelines, and are logically consistent. If errors are identified, two scenarios can occur. First, the verification issues are resolved in a revision of the designed and specified business knowledge. Second, the verification issues are ignored and the decisions, business rules, and fact types are deployed based on the current elicitated, designed and specified business logic. However, verification errors not properly addressed could result in the improper execution of the value proposition in the execution capability later on in the BRM processes, thus posing a possible risk to the organization that employs the business logic [24].

III. Research Method

The goal of this research is to identify verification capabilities that are being utilized in practice. Currently, research is conducted on business rules (management), however, the existing knowledge base is rather old and mostly from a theoretical perspective [15], [24], [27]. Additionally, most of the research that is conducted on business rules (management) embraces a deductive approach, while little is known on how verification is applied in practice. Therefore, research studies utilizing an inductive approach could lead to further theory refinement by taking into account verification capabilities are applied in practice. An appropriate focus of research with an inductive approach is on identifying new constructs and establishing relationships between identified constructs from a practical context (e.g., Edmondson and McManus, [28]). Therefore, through grounded theory based data collection and analysis, in our research we explore verification capabilities applied in practice and combine them into a framework to, on the one hand, guide organizations in the design and execution of the verification capability as part of business rules management, while on the other hand strengthen the currently available knowledge base with insights derived from practice.

To explore a range of possible solutions with regards to a complex issue group based research techniques are adequate [29]. Group-based research techniques are useful when the collection of possible solutions need to be combined into one view, backed by empirical evidence that is not present in the body of knowledge. Examples of group based techniques are brainstorming, nominal group techniques, focus groups and Delphi studies. Group based research techniques can be differentiated by the type of approach they utilize, face-to-face versus non-face-to-face approaches to gather research data. Of course, both the face-to-face and non-face-to-face approaches are characterized by their advantages and disadvantages; i.e., in face-to-face meetings, participants can provide (additional) feedback directly. On the other hand, face-to-face meetings are characterized to be restricted with regard to the number of participants as well as the possible existence of group or peer pressure.

For this study we selected a face-to-face approach to be more appropriate, also facilitating peer-discussion regarding the application of the verification capability at the selected governmental organizations. Earlier experiences of the researchers with similar approaches showed that participants will trigger each other to elaborate more in-depth on why and how a specific capability is applied.

IV. Data collection and analysis

The data for this study is collected over a period of three months, between January 2014 and March 2014. The collected data has initially been categorized based on the beta version of the DMN standard that was published in August 2013. Since no significant changes between the beta and the final version of the DMN standard occurred, we refer to the final 2016 version of the DMN standard in this paper [5]. The data collection was conducted through three rounds of focus groups. Between each individual focus group, the researchers consolidated the results.

When designing a focus group, a number of situational characteristics need to be considered: 1) the goal of the focus group, 2) the selection of representative participants, 3) the number of participants, 4) the selection of the main facilitator and research team, 5) the information recording facilities, and 6) the protocol of the focus group. The goal of the focus group was to identify the current verification capabilities being applied in practice. The selection of participants should be based on the group of individuals, organizations, information technology or community that best represents the phenomenon studied [30]. In this study, organizations and individuals that deal with the verification of a large amount of business rules represent the phenomenon studied; examples are financial and governmental institutions. Taking this into account, multiple Dutch government institutions were invited to participate. The organizations that agreed to cooperate with the focus group meetings were the: 1) Dutch Tax and Customs Administration, 2) Dutch Immigration and Naturalization Service, 3) Dutch Employee Insurance Agency, 4) Dutch Education Executive Agency, and 5)

Dutch Social Security Office. We believe that this is a representative selection due to several reasons; 1) they apply all degrees of automation to their decision making (i.e., human, a human supported by a machine, a machine supported by a human, and fully automated), 2) they design and execute a large variety of rule types (i.e., derivation, calculation, constraints, process, validation, and decision rules), and 3) they are required to indisputably implement the laws and regulations for all Dutch citizens and organizations.

Based on the written description of the goal and consultation with experienced employees of each government institution, participants were selected to take part in the focus group meetings regarding verification of business rules. In total, ten participants took part in the focus group rounds which fulfilled the following positions: One legal advisor, two BRM project managers and seven business rule analysts. All involved subject-matter experts had a minimum of five years of experience with the verification of business rules. Delbecq & van de Ven [29] and Glaser [31] state that the facilitator of the focus groups should have an appropriate level of experience with regards to the topic. Also the facilitator should have experience with the workings of face-to-face group based research techniques. The facilitator in this research project has a Ph.D. in BRM and has conducted nine years of research with regards to BRM. Furthermore, the facilitator has conducted research while utilizing many face-to-face research techniques before. Additionally, three researchers were supporting the facilitator during the focus group meetings. One researcher was the 'back-up' facilitator. The back-up facilitator monitored whether each participant provided equal input. When necessary, the back-up facilitator involved specific participants by asking for more in-depth elaboration on the subject at hand. The other two researchers acted as minute's secretary, taking notes. All focus group meetings were video and audio recorded. The duration of the first focus group was 192 minutes, the second 205 minutes and the third 207 minutes. All three focus group meetings followed the same overall protocol, starting with an introduction and explanation of the purpose and procedures of the focus group at hand, after which verification capabilities were generated, shared, discussed and/or refined.

Prior to the first round, the research team informed the participants with regards to the purpose of the research and meetings at hand, after which the participants were invited to submit their current documentation with regards to verification capabilities regarding business decisions and business logic. Prior to the first focus group meeting, the research team already consolidated similar verification capabilities that were derived from the received documentation. This was to ground and start up the discussion of the first focus group meeting. During the first focus group meeting, participants first explained their submitted documentation and why their verification capabilities were relevant in their context. For each capability, the group discussed whether it was related to business rules management processes in general or not, for example, some of the mentioned results focused more on the verification of process models or data types. The second and last part of the focus group meeting was committed to defining new or missing capabilities where participants thought they were missing from the already identified selection of capabilities. For each proposed capability, it's ID, label, description, rationale, classification, and example(s) were discussed and noted, see Table I.

Table I. Identical business rules verification

capability ID:	B4.
capability label:	Identical business rules verification.
capability description:	Identical business rule verification checks if a business rule occurs more than once in the exact same appearance in the same business rule set.
capability rationale:	Identical business rule verification is needed as redundant rules account for extra maintenance burden on top of the negative impact they have on performance.
capability classification:	Decision logic level verification
capability example: (underlined business rules are identical)	*Decision: Rights for Child Benefits* *1 – The Age of the Child is between 16 and 17* <u>*2 – The Child is registered as part of => 1 household*</u> *3 – The Child has the right to receive study benefits* <u>*4 – The Child is registered as part of => 1 household*</u> 5 – *The Registration Status of the Child is Household of 1*

When the first focus group meeting was finished, the researchers started analysis to consolidate the results. Consolidation of the results comprised the detection of incomplete and redundant capabilities. Next, the results of the analysis by the research team were sent to the participants of the focus group meeting fourteen days in advance before the next meeting. During these fourteen days, the participants assessed the consolidated results in relationship to three questions: 1) "*Are all capabilities described correctly*?" (in terms of the capability label and accompanied examples), 2) "*Do I want to remove a capability*?", and 3) "*Do we need additional capabilities*?"

During the second focus group, the participants discussed the derived capabilities. The group started to discuss their usefulness, and, again, whether all capabilities were described correctly. Furthermore, the participants were asked to validate whether the capabilities that were identified to be redundant from the consolidation by the research team needed removal from the selection of relevant capabilities. For example, one of the participants submitted the capability 'illegal value', while another capability labelled 'domain violation' already existed in the results of the first focus group round, which is an equivalent capability. As the end of the second focus group meeting showed signs of saturation amongst the participants. For this reason, the third focus group was redesigned as a validation session in which we solely wanted to validate the results that were derived from the first two focus groups. The discussion in the last focus group therefore focused on further refinement of the existing capabilities in terms of their descriptions, classification, and goals.

V. RESULTS

In this section, based on our data collection and analysis, we present our results with the help of a case which is further specified in [32]. This case does not adhere to the business rules provided by the governmental agencies. The reason for this is that per discussed capability, different case examples were adhered to in the focus groups by the participants. The reader therefore would get snippets of business rules from each agency, lacking the discussion of an integrated case. Therefore the results of the focus groups and Delphi study have been mapped onto an integrated case that is presented in an integrated manner. The case we selected comprises the determination of risk of malnutrition regarding a hospitalized patient, see Appendix A.

Table II. Business logic expressed in the DMN formal decision table format

Decision: Determine Malnutrition Risk			
Business rule #	**Input**	**Output**	**Annotation**
	Malnutrition Risk Points of the patient	Malnutrition Risk of the patient	
1	<= 3	1	Malnutrition of the patient is 1 (low)
2	]3..6[	2	Malnutrition of the patient is 2 (moderate)
3	>= 6	3	Malnutrition of the patient is 3 (high)

As stated in the background and related work section of this paper, the DMN standard features two levels of abstraction, the DRD and the DLL. For the demonstration of the business logic used in our examples we choose not to use, due to page size constraints, the DMN formal decision table format, but a simpler and compact representation; structured English. Business logic expressed in decision tables is easily transformed into structured English business logic, see for example Table II (decision tables) and Table III (structured English).

In total, the consolidated framework for the verification of business decisions and business logic consists of 28 verification capabilities, see Figure 2. Due to space limitations, we present each capability by its label, description, and example.

Table III. Business logic expressed in the structured English format

Decision: Determine Malnutrition Risk
BR1 - Malnutrition Risk of the patient must be equated to 1 IF Malnutrition Risk Points of the patient <= 3
BR2 - Malnutrition Risk of the patient must be equated to 2 IF Malnutrition Risk Points of the patient is >3 AND <6
BR3 - Malnutrition Risk of the patient must be equated to 3 IF Malnutrition Risk Points of the patient >= 6

To further structure our derived capabilities, the abstraction layers of the DMN standard are utilized for categorization as some verification capabilities are only relevant in the context of a certain abstraction level of business logic. Lastly, as some derived verification capabilities are relevant in a generic sense, the generic category has been added.

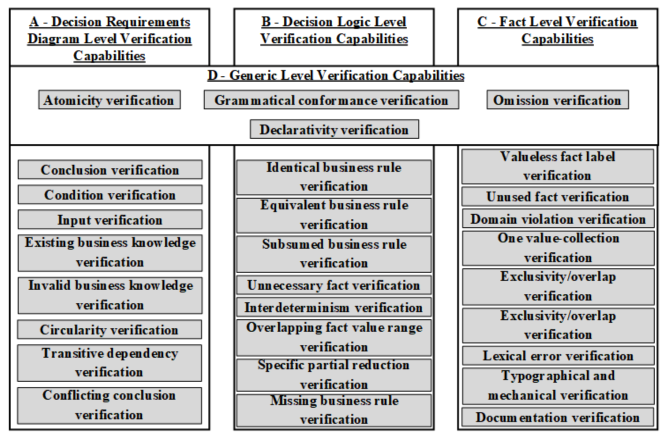

Figure 2. BRM verification capability framework.

A. *Decision requirements level verification*

Regarding the highest level of abstraction, the decision requirements level, eight verification capabilities were identified.

Conclusion verification

Conclusion verification checks if the conclusion fact of an individual decision is used as a condition fact in another decision. In a DRD, this situation can only legitimately occur once, namely with the top-level decision. Additional occurrences indicate an error in the logical completeness. For example, let’s examine the decisions “E - Calculate Body Mass Index Risk Points” and “F - Calculate Body Mass Index”. The conclusion fact “Body Mass Index” of decision F is used as a condition fact in decision E. If this would not be the case decision E would be floating and an error would occur.

Condition verification

Condition verification is a reversed form of conclusion verification. It first checks if a condition fact is a ground-fact or derived-fact. If a fact is a derived-fact, the test checks if the fact is the conclusion fact of another decision. Let‘s examine the same example as presented in the conclusion verification. The condition fact “Body Mass Index” of the decision “E - Calculate Body Mass Index Risk Points” is the conclusion of the decision “F - Calculate Body Mass Index”. If this would not be the case, decision E would be executed, but an error would occur.

Input verification

Input verification checks if the conclusion fact of an underlying decision is used as a condition fact in the parent decision. Contrary to conclusion verification and condition verification, input verification checks if there are no unnecessary decisions in the DRD. For example, let’s examine the decision: “C – Calculate Weight Loss Risk Points”. For this example, this decision has two connected decisions: “D - Calculate Weight Loss” and additionally, “Assess Weight Pattern.” However, only the conclusion fact of decision D is applied in decision C. Indicating that the decision “Assess Weight Pattern” is unnecessary and should be removed from the DRD.

Existing business knowledge verification

Existing business knowledge verification checks if a decision is accompanied with specified business knowledge. For example, let’s examine the same decisions as used in the example of input verification: “D – Calculate Weight Loss” and “Assess Weight Pattern.” In this specific instance, no business knowledge is specified for decision “Assess Weight Pattern”, while the business knowledge is required to execute the parent decision “C – Calculate Weight Loss Risk Points.”

Invalid business knowledge verification

Invalid business knowledge verification checks if each fact value of the condition fact of a decision is also present as a fact value of the linked conclusion fact of the underlying decision(s). For example, let’s examine the two decisions: “E - Calculate Body Mass Index Risk Points” and “F - Calculate Body Mass Index.” The conclusion fact of decision F is used as a condition fact in decision E. In this example, the conclusion fact of decision F contains a value range from 10 to 80 BMI points, while the condition fact in decision E contains a value range of 20 to 70 BMI points.

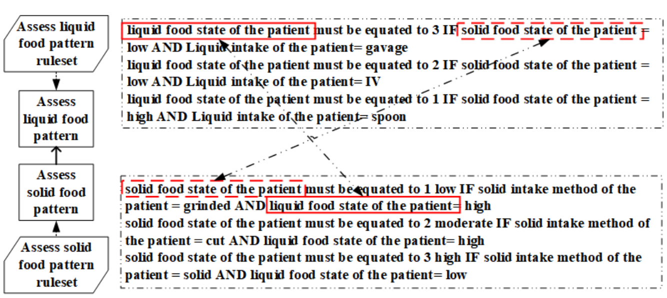

Figure 3. Example based on [32] depicting a circularity error

Circularity verification

Circularity verification checks if a conclusion fact of the parent decision is used as a condition fact in the underlying decision while at the same time, the conclusion fact of the underlying decision is used as a condition fact in the parent decision. For example, see Figure 3.

Transitive dependency verification

Transitive dependency verification checks if the same condition fact occurs twice in a set of three decisions that are connected to each other. For example, take into account a situation where there are three decisions: “Decision A”, “Decision B” and “Decision C”. “Decision A” applies the conclusion facts of “Decision B” and “Decision C” as condition facts. In addition “Decision B” applies the condition fact “intake solid food of the patient” to derive a conclusion. Additionally “Decision C” also applies the condition “intake solid food of the patient” in addition to an extra condition fact to derive a conclusion. Therefore the condition fact “intake solid food of the patient” is applied twice to eventually derive the conclusion of “Decision A”. This does not necessarily have to be an error, but usually implies an error in the business logic, which can be solved by removing either “Decision B” or the condition fact “intake solid food of the patient” in “Decision C”, see also Figure 4.

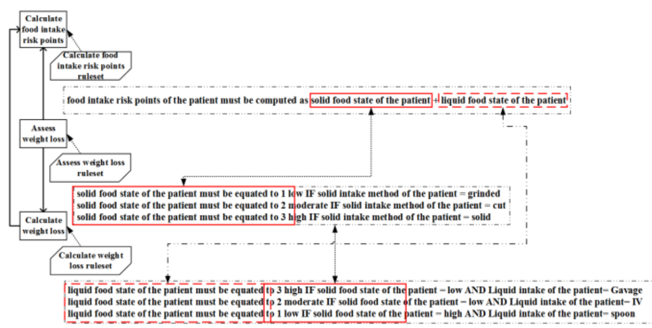

Figure 4. Example based on [32] depicting a transitive dependency error

Conflicting conclusion verification

Conflicting conclusion verification checks if there are conclusion facts that are established using different business rules and facts. For example, the conclusion fact “Food Intake Risk Points” of decision G could be calculated by the following business rules: “BR18 - Food Intake Risk Points of the patient must be equated to 4 IF Solid Intake of the patient > 5 days AND Age of the patient > 18 AND Liquid Intake of the patient <= 1 days” and “BR19 - Food Intake Risk Points of the patient must be equated to 4 IF Solid Intake of the patient > 5 days AND Age of the patient > 18 AND Liquid Intake of the patient <= 1 days ”. In this case, the conclusion fact is differently calculated and therefore the results of both business rules could contradict each other.

B. *Decision logic level verification*

Regarding the decision logic level, eight verification capabilities were identified.

Identical business rules verification

Identical business rule verification checks if a business rule occurs more than once in the exact same appearance in the same business rule set. Take for example the following two business rules: “Malnutrition Risk of the patient must be equated to 2 IF Malnutrition Risk Points of the patient is >3 AND <6” and “Malnutrition Risk of the patient must be equated to 2 IF Malnutrition Risk Points of the patient is >3 AND <6”. See also the completely elaborated capability description and rationale in Table I.

Equivalent business rules verification

Equivalent business rule verification checks for business rules which are expressed different, but have the same outcome. Take for example the following two business rules: “Food Intake Risk Points of the patient must be equated to 4 IF Solid Intake of the patient > 5 days AND Age of the patient >= 18 AND Liquid Intake of the patient > 1 days” and “Food Intake Risk Points of the patient must be equated to 4 IF Solid Intake of the patient >= 6 days AND Age of the patient > 17 AND Liquid Intake of the patient >= 2 days.” Both business rules have the same outcome, but are written differently.

Subsumed business rules verification

Subsumed business rule verification checks if business rules exist that are more comprehensive compared to a business rule with the same outcome. Take for example the following business rule: “Food Intake Risk Points of the patient must be equated to 4 IF Solid Intake of the patient > 5 days AND Liquid Intake of the patient > 1 days”. The previous business rule concludes exactly the same fact as the following business rule, which utilizes one more condition: “Food Intake Risk Points of the patient must be equated to 4 IF Solid Intake of the patient > 5 days AND Age of the patient <= 18 AND Liquid Intake of the patient > 1 days”.

Unnecessary fact verification

Unnecessary fact verification checks for facts that is included in a business rule, but is not required to calculate or derive the outcome. Take for example the business rule: “Body Mass Index of the patient must be computed as Current Weight of the patient / Square (Height of the patient)”. Additionally, we present the facts for this ruleset: 1) Body Mass Index, 2) Current Weight, 3) Height, and 4) Shoe Size. In this example the Shoe Size of a patient is not used in the business rule to calculate the outcome and is therefore unnecessary.

Interdeterminism verification

Interdeterminism verification checks if there are two business rules with the same condition facts but with a different conclusion. For example the business rules: “Malnutrition Risk of the patient must be equated to 2 IF Malnutrition Risk Points of the patient is >3 AND <6” and “Malnutrition Risk of the patient must be equated to 4 IF Malnutrition Risk Points of the patient is >3 AND <6”. The conditions of these two business rules are exactly the same, but the conclusion fact value is different, which leads to conflicting results.

Overlapping fact value range verification

Overlapping fact value range verification checks if condition fact value ranges in a business rule overlap each other which may lead to inconsistent business rule output. For example the business rules: “Body Mass Index Risk Points of the patient must be equated to 1 IF Patient Body Mass Index of the patient is >18.5 AND <20” and “Body Mass Index Risk Points of the patient must be equated to 2 IF Body Mass Index of the patient is >19 AND <22.” In this case, the ranges of the condition fact Body Mass index are 18.5-20 and 19-22, which consist of partly overlapping values.

Specific partial reduction verification

Specific partial reduction verification checks if two ranges in business rules can be combined. Take for example the following business rules: “Food Intake Risk Points of the patient must be equated to 6 IF Solid Intake of the patient > 5 days AND Age of the patient > 18 AND <= 30 AND Liquid Intake of the patient > 1 days” and “Food Intake Risk Points of the patient must be equated to 6 IF Solid Intake of the patient > 5 days AND Age of the patient > 30 AND <40 AND Liquid Intake of the patient > 1 days.” The conclusion is the same in this example so the two business rules can be combined into one business rule.

Missing business rules verification

Missing business rules verification checks if there are situations in which a particular inference is required, but there is no rule that succeeds in that situation and produces the desired outcome. Missing business rules can be detected when it is possible to enumerate all possible scenarios in which a given decision should be made or a given action should be taken. For example, when the first business rule of the decision ‘C - Calculate Weight Loss Risk Points’ is missing, it is impossible to conclude a total amount of risk points other than the fact values ‘1’ and ‘2’.

C. *Fact level verification*

Regarding the decision fact level, eight capabilities regarding verification were identified. In the verification capabilities above references are made to specific decisions that are part of the case that is utilized to demonstrate the capabilities. From this point on, this is not relevant as fact types and fact values can be and are usually independently managed and applied across different collections of business logic (like business rules or decision tables).

Valueless fact label verification

Valueless fact label verification focuses on the label of the fact in the fact vocabulary. It checks whether each fact type label is expressed without any fact values. For example, the fact type “Body Mass Index >=20” is a binary question, thus only comprising two fact values, “yes” and “no”. In this case the fact value “20” should be removed from the fact label and formulated in two separate rules.

Unused fact verification

Unused fact verification focuses on facts that are present in the fact vocabulary, but not utilized in any BR. Unused facts, especially at large amounts, can decrease efficiency as these unused facts need to be maintained just like the facts that are utilized in BR's. Such errors are often caused by the removal of a BR without checking whether the facts are still utilized in other BR's. For example, the following facts and BR's are expressed: 1) "Body Mass Index", 2) "Body Mass Index Risk Points", and 3) "Standardized Body Mass Index", BR's: "Body Mass Index Risk Points of the patient must be equated to 0 IF Body Mass Index of the patient is >= 20" and "Body Mass Index Risk Points of the patient must be equated to 2 IF Patient Body Mass Index of the patient < 20". In this case three fact types are available, but the given BR set does not utilize the fact type "Standardized Body Mass Index".

Domain violation verification

Domain violation verification focuses on how fact values are expressed, in terms of its format, against how they should be expressed. This is important as it influences if the executability of the BR of which the fact types are part of. For example, consider a BR that utilizes the following fact: "Current Weight". The weight of the patient is usually expressed as an integer, for example "122". However, when the data type of the fact "Current Weight" is designed as a string the weight can only be expressed as: "one hundred and twenty-two kilograms".

One value-collection verification

One value-collection verification focuses on collections and the amount of fact values a fact contains. Less than two fact values in a collection can be caused by 1) not enough fact values are created in the specification process or 2) due to changes to laws and regulations that result in the removal of fact values as part of the collection. For example, the fact type "Malnutrition Risk" normally comprises three fact values "1", "2" and "3". However, when both the first and second fact values are removed, the fact comprises a collection with only one value.

Fact value overlap verification

Exclusivity/overlap verification focuses on the detection of fact values that are not exclusive, thus overlapping each other. This verification capability is only applicable for a fact that comprises a collection of fact values. For example, the fact "Body Mass Index Risk Points" consists of several fact values, from which some are categories of values, which indicate a certain risk level of a patient. In this case, the following fact values are present: "> 20", "18.5..20", "19..21" and "< 22". Both the fact values "18.5..20" and "19..21" are not exclusive as they partly overlap. This could result in a situation where two fact values are valid at the same time, potentially resulting in conflicting conclusions.

Lexical verification

Lexical error verification focuses on the usage of a wrong fact type in BR's. Take for example a wrong synonym or a complete other word than required. Another example within a BR: "Food Intake Risk Points of the patient must be equated to 0 IF Hard Intake of the patient <= 5 days AND Age of the patient <= 18 AND Fluid Intake of the patient <= 1 days." In this case, 'Solid' and 'Liquid' are replaced by 'Hard' and 'Fluid'.

Typographical and mechanical verification

Typographical and mechanical verification focuses on spelling, capitalization and punctuation errors in facts and fact values as part of business rules. An example of a typographical error would be: "Fod Intake Risk Points of the patient". Moreover, an example of a mechanical error would be: "Food Intake Risk Points of the patient."

Documentation verification

Lastly, documentation of each fact should be available in the fact vocabulary. If a fact is added to the fact vocabulary without any documentation, business rule analysts cannot utilize the fact vocabulary as a single point of truth, as double or conflicting facts could exist. For example, when the following two facts exist in the fact vocabulary: 'patient weight' and 'weight'. When no documentation is added for one of these facts the difference between both is hard to distinguish. However, automated verification is only able to check whether documentation is available, and not if it is semantically correct.

D – Generic verification level

Regarding the generic verification level, four capabilities regarding verification were identified.

Grammatical conformance verification

Grammatical conformance verification checks that all individual components in the business rule set are verified on whether they are designed according to the language-related guidelines. Take for example (regarding decision logic-level verification), the business rule "Body Mass Index Risk Points of the patient must be equated to 2 IF Patient Body Mass Index of the patient <= 18.5," which is a business rule to determine "E. Calculate Body Mass Index Risk Points". A syntax requirement of a business rule language could state that the combination of elements for a business rule needs to be consequent, in this case: fact (Body Mass Index) plus operator (=<) plus operand (18.5).

Declarativity verification

Declarativity verification checks whether there is no implicit or explicit order in which decisions, business rules, or facts are executed or evaluated. For example (regarding decision logic-level verification), we take the combination of two business rules: "BR14 - Food Intake Risk Points of the patient must be equated to 2 IF Solid Intake of the patient <= 5 days AND Age of the patient > 18 AND Liquid Intake of the patient <=1 days" and "BR15 - Food Intake Risk Points of the patient must be equated to 4 IF Solid Intake of the patient <= 5 days AND Age of the patient > 18

AND Liquid Intake of the patient > 1 days.” This part of the ruleset may not imply any sequentially as it does not matter if business rule 15 is executed before business rule 14. The same holds for the sequence in which the business rule evaluates the condition facts.

Omission verification

Omission verification checks if required components on all three layers are missing. For example (decision requirements-level verification), decisions in a DRD modelled without a source or input data, or missing operands (i.e., =, >, =<), condition facts, conclusion facts, and fact values. Moreover, in another example (decision logic-layer verification), the operator and fact value of the conclusion fact are missing in the following business rule: “BR16 - Food Intake Risk Points of the patient must be equated to <…> IF Solid Intake of the patient <…> 5 days AND Age of the patient > 18 AND Liquid Intake of the patient > 1 days”.

Atomicity verification

Atomicity verification focuses on the atomic design principle. This means that all components need to be normalized in such a state that no further normalization is possible. Therefore it checks whether all components are expressed and modelled in their atomic state. For example (decision requirements-level verification), it checks whether each decision is expressed in its atomic state, from which no other decisions could be derived, thus the decisions are fully normalized. Take the decision “Calculate Weight and Circumference Loss”, which actually comprises both the Weight and Circumference loss of a patient. As both decisions are calculated using different business rules and facts, the decision should be further normalized into two unique decisions, one comprising only the weight loss and one comprising the circumference loss of a patient.

VI. Conclusions

Business rules, as part of business logic, are increasingly being utilized in organizations as building blocks for (automated) decision making. In this research we aimed to find an answer to the following research question: “*Which verification capabilities are useful to take into account when designing a business rules management solution?*” To accomplish this, we have conducted a three round focus group with five large Dutch governmental institutions. Our rounds of data collection and analysis resulted in a collection of 28 capabilities that, depending on the situation, must be taken into account when designing the verification capability as part of a BRM solution, see Figure 2. The BRM verification capability framework resulted from this study features capabilities for 1) the business decisions level, 2) decision logic level, and 3) the fact level. Additionally, our results presented a fourth category, 4) generic level capabilities with regards to verification.

From a theoretic perspective the verification framework provides a framework for further development and research into the verification capability and possible relationships with other BRM (sub)capabilities. This is important because practice often seems to confuse validation with verification and vice versa, however, both are different, see also (self-reference 2017). Further theoretical maturation is needed as the current Decision Management and Business Rules Management body of knowledge offers few means to structure verification of business decisions and business logic.

From a practical perspective, the verification framework offers practitioners a set of building blocks that could make up the verification in their organizations tooling. Depending on the situation, i.e., the language used to formulate the business decisions and business logic and the maturity of the tooling utilized, the framework offers verification types that can be implemented in different levels (fact-level, business logic level, and business decision level).

VII. Discussion

As is generally true with empirical research, our results are subject to interpretation and are limited to the data and its context that was analyzed. Four threats to the validity of the conclusion are identified. First, the sample of organizations included is solely drawn from governmental institutions. Although we believe that governmental institutions adequately represent organizations that apply BRM, we lack the inclusion of commercial organizations in this study.

Second, regarding the research method and techniques utilized, our study included a sample of ten verification subject-matter experts. Despite the expertise levels of these ten subject-matter experts was substantive, this could be seen as a low number of participants. We argue that, given the maturity of the body of knowledge on verification with regards to business decisions and business logic, the qualitative approach with a lower number of participants was more suitable. This approach offered a more in depth view of the ‘verification’ phenomenon at these organizations and provides the body of knowledge with a basis to continue more ‘broad-focused’ research on the topic.

Third, with regards to the completeness of the results, this study allowed us to identify a large chunk of relevant verification capabilities in the Dutch governmental context. While we believe that the included organizations represent the Dutch governmental agencies fairly, the Dutch government houses many more governmental agencies that could not participate or were not involved in this study due to the scope and other practical matters. Of course we cannot claim that the verification capabilities presented in this paper represent the full spectrum of verification capabilities possible or utilized in practice.

Fourth one additional relevant factor with regards to our results might be the importance of each capability in practice, which we yet have to find an answer to. We stress that future research should focus on finding answers to such knowledge gaps.

VIII. Future research

This study and its results revealed multiple possible and interesting research directions. Undoubtedly the first research direction would be the shift from a narrow and deep focus of qualitative research to a more broad focus including both qualitative and quantitative research methods and data collection & analysis techniques. This allows for the inclusion of more participants, thus larger sample sizes, and therefore improves the generalizability of future results. The latter is important to both the body of knowledge and practice as it ensures validity of verification as a capability and drives adoption in practice. Additionally, future studies should include both governmental and commercial organizations and possibly identify best practices for both types of organizations. It would be interesting to find out whether verification is implemented significantly different in a commercial setting. On the one hand, this is possibly due to the fact that a governmental organization has to 'lead by example' rather than take risks on purpose. On the other hand, concerning the availability and expectations of a commercial organization's services (being very dependent on correctly implemented and executable business decisions and business logic), the possible risks could be much higher.

One dimension that could be explored in future research are the situational factors that drive the verification goals. For example, the type of organization, language utilized or type of services delivered could affect which verification capabilities are implemented. Such factors help organizations to easily identify where to focus on when designing and implementing verification capabilities.

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APPENDIX A: Determine malnutrition risk DRD

Decision Requirements Level

In the decision requirements level, seven decisions are modelled with their corresponding business knowledge, input data and knowledge sources, see Figure A-1.

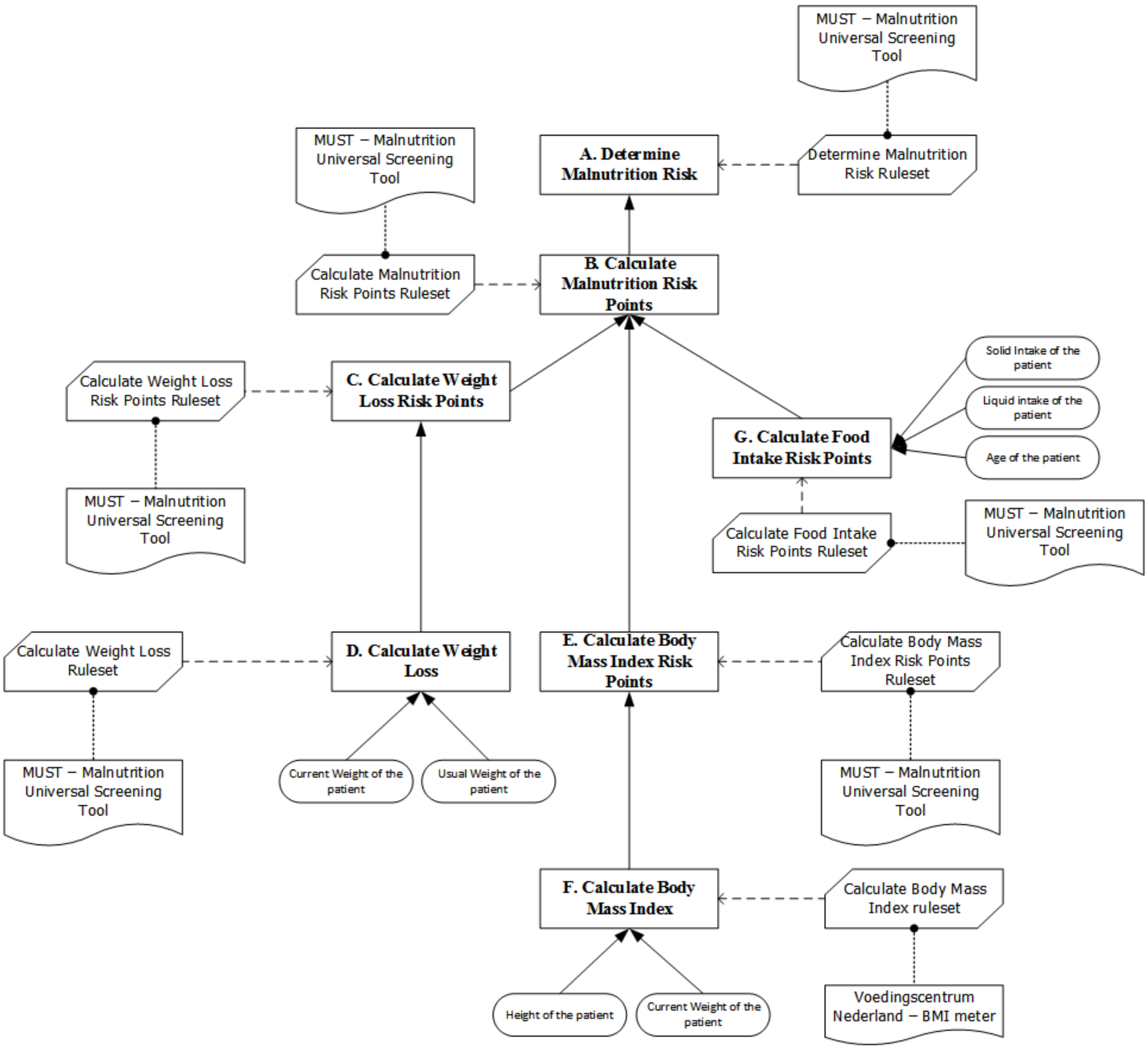

Figure A-1. Decision Requirements Level Diagram – Assess malnutrition risk [32]