Blueprinting Organ Donation: A 'Policy-first' Approach for Developing Agent-based Models

Michael Belfrage[1,2], Christopher Frantz[3], Bertilla Fabris[1], and Fabian Lorig[1,2]

[1] Department of Computer Science and Media Technology, Malmö University, Sweden.
[2] Internet of Things and People Research Center, Malmö University, Sweden.
[3] Department of Computer Science, Norwegian University of Science and Technology.
{michael.belfrage,bertilla.fabris,fabian.lorig}@mau.se,
{christopher.frantz}@ntnu.no

Abstract. Agent-based models have long been argued a useful tool to support policy analysis, variably targeting the assessment of policy design, as well as establishing its performance. Challenging, however, remains appropriate empirical parameterization and validation of such models. This paper contributes to the development of rigorous accounts of policy modelling primarily driven by policy documents in order to develop general conceptual model. Such models can then serve as a basis for early validation by subject matter experts, but more importantly, inform the subsequent inquiry relevant for the parameterization of such models, while at the same time offering the opportunity to detect deviations from regulated practice. Relying on the scenario of organ donation based on the Swedish legislation, we explore the merits of such an approach, and sketch the individual steps from policy documents to conceptual model. Supporting the methodological process, this paper employs the Institutional Grammar 2.0, which offers selected features supporting the proposed modelling approach.

Keywords: Agent-based Social Simulation, ABMS, Formulation, Conceptualization, Policy Model, Policy Analysis

1 Introduction

The field of social simulation seeks to emulate the dynamics of social systems – which are part and parcel of contemporary society – and have become increasingly important for policy-making decisions (1; 2). Social systems are constituted by individuals whose interactions with each other and their environment are governed by both formal and informal institutions (3; 4). Informal institutions, such as norms and shared strategies, tend to emerge endogenously from the micro-level as utility-maximizing agents adapt their behavior according to the environment. In contrast, formal institutions, such as rules, are implemented either through the collective action of society or a subset thereof, or imposed exogenously by policymakers in a top-down fashion through policy change. The aim of these policy changes is to introduce new institutional constraints and rebalance the utilities associated with different behaviors in the agents' choice sets to avoid sub-optimal macro-level outcomes (5; 6). Accordingly, informal institutions can be difficult to discern as they can be unspoken and decentralized, while formal institutions are traceable, and commonly documented, provisions that are centrally mandated (6).

To better understand and more realistically simulate social systems aimed at addressing societal challenges, high-fidelity models are required (7; 8). Fidelity can be understood as the property describing how closely the simulation model matches the target system. However, delineating state-of-the-art social simulation models of sufficiently high fidelity is difficult, as it raises questions about model formalization i.e., methods that guide what factors to include and deciding at what granularity these processes should be modelled. Here granularity, also referred to as resolution, denotes the level of detail at which the model simulates the target system (9). These decisions are contingent upon aspects of the modeller's ontology (7), the target system itself, and the purpose of the model (10). This complexity makes reproducibility of modelling difficult, as formalization could be understood as the execution of systems design (11).

In this paper, the case of organ donation is used to introduce the first step of an approach seeking to increase the methodological stringency, traceability and transparency of model formalization for social systems. Our aim is to formalize a high-fidelity model enabling policy exploration by applying the Institutional Grammar 2.0 (IG) to policy documents (6). This initial step provides insights into the formal institutions of the organ donation system, which serve as a foundation for future endeavors aimed at elucidating the informal institutions through interviews with domain experts.

More specifically, in this paper, we address the following questions:

- How can policy documents be leveraged as a starting point to systematically develop high-fidelity models of social systems?
- How can Institutional Grammar 2.0 aid the methodological stringency, transparency, and traceability in the modelling process?
- To what extent can a 'policy-first' approach serve as a basis for guiding further inquiry into institutions in use?

2 Organ Donation and ABM

Organ donation (OD) systems must operate within strict medical, logistical and legal constraints. Agent-based modelling (ABM) can be used to explore the effects of these constraints on patient health or transplant capacity as evaluators, demonstrating its ability to appraise waiting list matching policy performance (12). Here, *donation* refers to the process of harvesting organs from deceased patients, while *transplant* implies the transferal of donated organs to patients on waiting lists. Models of OD systems are used to investigate, e.g., waiting list structure (13; 12), proposed policy (14) and policy generation (15). Scenarios and Key Performance Indicators (KPI)[4] vary depending on the model purpose. Organ utilization and *observed* over *expected* transplants are the key metrics chosen to inform policy change at the organ procurement organization level (15), as are waiting time, waiting list mortality, and survival rates after one year and long-term (14). Geographic proximity and mortality risk are simulated to assess pre-transplant and post-transplant outcomes (13). The design of regions for organ allocation has been explored using a systems dynamics approach, although this exploration often assumes fixed time-intervals for arrivals of organs to the transplantation facilities (16).

Many existing models of OD are constructed employing an hybrid approach of ABM and Discrete Event Simulations (DES). Since ABM has the ability to supplement DES's lack of entity movement and real-time agent deliberation, the two approaches are combined to model complex systems (17). Most agent-based models of organ donation systems focus on allocation policy optimization within one type of organ transplant. Explored policies include the long term effects of high emergency lung transplants interventions (14), increasing high-risk kidney usage (15), and the practice of multi-listing for kidney transplant patients (18). Teng and Kong (13) develop a model to inform both patient and organizational choices regarding liver allocation policies, considering geographical distance as a determinant of cold ischemia time (delta between donation and transplantation), which is a central predictor of post-transplant success . Logistics are approximated via geodesics (19; 13). Although models can simulate micro-level events (13), most previous research considers transplant capacity and KPI efficiency as optimizers to increase macro-level performance (14; 19; 18; 15; 20).

With existing models captured at brevity here, to our knowledge, the organ donation procedure itself has yet to be explored, particularly from a policy-first perspective. This limitation hinders a thorough investigation into the procedural intricacies of organ donation and its policy implications. One approach to afford a structured analysis of policy is the Institutional Grammar, since it allows for structured analysis of policy text.

3 The Institutional Grammar 2.0

Institutional Grammar, originally devised by Crawford and Ostrom (4), is frequently applied for the purposes of policy analysis, e.g., (21; 22). It has also been applied to explore optimal parameterization of existing institutional arrangements (23), the modelling of normative processes (24), the emergence of institutions in ABMs (25), and how to implement models of social systems (26). IG 2.0 (IG) (6), applied in this work, is a revised form of the original Institutional Grammar that is able to capture institutional structure more comprehensively and at greater granularity useful for the purpose of agent-based modelling. In IG, the institutional statement is the unit of analysis which can generally be classified as regulative or constitutive. The constitutive form could be thought

[4] Key performance indicators essentially reflect the dependent variables in the simulation model.

of as structuring and parameterizing the institutional setting by defining necessary entities (such as actors, objects and actions) and their legal functions within the social system, while the regulative form seeks to capture behavior and associated incentives for specific roles agents exhibit (6).

Institutional statements are represented using an integrated syntax that is able to capture the specific features of both regulative and constitutive statements, and are composed from associated syntactic components, an aspect described in more detail in (6). Whereas regulative statements primarily regulate behavior, constitutive statements define and relate entities in an institutional setting. Given the focal scope, in this work, we focus on the operationalization of regulative statements. Regulative statements are composed of distinctive components, including the actor that is subject to the regulation expressed in the statement, represented by the *Attributes* component [A]. Applied to context of the organ donation system, this mainly refers to medical doctors performing donation procedures. The *Deontic* [D] component is a prescriptive operator moderating whether the activity is permitted (may), obliged (must, shall), or forbidden (must not, may not, shall not). The *Aim* [I] describes a procedure, goal or outcome that is being regulated (donation procedures). The *Context* [C] is special in that it attains the dual function of defining the activation and delimiting the applicability of the statement (e.g., being an organ donor) on the one hand (in the form of *activation conditions* [Cac]), but also moderates or qualifies statements in execution (in the form of *execution constraints* [Cex]). The *Object* [B] component holds entities that are receivers of an activity (the *Direct Object* [Bdir]) - often biological material or organs in the donation context, or variably entities that are indirectly affected by the action regulated in the statement (*Indirect Object* [Bind]). The final *Or else* [O] component indicates vertical nesting and informs about some consequence (e.g., pay-off or sanction) that applies in the case of non-fulfillment of the regulated activity. The Or else component is special in that it, in itself, represents a separate institutional statement.

Delaying further illustration at this stage, the methodological steps in this work specifically rely on the IG's ability to identify conceptual linkages between different activities expressed in institutional language (supporting the establishment of procedural order displayed in Section 4.4), as well as the systematic extraction of behavioral instructions informing the individual actions and associated affordances relevant in the conceptual model (an aspect highlighted in Section 4.5).

4 Formalizing Social Systems

In this section, the individual steps of the modelling approach are described for the organ donation scenario. The initial phase involves policy discovery, which entails locating and identifying all pertinent policy documents within the social system of interest, encompassing materials such as propositions and investigations. This serves to provide the modeller with more contextual knowledge than what is contained in the legal document. Through this process, we identified three primary model components of this process: (1) the organ donation procedure, (2) matching organs with suitable recipients, and (3) managing the logistics involved in transporting organs from the harvesting facility to the transplant hospital. While previous simulation studies have investigated the two latter submodels, none have yet to explore the organ donation process regulated in the legal documents. To address this gap, we apply IG to the Swedish transplantation law[5] to develop a model for exploring policies regarding organ donation from deceased donors.

4.1 Preprocessing

Following previous work applying IG to policy documents we did not parse titles, preambles and headings. Striving to keep the structure of the original text as intact as possible the divisions according to sections and sub-sections was kept unaltered (27). The translation from Swedish to English was conducted using `DeepL.com`, a convolutional neural network that uses parallel text alignment to pair corresponding segments of text in different languages, aiming to achieve accuracy and consistency in translation. While the IG framework is language agnostic[6], this translation was chosen to enable non-Swedish speaking researchers to partake in the coding process. This approach also serves to enhance the reliability and transparency of our work. The translator output was then validated by two researchers.[7]

The IG coding approach was performed iteratively, focusing on establishing an initial level of familiarity with the domain as well as maintaining uniform coding conventions. Coding was performed collaboratively and whenever disagreement arose, discussions were held until consensus was reached. Accordingly, this process both served to familiarize the researchers with the legal boundaries of the organ donation process and furthermore to identify where additional expert information was required. The gaps in information found via this process can form the basis for interview questions with key-stakeholders whose function is constituted in the legal documents, extending the method to the informal institutions of the target system. The translated text was then broken down to a sentence level, and later to institutional statements that capture distinct institutionally-relevant activity (e.g., regulated actions).

After completing the translation, it was determined that out of the 17 paragraphs contained in the Swedish transplantation law (1995:831), denoted as $TL \in \{\S1 : \S17\}$, a subset of five paragraphs fell within the model scope, represented as $MS \in \{\S1, \S3, \S4, \S12, \S13\}$, such that $MS \subseteq TL$. Consequently, the

[5] Swedish Transplantation law 1995:831 and proposition 2021/22:128.

[6] IG has been applied to a wide range of languages, covering a broad range of language families, including Romance, Germanic, Slavic, Baltic, and Chinese.

[7] While we feel confident that this process allowed us to translate Swedish text to English with high accuracy and speed for the purpose of this study, our next step will be to validate the output of this process with legal experts to ensure no legal meaning was lost or altered in translation.

remaining paragraphs $MS^{\complement}$, were excluded because they focus on specific cases where the provisions of the act do not apply (§2), transplantation from living donors (§5:§11), sanctions (§14), and the appeals process (§17).

4.2 Determining the institutional setting

After identifying the paragraphs which fell inside the scope of our model, we structured the institutional statements sequentially (see Fig. A) according to ten different regulated activities. These are characterised based on distinctive, yet potentially overlapping actors, action alternatives and associated consequences. Outcomes associated with a specific decision-making process serve as conditions to activate subsequent actions as well as associated decision-making arenas, or variably lead to the rejection of candidates as donors.[8] Hence, outcomes establishing the progression of a candidate through the organ donation procedure act as a condition for transitioning into the following composed of a different set of roles, associated responsibilities and alternative outcomes.

The donation process begins with a patient receiving life-sustaining treatment. If the prognosis for recovery is deemed poor and the patient meets the criteria to be a potential donor, a conversation known as a turning point discussion may occur between two licensed physicians. This discussion permits the initiation of organ preservation treatment, which can extend beyond the standard 72-hour time frame. Subsequently, the transplantation coordinator is contacted, and an investigation into the patient's consent for organ donation ensues. In the absence of consent, or technically, if the patient declares non-consent, as Sweden adopted an opt-out policy for organ donation in 2022 (28), the organ preservation treatment is terminated. If consent is granted, medical evaluations for donation suitability are conducted. Termination of the process is possible if the medical criteria are not met. Following this, the patient may be declared deceased. If the organ donor has relatives who can be reached, they are briefed before the transplantation procedure begins. Using policy documents addressing relevant subsets of the specific steps, we constructed the process flowchart in Fig. A.

4.3 Statement selection

This basic structure offers the starting point for explicit grouping of institutional statements. Central for the modelling process in this context are less the operational activities, such as organ-preserving treatment, but the key decision point that invite for parameterization based on empirical input – and hence yield

[8] Note that this termination in itself can lead to entering alternative decision-making processes that offer different moderators and outcomes. However, for the purpose of this study – aimed at capturing the organ donation process – such arrangements are out of scope. The scope is naturally determined by the document selection which focuses on the activities working toward the establishment of eligibility for donorship on personal, medical and ethical grounds.

great possible opportunity to evaluate the policy at hand. Operationally, the scaffolded structure provides a basis to systematically filter institutional statements referencing information or processes that are outside the scope of the donorship process, and hence the model. Essential for our context is, thus, the selection of the decision-making processes (labeled as decision-making points in Appendix 2), the labels 2, 5, 6, as well as the interlinked decision 8 & 9.

While behavioral aspects like obligations, permissions, and conventions are primarily addressed in regulative statements, the identification of constitutive statements — typically used to define actors, their associated statuses, and policy aspirations — was carried out using a sorting heuristic based on the taxonomy for constitutive functions [F]. This approach specifically emphasized statements declaring the purpose of the policy itself rather than focusing on central features of relevant model entities, such as defining distinctive roles and associated authority (e.g., authority to determine the administration of organ-preserving treatments), among other aspects (29). While far less extensive, the filtering of regulative statements was performed based on the initial scope and the granularity of the preconceived model, especially with respect to activities or moderators hard to establish without further empirical support for their operational relevance.[9] This selection process resulted in the inclusion of 18 constitutive statements and 43 regulative statements.

4.4 Operationalizing procedural order of decision-making arenas

After ordering the institutional statements according to the empirically derived decision-making arenas based on the specific action they govern, a following step is to make their procedural interlinkages explicit. We draw on a notational schema that maps to a subset of the IG, but operates on a more coarse-grained level, centrally focusing on preconditions and effects associated with individual activities. This was achieved by labeling each institutional statement with an identifier indicating the deontic of the individual action: discretionary action (DA), obligatory action (OA), and lastly prohibited action (PA). After denoting the action, a suffix indicating the action's relation to other actions within the action situation is added: (c) indicating a condition, (pi) for procedural instruction, (co) for condition outcome, (po) for procedural outcome, (Cex) for execution constraint, and (OE) for or-else. Additionally, any institutional statement could be horizontally nested, meaning that it is relationally connected by some logical operator to another institutional statement, such as and (a), or (o) xor (x). However, an action does not only necessarily relate to other actions within the same action situation but also across, something we indicate using arrows followed by the unique identifier of that specific action.

[9] Three regulative statements were excluded: one statement giving doctors discretion to evaluate other sources of information for consent, one ethical statement declaring that any investigation into medical feasibility should not interfere patients' continued care, and one statement specifying that consent cannot be given by patients with cognitive disabilities.

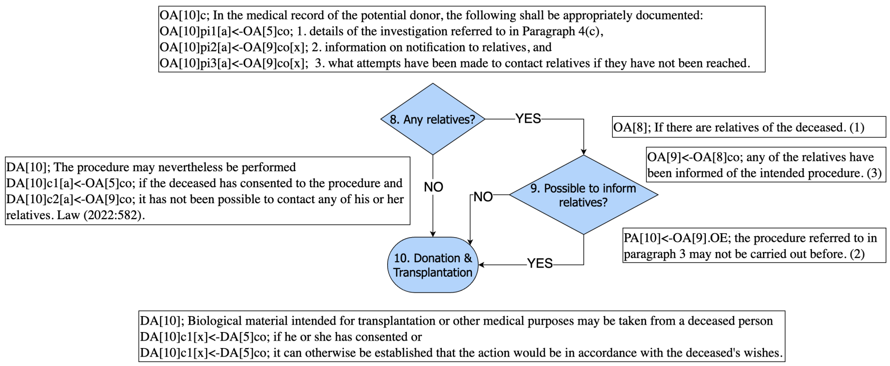

Fig. 1. Decision-making arenas 8, 9 and 10

Fig. 1 depicts this process for the three last decision-making arenas shown in Fig. A, together with an excerpt of atomic institutional statements defining different actions, conditions, outcomes and their interlinkages. The syntax reads as follows, starting from the left of Fig. 1, OA[8] denoting the obligatory action 8 (establishing whether the donor has relatives). This action (OA[8]) can lead to the condition outcome of action situation 8 (OA[8]co), where if the donor has relatives, they need to be informed (OA[9]), this interlinkage is represented by (OA[9]←OA[8]co). The relatives of the donor needs to be informed before the transplantation procedure or else (OA[9].OE), decision arena 10, which is the transplantation procedure, is prohibited (PA[10]), denoted (PA[10]←OA[9].OE).

However, it is also possible that the donor does not have relatives, resulting in a the direct progression to the donation procedure (DA[10]), making it a discretionary action. Additionally, assuming the donor does have relatives, it is also possible that the hospital staff is not able to contact them, this too is a condition outcome of obligatory action 9 (OA[9]co). However, the donation procedure may still be performed, if the deceased has consented to it (DA[10]c1[a]←DA[5]co), and the hospital staff has been unable to contact the donor's relatives c2[a], (DA[10]c2[a]←DA[9]co). Note here that the three remaining institutional statements at the bottom of Figure 1 outline conditions under which the organ donation procedure (DA[10]) is considered a discretionary act. These conditions are described by two conditional statements, both denoted with the same identifier (DA[10]c1[x]←DA[10]), reflecting a simplifying assumption where consent is either given or not.

4.5 Classification

Addressing the challenge of affording a uniform input accessible to downstream processing, the operational coding of institutional statements relies on the introduction of component level annotations that augment the individual components of institutional statements. This serves the purpose of disambiguating concepts when used in language, such as ensuring the uniform labelling of referenced or inferred concepts (e.g., ‘doctor’, ‘administration’) as well as to abstract from grammatical use (e.g., ‘transplant’, ‘transplants’ vs. ‘transplantation’). To this end, we introduce a range of classification labels that afford the mapping of concepts referenced distinctive institutional statements into general concepts relevant in the context of an agent-based model. While the conceptual linkage is established based on the discussion in the previous section 4.3, the focus here is to capture the functional semantics of individual statements, i.e., the atomic actions that require consideration in the modelling process.

In this context, the primary task involves identifying relevant agents, their properties, associated actions, as well as inanimate entities (e.g., organs) and abstract activities (e.g., transplantation). While selected classifications draw on predefined categories that structure the arrangement in the institutional setting (e.g., Context taxonomy – capturing general contextual features such as temporal and spatial aspects, as well as general labels for deontic values – defined in (29)), the central ones are inductively derived based on the application case, capturing relevant features of the policy setting. The central classification schemes, along with the corresponding IG component they align with, as well as indication of origin, are provided in Table 1.

Table 1. Excerpt of labels for *annotations-component* mapping

Component	**Annotation value(s)**	**Origin**
Agent ([actor])	doctor, patient, donor, relatives, administration	Policy, inferred
Deontic ([deontic])	prohibition, obligation, permission	Stringency taxonomy
Actions ([act])	plan, preserve, inform, extract, cannotContact	Policy
Objects ([entity], [actor], [activity])	Entity examples: organs, infrastructure; Actor examples: see above; Activity: organExtraction	Policy
Constraints ([ctx])	time, duration, place	Context Taxonomy

To establish operational linkages between policy statements and their corresponding labels, we employ the notation IG Script (30; 29). This notation serves a dual purpose: capturing behavioral structures, such as the connections between different actors and conditions and their associated regulated activities, and identifying affected actors. Additionally, it supports the annotation of encoded statements using the classification scheme described above, facilitating an unambiguous linkage of concepts crucial to the modelling process. To this end, IG Script draws on symbols representing the individual components (e.g., ‘A‘ for Attributes, ‘I‘ for Aim, ‘Cac‘ for activation condition), the contents of which are scoped using parentheses.[10] Square brackets are used to associate the

[10] Nested statement structures are further scoped based on braces. The use of brackets indicates the annotations of components to establish semantic disambiguation — see

developed classification scheme with the corresponding components, following a ‘class=value‘ structure (e.g., ‘[actor=doctor]‘).

Exemplifying this encoding for a selection of raw statements from the illustrative decision-making arena referred to in Section 4.4, we arrive at the coding of the following statements:

```
If there are relatives of the deceased, the procedure referred to in
     paragraph 3 may not be carried out before any of the relatives have been
      informed of the intended procedure.
```

In the encoded form, the statement reads:

```
Cac{If there F[state=exist](are) E[actor=relatives](relatives) of the
     deceased,}
A[actor=doctor]([responsible doctor]) D[stringency=obligation]([must]) Bdir[
     actor=relatives](any of the relatives) have been I[act=inform](informed)
      of the Bdir[activity=organExtraction](intended procedure).
O{the A[actor=doctor](doctor) D[deontic=prohibition]([may not]) Bdir[
     activity=organExtraction](procedure referred to in paragraph 3 may not
     be carried out) before }
```

This statement hence highlights that if relatives exist, doctors are required to contact those, or otherwise not proceed with the transplantation.

A particular feature of the encoding based on the uniform structure of institutional statements in the IG is the inference of explicit actor information (see the ‘doctor‘ in this example). Where, for instance, the actor is not explicitly stated, it is inferred contextually based on other statements, hence ensuring a complete representation of the institutional setting.[11]

The same process is then performed for all statements relevant to the institutional model, with an exemplar for the last decision-making arena shown in the following.[12]

The final statement shown here governs the extraction process itself and highlights its dependence in the prior consent as a decisive aspect.

```
"Biological material intended for transplantation or other medical purposes
     may be taken from a deceased person
if he or she has consented or
it can otherwise be established that the action would be in accordance with
     the deceased's wishes."
```

(29) for comprehensive introduction of all IG Script features and their correspondence to IG 2.0 features.

[11] The purpose is to establish a uniform structure for the encoding, but also to make the adopted interpretation explicit, and hence accessible to inter-coder discussions.

[12] A further statement relating to this decision arena is shown in Appendix B.

```
A[actor=doctor]([Medical doctor]) D[stringency=permission](may) I[act=
     extract](take) Bdir[entity=organ](biological material) Bdir,p[purpose=
     donation](intended for transplantation [OR] other medical purposes) may
     be taken from a Bind[actor=donor](deceased person)
{Cac[condition1]{if A[actor=donor](deceased person) he or she I[act=consent
     ](has consented)} [OR] it can
 Cac[condition2]{Cex(otherwise) E[entity=consent]([consent]) F[func=
      established]([can] be established) that the P(action would be in
      accordance with the deceased's wishes)}}.
```

Using the software IG Parser that supports the encoding of institutional statements,[13] the encoded information is transformed into a uniform output structure[14] that allows for post-processing, and subsequent aggregation capturing the key interactions relevant in this specific institutional setting. This aspect is further discussed as part of the model construction process.

4.6 Model Construction

Following the identification of statements in Section 4.3, establishing their procedural order and interrelationships in Section 4.4, as well as the development of a conceptual mapping between entities and activities expressed in institutional statements in Section 4.5, at this stage we can construct the central model features, both by capturing the underlying interaction patterns, as well as the order of interactions, as well as associated action alternatives.

For the purpose of the visualization of the key model features, we rely on a sequence-diagram inspired depiction of the full process (see Figure 3), with particular focus on the 'positive case', i.e., foregoing possible premature termination points (e.g., rejecting potential donor as actual donor). This allows us to a) capture all relevant actors in the policy setting, b) express key decision points and actor interactions/-dependencies, and c) reflect temporal constraints explicitly – an aspect central to this specific policy arena. In this example, this is specifically pronounced with respect to the 72 hour limitation on organ preservation, a period that can only be extended in exceptional circumstances.

Note, however, that we rely on three distinct forms of linkages/interactions amongst individual actors referenced in the institutional setting, including 'upon-actions' that do not reflect active interactions, but rather actions performed upon a given actor (who is merely passively involved), denoted using uni-directional dashed lines. An example of such is the administration of organ preservation treatments targeting a potential donor (such as intubation), an aspect that – at this particular stage – no longer relies on cooperation of the donor) (28). The standard uni-directional arrows represents traditional interactions among active parties (i.e., interactions necessitating the active involvement of either side). The third arc-type is the self-loop, indicating an internal process, such as the turning point discussion where two licensed physicians deliberate over the patient's suitability for organ donation.

[13] URL of deployed software: https://newinstitutionalgrammar.org/ig-parser.html

[14] We forego the discussion of the generated tabular output structure at this stage, given the focal emphasis on the general process.

Reviewing the generated model at large, we can hence observe medical personnel as the key actor initiating and coordinating central activities involved in the organ donation process. However, personnel's involvement depends on the presence of a potential donor, an aspect well supported by the underlying policy. Central to the personnel's activities is the turning point discussion, which initiate organ preservation treatment and contact with the transplantation coordinator.[15] The question marks of this and other procedures in the diagram, indicate that necessary temporal information is missing and will have to be obtained in the upcoming modeling steps. The then following procedures are the assessments of donor's consent and the medical conditions for donation. Upon completion of these procedural steps the patient's state changes from *potential donor* to *donor* as indicated by the parallelogram.

The donor's medical status further determines the time frame of the overall process, while leaving in question the allotted time frames for the involved activities, let alone the ability to perform those concurrently. Following the declaration of death highlights key time spans that variably involve the relatives (if any), and possible practical impediments associated with this process (what constitutes an "attempt to contact"?). The final activities involve the donation (extraction of organ) and transplantation (insertion into recipient) surgeries. Similar to the previous activities, relevant questions pertain to potential activities not captured by the policy, as well as the assessment of the practical relevance and conventions associated with each of those steps.

5 Discussion

We applied the IG framework to Swedish transplantation law as a starting point of formalizing a high-fidelity policy model of the organ donation system. This approach holds conceptual promise, as any policy model should start with a high-resolution representation of the status quo before exploring alternative policy interventions. While other model formulation frameworks exist they tend to be flexible to accommodate various applications, our ambition is to develop a model formalization approach. This approach involves methods that guide the modelling process toward a formal construct ready for implementation, providing methodological support for the modeller to lean on. In this initial step, we present a method for establishing a conceptual model based solely on the analysis of policy information, reflecting this 'policy-first' philosophy. While this starting point does have its drawbacks, notably in its potential exclusion of novel and unregulated applications, it also presents a unique opportunity to be more methodologically stringent during the modelling stage of social systems, increasing transparency and reproducibility.

Through the coding of legal documents using the IG, modellers can acquaint themselves with the legal boundaries of the social system, identify key-stakeholders, and pinpoint areas in the conceptual model that lack empirical

[15] This information is derived from proposition 2021/22:128 as indicated by the color.

support. To target this lack of information, questions can be formulated and directed towards domain experts. Additionally, a series of questions targeting informal institutions can be posed to achieve a comprehensive understanding of the broader social system's institutions. Accordingly, this approach also lends itself towards identifying the next steps in the formalization process of an agent-based model, preparing the modeller for a productive and efficient engagement with domain experts. Given the potential cost and time available for interactions with domain experts, such preparatory measures should be crucial for the resulting model's quality (and possibly validity). Thus, allowing the modeller to forgo inquires of fundamental understanding and directly frog-leap to conceptual model validation and iterative improvement of an already existing construct.

Although constrained by brevity, our current paper has relied on excerpts and examples to showcase our modelling approach. As we look ahead, our goal is to further develop this approach by creating a step-by-step process for formalizing agent-based models of social systems. The upcoming steps will focus on improving coding efficiency of the approach.

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A Donation Procedure Flowchart

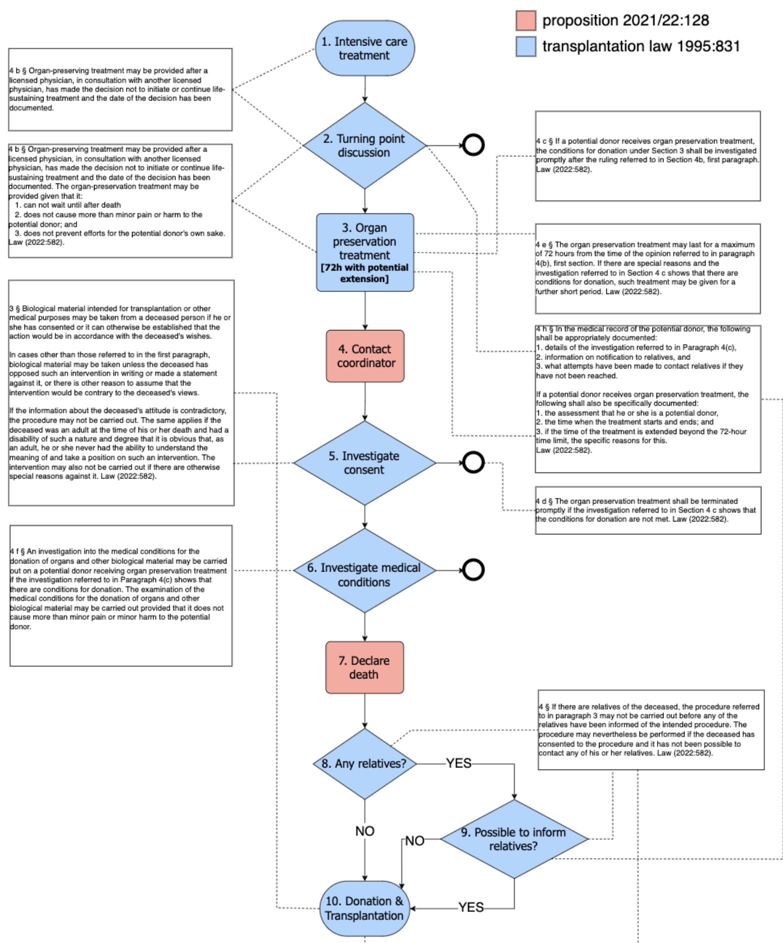

Fig. 2. Reconstructing the donation procedure from policy documents

B Coded Statement from last decision-making arena

A further statement complementing the statements exemplarily shown as part of the main text for the discussed decision-making arena is the following:

```
"The procedure may nevertheless be performed if the deceased has consented
     to the procedure and it has not been possible to contact any of his or
     her relatives." Law (2022:582).
```

In its IG-Script-encoded form, the statement reads:

```
A[actor=doctor]([doctor]) The Bdir[activity=organExtraction](procedure) D(
     may) Cex(nevertheless) I[act=perform](be performed) Cac\{Cac\{ if the A[
     actor=donor](deceased) I[act=consent](has consented) to the Bdir[
     activity=organExtraction](procedure)\} [AND] Cac\{A[actor=administration
     ]([medical administration]) I[act=cannotContact](it has not been
     possible to contact) Bdir,p(any) of his or her Bdir[actor=relatives](
     relatives)\}\}. Law (2022:582).
```

C Donation Procedure Sequence Diagram

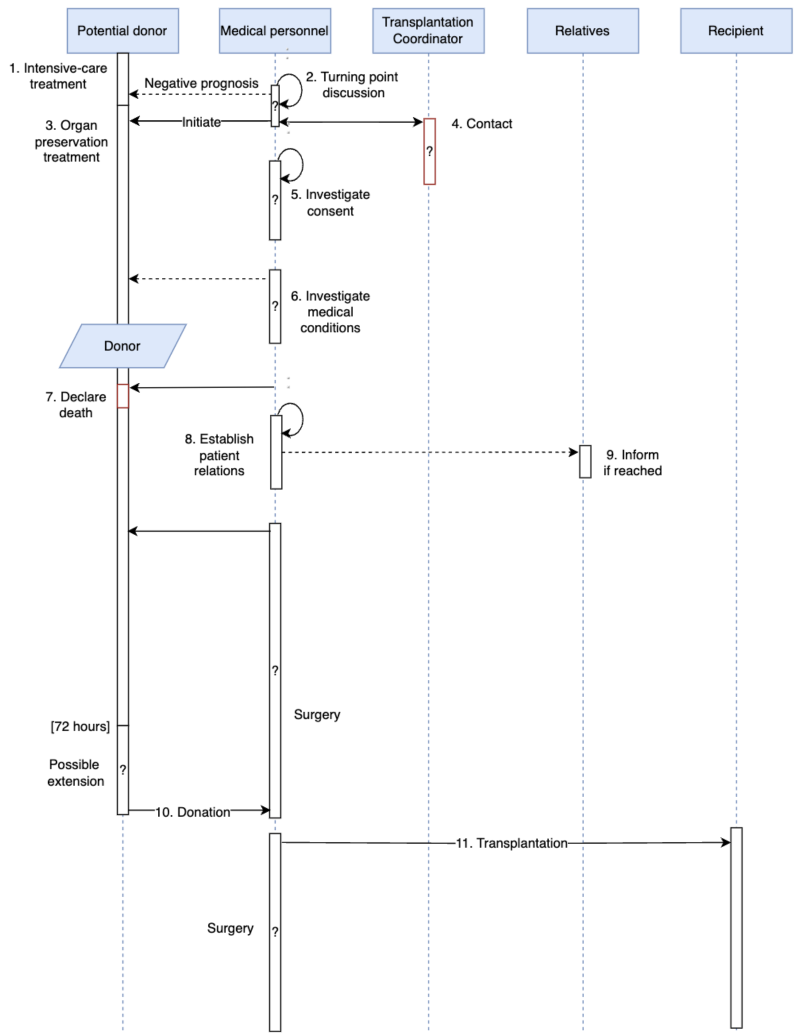

Fig. 3. Sequence inspired diagram