A Governance Framework for (Semi) Automated Decision-Making

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***Abstract*—Proper decision-making is one of the most important capabilities of an organization. Therefore, it is important to have a clear understanding and overview of the decisions an organization makes. A means to design and specify decisions is the Decision Model and Notation (DMN) standard published by the Object Management Group in 2015. In this standard, it is possible to specify how a decision should be taken but lacks elements to specify the actors that fulfill different roles in the decision-making process. Additionally, DMN does not take into account the autonomy of machines. In this paper, a framework is proposed and demonstrated that takes into account different roles in the decision-making process, and also includes the extent of the autonomy when machines are involved in the decision-making processes. Based on the model presented, we identify several directions for future research, including more rigorous validation of the proposed model to ensure the model is applicable in most, if not all, contexts.**

Keywords - Decision-Making; DMN; RAPID; Autonomy.

I. INTRODUCTION

In September 2015, the Object Management Group (OMG) released a new standard for modelling decisions and underlying business logic, DMN [1]. In line with the DMN standard, a decision is defined as: "*A conclusion that a business arrives at through business logic and which the business is interested in managing.*" [2]. Furthermore, business logic is defined as: "*a collection of business rules, business decision tables, or executable analytic models to make individual decisions."* [1].

Proper decision-making is one of the most important capabilities of an organization [3]. In the previous decades, decision making was a capability only executed by human actors. However, given the technical developments in computer hard- and software, the possibilities to automate decision-making have increased. Examples of techniques applied during automated decision making are business rules systems, expert systems, and neural networks [4]. To achieve proper decision-making, organizations must design and specify their decisions and decision-making processes. One aspect that influences the specification of the decision and the decision-making process is the level of automated decision-making. Machines can execute decisions only when the decision and the underlying business logic is specified formally [5]. Furthermore, when organizations choose to specify their decisions and decision-making processes, the level of detail is of importance. This is based, amongst others, on the type of decision and the actor that executes the decision. For example, a strategic decision needs to be specified on a different level of detail compared to an operational decision and therefore needs a different type of specification and a different decision-making process.

While DMN is mainly applied to express operational decisions that will be automated, it can also be used for manual decision-making. However, the current DMN standard lacks a formal concept to specify a governance structure for each decision. In this context, a governance structure is defined to express the roles and responsibilities relevant to a decision and the underlying decision-making process. This becomes important when a decision is executed by instantiating a decision-making process that features both human and machine actors. Research on specifying a proper governance structure for decision-making already concluded that assigning clear roles and responsibilities are the most important steps in the design and specification of decisions and result in better coordination and quicker response times [3][6].

Another aspect of designing and specifying decisions and decision-making is the use of machine actors instead of human actors. Assigning machine actors to parts of the decision-making process requires organizations to evaluate the autonomy of the machine. Machine autonomy refers to the system's capability to carry out its own tasks and making decisions [7]. As Parasuraman, Sheridan and Wickens [8] stated in their work, the question now is: "*which system functions should be automated, and to what extent?*" For example, when possible, do we want to let a machine decide whether a person should or shouldn't be admitted to enter a given country, based on the premise that the machine is more accurate compared to a human actor in determining the eligibility of a person.

One reason why it is essential to include proper governance structure when designing and specifying decisions and decision-making processes is the increasingly stricter laws and regulations on digital privacy and data regulation, i.e., the Health Insurance Portability and Accountability Act (title II) and the General Data Protection Regulation [9]. Such laws and regulations can prohibit the use of machine actors in decision-making, and when it allows organizations to include them, specifies exactly what is allowed and what is not allowed. For example, how exactly personal data is processed, and which roles have access to it. Thus, to design compliant decisions and decision-making, an organization must be able to define exactly what actors are responsible for, and, when a machine is made responsible, how autonomously it will operate.

In literature, studies are conducted that resulted in a model to define, for example, the autonomy of a machine in decision-making [8][10][11]. Moreover, studies are conducted that specify the roles that are used to design decision-making processes between stakeholders [3][12]. However, to the knowledge of the authors, no studies exist that combine both.

Therefore, in this paper, a model is proposed that includes the roles and responsibilities aspect, taking into account human-machine interaction, while also including the autonomy level of a machine as part of the human-machine interaction in decision-making. To be able to do so, the following research question is addressed: "*How can a governance structure be designed to explicate the decision-making process?*"

The remainder of this paper is organized as follows. First, a literature overview is presented in section two in which the existing models that define the possible interaction between a human and a machine are explored and compared. This is followed by the construction of the model in section three. Next, in section four, the case to demonstrate and validate the model is described, which is followed by the actual demonstration of the model. Lastly, the conclusions are drawn and we propose directions for future research in section five.

II. Background and Related Work

The DMN standard consists of two levels: the Decision Requirements Level (DRD) and the Decision Logic Level (DLL). The DRD level consists of four concepts that are used to capture essential information with regards to decisions: 1) the decision, 2) business knowledge, which represents the collection of business logic required to execute the decision, 3) input data, and 4) a knowledge source, which enforces how the decision should be taken by influencing the underlying business logic, see Figure 1. The contents of the DLL level are represented by the business knowledge container in the DRD level. In the current version of DMN, two standard languages are suggested for expressing business logic, Friendly Enough Expression Language (FEEL) and Simple Expression Language (S-FEEL) [1]. However, it also allows the use of other, more adopted languages like JavaScript, Groovy, and Python [1]. Still, the language selected to represent the decision logic does not influence the decision requirements level. Analysis of the DMN standard reveals that no formal elements exist to specify roles in the decision-making process. To add to the DMN standard, roles and responsibilities should be taken into account.

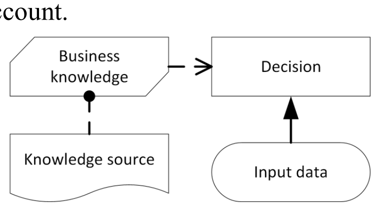

Figure 1. DRD-level elements

A. *Roles and responsibilities in decision-making*

In the current body of knowledge, frameworks that define roles and responsibilities in decision-making processes exist. These studies focus on different perspectives in the decision-making process. For example, there are studies that focus on the influences of decision-making roles, i.e., family/collegial pressure and gender or cultural preferences [13][14]. In addition, there are also studies that focus on specific application areas for decision-making, i.e., transportation, medical, financial and governance [15][16]. For example, in a patient-doctor context where a treatment has to be decided, multiple roles are relevant, i.e., the patient, different medical specialists, the doctor, a nurse, and in some cases family members of the patient [16].

However, as the scope of this paper lies on the creation of a framework which can be applied to define the governance structure of any decision, a more generic set of roles and responsibilities is required.

The work of Rogers and Blenko [3] features a generic model named RAPID, which presents five different roles that are applied during the decision-making process. However, one limitation in the original study is the focus on decisions that are only executed by human actors. To ground our framework construction, a detailed description of the RAPID framework is provided here.

RAPID focuses on assigning a set of specific roles with regards to a decision. This framework is characterized by a simple, yet grounded in practice approach and consists of five different roles and underlying responsibilities that are related to a decision. The first role is ***Recommend***, which is responsible for making a proposal and gathering input for decision-making. This role communicates with the input role to ensure their viewpoints are embedded in the recommendation. The second role is ***Agree***, which is responsible for evaluating a proposal provided by the recommender. This role has veto power over the recommendation. When this role declines a recommendation, a modified proposal has to be made. The third role is ***Input***, which is responsible for providing input (data) to make the decision and are typically consulted on the decision. The opinion of this role is non-binding, but should be taken into account to ensure the decision does not falter during its execution. The fourth role is Decide, which is responsible as the formal decision maker and is accountable for the decision and its results. This role has the most authority compared to the other roles as it is able to resolve the decision-making between the previous roles by making the actual decision. By doing so, this role has the power to commit an organization to action based on decision-making. Lastly, the fifth role stands for Perform, which is responsible for executing the actual decision in the organization after it is decided by the previous role.

Based on RAPID, Taylor [12], in a professional article, adapted the RAPID model but made a distinction between a human and a machine for decision-making processes in which he stresses that the action component can be different between these two. For example, when a decision must be executed in an organization, human actors perform the actual

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decision and also handle possible exceptions. When a machine executes decisions, exceptions are filtered out and send to human actors for further examination. Another significant difference between a human and a machine actor is the explicitness of business rules that a machine must be able to execute, and therefore must be maintained adequately versus the implicit knowledge for the decision-making utilized by human actors in the actual decision-making process.

B. *Autonomy level of stakeholders in human-machine interaction*

Machine autonomy broadly refers to a machine's capability to carry out its own processes and tasks, along with the decision-making needed to do so [7].

With regards to machine autonomy, also referred to as robot autonomy or computer autonomy, many authors added a framework to the body of knowledge that define autonomy levels. Both general and context-specific frameworks for levels of autonomy (LOA) exist, while some define very detailed levels of autonomy, others utilize autonomy as a concept without exactly defining the spectrum of autonomy [17]. In this paper, the focus is on generic LOA frameworks. Regarding generic LOA frameworks, the work of Sheridan and Verplanck [18] and later Parasuraman, Sheridan and Wickers [8] defined ten levels of autonomy for decision-making with automation (i.e., machines/computers), also abbreviated to LOADAS. Their classification ranks from full human decisions and actions (level 1) until full autonomy without interaction with humans (level 10) and takes into account several variants with alternatives. For example, veto voting by human actors and the level of interaction between a machine and human actor. This LOA framework is, to the knowledge of the authors, the most popular work as it is cited numerous times and used in the construction of many other theoretical and practical constructs. However, the ten LOA levels described in the work of Parasuraman, Sheridan and Wickers [8] are too much prone to interpretation, which can be concluded by how the different authors of subsequent LOA frameworks and related work described this framework. For example, the work of Endsley and Kaber [19] describes that the first of ten levels is not fully manual as it is handed over to the machine to execute it. This is in contrast with the interpretation and description by Miller and Parasuraman [20], which describes that a human actor is responsible for everything in the decision-making process, including the execution of the decision. A second example of an interpretation that is not specific enough with regards to this framework is the notion of levels one and two in the work of Beer, Fisk and Rogers [7], which state that these two levels are exactly the same. This would mean that the model contains a redundant level.

Endsley and Kaber [10] defined in their work ten categories of the level of automation along with definitions for the level of autonomy for each category, based on earlier work by Endsley [19]. However, the ten levels, which are all activity focused, are grounded by five levels of autonomy defined by Endsley [19], which are: 1) manual support, 2) decision support, 3) consensual AI, 4) monitored AI, and 5) full automation. This framework's strength is its simplistic approach to autonomy, which is also its drawback. Compared to the framework of Parasuraman, Sheridan and Wickers [8], this framework lacks proper detail with regards to the possibilities a machine nowadays has. For example, based on the five levels of autonomy it is based on, it is unclear how recommendations are provided and how the human actor is informed about executing the actual decision or the result of the decision after execution by a machine.

A third generic framework is the Autonomy Levels For Unmanned Systems (ALFUS) [11]. This framework includes increasingly complex environments in which a machine makes decisions and executes actions. The LOA levels included in ALFUS, range from zero (remote control) to ten (full intelligent autonomy). At the lowest LOA, there is 100% interaction between a human and machine actor, while at the 10^{th} LOA, almost no interaction between a human and machine actor is present. While ALFUS describes in more detail the amount of interaction between human and machine actors, the composition of this interaction is left implicit as it requires the ALFUS generic framework to be instantiated into program specific ALFUS frameworks [11].

The currently available frameworks very accurately describe what levels of autonomy could be taken into account and how the interaction is possible between human and machine actors. However, as pointed out earlier, the existing frameworks lack the exact separation of tasks and responsibilities in complex human-machine interaction environments. Therefore, in the next section, a model is proposed that combines both the roles relevant for decision making with the different levels of autonomy possible for machines in human-machine interaction to overcome this gap.

III. GOVERNANCE FRAMEWORK CONSTRUCTION

For the construction of our framework that fills the gaps identified in the previous section, two perspectives have to be merged: detailed decision-making roles and detailed LOA's. Regarding the decision-making roles, the RAPID framework [3] is adopted due to its generic nature, thus is applicable in all contexts. Then, with regards to autonomy, the LOADAS framework [8] has been adopted due to the fact that it is utilized by many newer autonomy frameworks. However, the low level of detail and different interpretations of this framework and those that preceded LOADAS were already considered a drawback for the design and specification of decisions and decision-making as discussed in the previous section. Therefore, these models have been analyzed to identify Situational Factors (SFs) that need to be taken into account for the construction of the governance framework. By doing so, the governance framework adopts all essential constructs from related work on the subject of autonomy. Analysis of the models resulted in four SF's. The four SFs identified from the literature are: 1) type of actor, 2) alternatives, 3) veto and 4) inform.

The first SF is the type of actor, see for example "*The **computer** informs the human only if asked*" [8]. Simply stated, when decision-making is defined, a choice has to be made whether this should be performed by a human actor only (variant one), a combination of a human and a machine actor (variant two) or solely by a machine (variant three). The second SF concerns the alternatives and the number of alternatives that are provided by a machine actor to the human actor, see for example "*The computer narrows the selection down to a few* ***alternatives***" [8]. This SF comprises three possible variants. The machine actor could provide a full list of possible alternatives to the human actor, offering no filtering or selection at all (variant one). In the second variant, the machine actor could provide a selected set of alternatives for evaluation by a human actor. This means that the machine actor already filtered out one or more alternatives. The amount of alternatives in this variant depends on the context of the decision-making, and therefore is not fixed compared to the first and third variant. Lastly, the machine actor could provide one alternative to the human actor, which means that the machine actor performs the complete selection for the human actor, which only has to decide whether to execute the provided alternative or not (variant three). The third SF is veto, which encompasses the time a human actor is provided by the machine actor to activate a veto over the decision-making by the machine actor, see for example "*Allows the human a restricted time to* ***veto****…*" [8]. The amount of time provided by the machine actor to veto depends on the context of the decision-making, which results in two possible variants, decision-making including a veto possibility regardless of the time specified to do so (variant one) or decision-making without the possibility to veto (variant two). The fourth SF comprises the interaction between the human and machine actor regarding the output of the decision-making, see for example "***Informs*** *the human only if the computer decides to*" [8]. This interaction could entail four possible variants. The first variant requires the machine actor to always inform the human actor with the result of the decision-making by the machine actor. The second variant requires the human actor to file a request for information about the decision-making by the machine actor. The third variant leaves the responsibility to inform the human actor about the decision-making in the hands of the machine actor, which has to decide whether it is necessary. For example, this could be determined by the machine actor based on pre-programmed or self-learned exceptions. The fourth variant is a fully autonomous state regarding decision-making by the machine actor, ignoring the human actor.

Combining the RAPID roles and the four identified SFs a framework is created that supports the detailed design of a governance structure, see Figure 3. In the governance framework, each role involved (five in total) is characterized by four SFs in the decision-making process and should be specified accordingly.

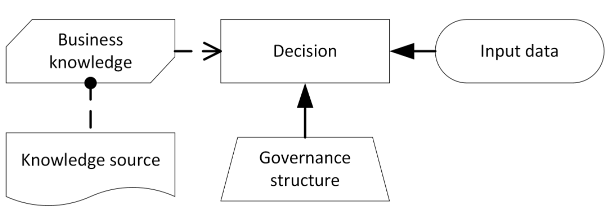

Figure 2. Governance structure to complement DMN 1.1

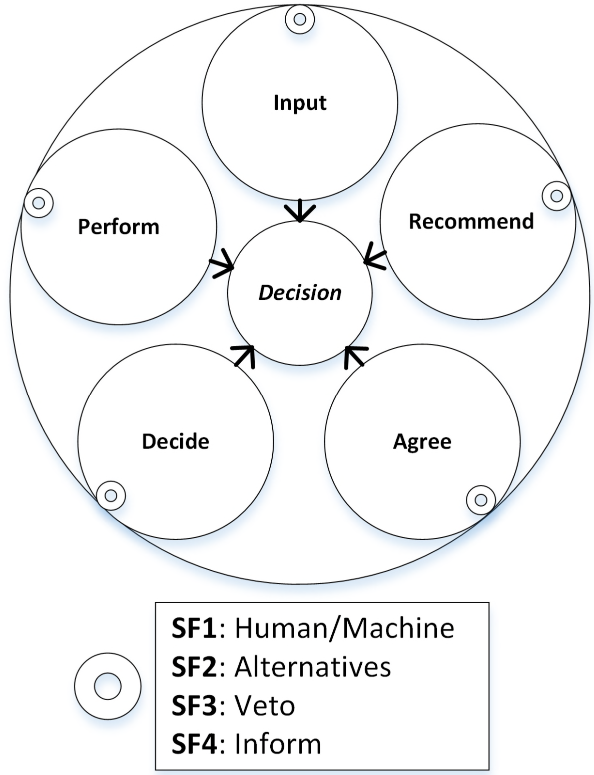

Figure 3. Governance Framework for Decision-making

Based on Figure 3, a governance structure for each decision can be taken into account. Therefore, an additional element to enrich the current DMN standard is proposed, see Figure 2.

IV. CASE DESCRIPTION & APPLICATION

The hypothesized application of the model is demonstrated using a scenario with three variants. The first two variants are based on case study data, while the third variant is based upon a real-world situation, but is not an exact real-life organizational interpretation of it (simulation). First, the scenario is described after which the application of the model is demonstrated using the scenario.

A. Description of scenario

The scenario used to demonstrate the model embodies a governmental institution that is responsible for providing digital services to apply for child benefits, see Figure 4. In this scenario, civilians need to provide information for the governmental institution to be assessed whether the household is eligible to receive child benefits, and when this is the case, the amount of the child benefits and for what period the child benefits can be received. In this scenario, a citizen applies for child benefits.

B. Application of the model

The application of the model is demonstrated using three variants of the scenario. Each of the variants is characterized by a different composition of roles and corresponding SFs.

In the context of this demonstration, three steps are required before the model can be demonstrated: 1) the decision has to be modelled in DMN. In this context, this means that the DRD for this particular decision has to be established (the decision, its input data, its ruleset and relevant sources), see Fig 1. 2) The governance structure element has to be added to the DRD, connected to the appropriate decision, see Figure 2. Lastly, 3). The roles and SFs need to be specified. An example template to do so is presented in Table 1.

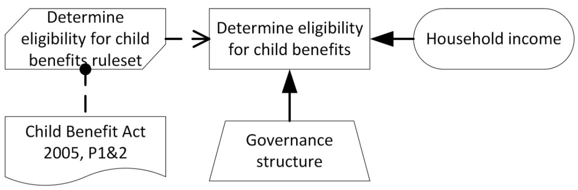

Figure 4. DRD for determining eligibility for child benefits

To demonstrate the usefulness of this template, the governance structure for the scenario in this demonstration is also specified in Table 1. For each variant, the design is changed and depicted in a new table.

Variant 1: Manual human decision-making

TABLE 1. GOVERNANCE STRUCTURE FOR VARIANT ONE

	SF1: Human/ Machine	**SF2: Alter-natives**	**SF3: Veto**	**SF4: Inform**
Input	Human (applicant)	N.A.	N.A.	Always
Recommend	Human (template)	N.A.	N.A.	Never
Agree	Human (manager)	N.A.	N.A.	Never
Decide	Human (employee)	N.A.	N.A.	Always
Perform	Human (employee)	N.A.	N.A.	Always

In the first variant, the applicant fills in a paper template and delivers it to the governmental counter (**Input**). Then, the governmental employee assesses the situation by analyzing the information in the template (**Recommend**) and decides for which benefits the household is eligible (**Decide**) based on a discussion about the case with the manager (**Agree**). In practice, it can be the case that one actor fulfills multiple decision-making roles. When the decision is made, the governmental employee enters the outcome into the governmental system (**Perform**). This allows the applicant to, on a monthly basis, pick up the appointed benefits at the governmental counter. Lastly, the applicant is informed by letter regarding the outcome of the decision and is able to make an appeal within two weeks.

The template used contains information about the different benefits available and thus guides the decision-making for both the input and decide roles.

Variant 2: Machine-supported decision-making

TABLE 2. GOVERNANCE STRUCTURE FOR VARIANT TWO

	SF1: Human/ Machine	**SF2: Alter-natives**	**SF3: Veto**	**SF4: Inform**
Input	Human (applicant)	N.A.	None	Always
Recommend	Machine (system)	One	None	Always
Agree	Human (manager)	N.A.	N.A.	Always
Decide	Human (employee)	N.A.	N.A.	Never
Perform	Machine (system)	N.A.	None	On request

In this variant, the applicant fills in an application template and uploads it to the online governmental portal (**Input**). Then, the government employee receives a notification of the system, which also provides a suggestion (**Recommend**) with regards to the eligibility of the application. The governmental employee decides (**Decide)** based on a discussion about the case with the manager **(Agree**), taking into account the suggestion of the system. Next, the system notifies the applicant and transfers the benefits automatically once a month (**Perform**).

In this variant, the machine generates a suggestion and is provided with the result of the decision as it needs to apply machine-learning to increase and maintain the accuracy of suggestions.

Variant 3: Autonomous decision-making

TABLE 3. GOVERNANCE STRUCTURE FOR VARIANT THREE

	SF1: Human/ Machine	**SF2: Alter-natives**	**SF3: Veto**	**SF4: Inform**
Input	Machine (system)	None	None	Always
Recommend	Machine (system)	None	None	Never
Agree	Human (citizen)	None	30d	Always
Decide	Machine (system)	None	None	On request
Perform	Machine (system)	None	None	Always

In this variant, the citizen's data (all digitally available) is evaluated on a yearly basis by a machine to determine the eligibility for benefits (**Input**). Based on this, the citizen is informed about the pre-filled applications and is able to veto the data in the pre-filled applications or veto the eligibility in general. For this example, the time to veto is one month (**Agree**). When no veto is cast by the citizen, the system decides to process the relevant benefits (**Recommend &**

Decide) and the benefits are automatically transferred once a month (**Perform**).

In the last variant, the citizen is informed about his/her pre-filled and analyzed data on top of the actual confirmation after the benefits are approved after no veto has been cast by the citizen.

The tree variants described provide an overview of a decision-making process, the role distribution between humans and machines, the autonomy of the machine, and SF's that have to be taken into account. The framework can also be applied to guide the creation of a roadmap, as it shows how decision-making processes can be further automated and plan accordingly.

V. Discussion and Conclusion

Since the DMN standard is getting more commonly utilized in practice, more decisions are being modelled explicitly for documentation or automation. However, the current DMN standard does not take into account roles and autonomy regarding decisions and the underlying decision-making process. In this paper, a governance structure framework is being proposed to complement the design and specification of decisions in the DMN standard. To do so, the theoretical constructs of decision-making roles (RAPID) and autonomy levels together with four SFs (LOADAS) are combined. The proposed governance structure framework has been demonstrated using a scenario based on three variants. For each variant, the roles, responsibilities and SF's (human-machine, alternatives, veto and inform) are different. These variants demonstrate that various choices in decision-making processes lead to design considerations that should be taken into account. For example, when machines autonomously decide on what benefits are relevant, what is the best method of informing humans in a specific context, or the appropriate timeframe applicable to veto a decision by a human, in a specific context?

The suggested framework has its limitations. The framework is a suggested solution derived from the existing knowledge base in the area of decision management, decision-making and machine autonomy, and thereby the result of a 'generate design alternative' phase [21]. However, we believe that the proposed framework reached a level of maturity such that it can enter a detailed validation phase. In a planned study, a collection of cases will be used to further validate the framework and to further demonstrate its practical usefulness.

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