MOSTRO deliverable $n°2$ – WP1

Ontology of organizations and security (preliminary version)

"Designing Organizations: Towards a Model"

ISTC-CNR

1 Organizations as layered structures

The purpose of this deliverable is to draw a preliminary model of an ontology of organizations. One of the main concerns that have to be taken into consideration while drawing the model is security; this is because security issues often arise from social relationships in and between organizations, thus an analysis of the organizational dimension may hopefully shed light on problems related with security. Roughly speaking, the kind of organizations we want to represent are designed complex social entities governed by norms, thus, at an intuitive level, our model is meant to capture entities like the FIAT company, the Italian State or Al Quaeda but, at least for the time being, we don't commit to represent "emergent" entities or self-organized groups, like a group of friends meeting every thursday at Mollie's pub. This latter kind of organizations are in a way more difficult to deal with, because many of the components that we will especially address (like roles, internal structure, rules, objectives) are left implicit most of the times.

Things like roles, norms and objectives are usually considered as the basic constituents of organizations in philosophical, sociological and computer science studies. In this proposal we would like to conjugate the foundational attitude of philosophy and sociology with the attention to applications typical of computer science. Thus, the aim of this work is not that of introducing new entities in the analysis, but that of giving a more coherent account of the basic entities and their relationships.

Before sketching the core of our proposal, a terminological specification is in order. The term "organization" is quite ambiguous and used with many

different meanings in literature. It can indicate a particular entity, a specific instantiation of an organizational structure, thus with particular sub-units as its elements and particular agents playing the roles defined in the structure. But it can also indicate such structure devoid of implementation, namely the network of relations holding among the units of the organization, in which it is not specified who plays a certain role or which are the physical agents who fill a certain unit; in this deliverable we will focus on this second meaning; we will call more precisely this object "organizational design", but we will often use "organization" in the text for the sake of simplicity.

Thus, we will restrict our analysis to what we call the "design layer", e.g. the organization seen from the standpoint of a designer, who is mainly concerned with the structural and *a priori* regulative and teleological aspects. We follow a *top-down* approach to design: starting from a very general idea of the organization under development the designer(s) ends up with complexly interrelated sub-units that have specific tasks.

So, there are three important features of our model:

1. the design of the organization is kept separated from its possible realizations;

2. the design of the organization is represented as a multileveled structure;

3. choices in design are driven by teleological considerations.

Now let's elaborate a bit on this. The idea of having two distinct components of the model, one relative to the design and one relative to the concrete realizations of this design is already present in [1] and [9]; these scholars noticed that it is very useful to distinctly model the level of roles and that of agents. For instance, if one were to model the FIAT organization, one should distinguish between the tasks abstractly assigned to a prospective worker and what in fact an individual worker does in order to accomplish that task.

With respect to design, these approaches represent organizations as composed by interrelated roles. For example, the organization model of OperA [1] consists of a *social structure*, i.e. roles and groups of roles, and an *interaction structure*, which contains the interaction relations between the elements of the social structure. Similarly, in [9, p. 146] we read that "an organization is structured through a set of roles, to which are associated deontic notions (...), that apply to the agents that are the actual holder of such roles, when playing those roles". However, their structures are, in some

sense, *flat*. This does not mean that these authors disregard the fact that roles can be arranged in a hierarchy (this is often the case in their models, e.g. in OperA [1] roles are hierarchically arranged by dependencies or power relations holding among them), but rather that they recognize solely roles as the structural elements of organizations from a design's point of view. In our opinion, even if roles are, so to speak, the "atoms" of organizations, there are also sub-organizations as elements of organizations and taking the latter into consideration gives the opportunity to analyze the organization from different perspectives.

Moreover, an organization, its sub-organizations and its roles can also be connected with external organizations, namely entities over which the organization has not any power or control. In other terms, even though they are part of the design of an organization o, they are not designed by the designer of o and their own design can be (partially) encapsulated, i.e. their structure can be not completely accessible to the design of o. Different kinds of organizations can choose to make public or maintain private their structures.

The increase in complexity is not negative in this case, because it corresponds to the acquisition of a very important feature of the model; namely, the model can represent the structure of an organization at different "levels of granularity" (see [3]). This is compliant with many real world situations, where big organizations can be structured in departments, that can be directly linked one another or with "atomic" roles.

This structural aspect is already present in some works as [2], [4] and [11]. In [4] authors propose an organization ontology for the TOVE enterprise model in which organizations are seen as composite entities whose parts are divisions and subdivisions; on the other hand, the teleological aspects are explained with reference to goals of the organization and subgoals which are assigned directly to roles. Similarly, in Enterprise Ontology (EO) [11] an organization – called organization unit – can be decomposed on smaller organizations (persons can be seen as organization units), so that an organization structure is built by means of management links[1] between organization units. The decomposition of goals – called in EO purposes – was not taken into account in EO. Thus, in a sense, structural and teleological aspects are interpreted in the two just mentioned approaches as two independent dimensions of organizations.

Our claim is that with this assumption an important insight is lost, namely that are exactly teleological considerations that drive the design

[1] "To manage" means "to assign purpose to".

of organizations. Roles and sub-organizations are created with the precise aim of accomplishing certain objectives whose achievement brings about the achievement of the overall objectives of the organization[2]. It's worth noting that in our approach roles are specific organizations, namely unstructured organizations.

This is not the case in TOVE or in EO, where roles and sub-organizations (sub-divisions, organization units) are not explicitly linked.

In our global model these are seen as two different "metaphysical" layers[3].

a. *Design Layer*: it can be viewed as the conceptual and socially constructed, designed level. Here sub-organizations and roles, objectives, norms are to be found.

b. *Ground Layer*: it is the basic layer, in which agents, resources, products that the particular organization has to deal with are to be found.

These two layers are obviously connected in an organization and this should be made explicit in the final model[4]. The intuition is that the model should comprise specific elements especially meant for this connection; these could be decisions, contracts and other things belonging to what we could call the "factual knowledge" of the organization. For instance, a contract can store the information that a certain agent has been hired by the organization to play a certain role, and thus contains information that connects entities belonging to the two different layers.

The importance of these choices for security is twofold: on the one hand, the possibility of analyzing the structure independently of its realizations allows to detect mistakes at the design level: for instance, if there is a

[2]These intuitions are already present in classical works as [5], more recently in [8] and [10].

[3]This distinction has been studied in [7].

[4]Taking inspiration from [6], we could draw a parallel in order to understand what such complex entities are. In that work it was argued that every time that an agent plays a role, a new entity, a qua individual, arises. For instance, when the individual Giorgio Napolitano plays the role President of Italy, a new entity, Napolitano-qua-President arises. The introduction of these entities is in some cases very useful, as when a person participates to a voting event in which (s)he plays two roles and thus votes twice. We could say that we count two votes because we have two qua-individuals. For more details, see [6]. Similarly, for organizations we could say that we have many different persons who can play roles defined in the organizational structure. Each time that an organizational structure is "realized" by assigning players of the roles, we can theorize that a new social entity arises which is given by that specific group of persons qua organized in that structure.

dependency relation between two sub-organizations whose objectives are incompatible. On the other hand, if design and realization are clearly distinct, it is possible to check whether the "concrete players" of roles display the behaviors that were expected from the prospective players by the designer. For instance, it can be the case that an agent playing a certain role doesn't follow the norms that are "encoded" in the role itself (either with malice or for unfitness to the role).

Since our model is still being developed, many important features of organizations are still missing. For example we have not yet introduced the roles' hierarchy which is defined e.g. in OperA by means of dependency relations or in TOVE by means of the relation "being a subordinate of", such that the role r is a subordinate of the role r' if and only if r has strictly less authority than r'. Besides, we did not talk much about goals' decomposition and dependencies, even though we assume them in our model. For example TOVE supplies the decompositions the organization's goals (*organization-goal*). Organization-goals can be decomposed into an AND/OR subgoal trees.

Obviously this vision is quite static as it is and this is of course a limitation of the model, but we already have an idea on how to implement change in a further development: the static structure should be complemented with a set of so called "meta-norms", norms that establish which changes can be introduced in the structure and how.

More precisely, it is not sufficient to provide at the design phase a representation of how the organization must be structured. This is because organizations need to adapt to a changing environment, and thus to be flexible and able to evolve. In order for this capability to be established from the beginning, the designer must provides some norms that regulate changes inside the organizations. As an instance, these norms can establish that only the player of a certain role inside the organization can decide to create a new sub-organization or a new role when needed. These norms are thus a necessary component for the design phase and will very likely be the next step of advancement of the present model.

2 A (partial) formal model

In this section we will formally introduce our model of (the design of) organizations. More specifically, we will clarify the basic notions the model is based on, namely the *objectives*, the *structure*, and the *institutional setting* of the organization under development, and the mechanism enabling

for representing design at different levels of detail. We think that this last aspect is fundamental to ensure the correct behavior (in particular from the standpoint of *security*) of an organization through the design process: after each design step it is possible to verify whether the chosen 'implementation' satisfies the initial requirements.

The proposed model must not be intended as a complete description of (the design of) organizations. It can be seen as an extendable and general *kernel* that tries to make explicit the design mechanism and to clarify how this contributes to the specification of organizations. In this perspective it is more a *meta*-model of (the design of) organizations. To have a more complete and applicable model we need, on one side, to cover additional important aspects of organizations (like, for example, *resources*), and, on the other side, to analyze at a deeper level of detail all the 'ingredients' of our model as, for example, specific institutional relations between organizations (e.g. dependence, delegation, trust, etc.), specific links between objectives (decomposition, generality, etc.), etc.

These possible extensions/deepenings can benefit from the great amount of work done in philosophy, logic, computer science, cognitive science, sociology, linguistic, etc. On the contrary, the development of procedures to understand the behavior of structurally complex organizations is a much less mature field. These procedures seem necessary to check how a specific structural implementation chosen for an organization matches the given requirements for it at a coarser or finer level of detail. Therefore, with respect to this aspect, we expect really hard work.

We start by giving the general definition of (the design of) organizations, and then we provide additional explanations to the general notions considered in this definition.

Definition 1 (Organization). *An organization o is a 4-tuple*

$$o = \langle \mathcal{OBJ}, \mathcal{STR}, \mathcal{REL}, \mathcal{EXT} \rangle, \textit{ where}$$

- $\mathcal{OBJ}$ *is a set of objectives, the* objectives *of o;*
- $\mathcal{STR}$ *is a set of organizations, the* (direct internal) sub organizations *of o;*
- $\mathcal{REL}$ *is a set of* institutional relationships *in which o is directly involved, i.e. the* institutional setting *of o;*
- $\mathcal{EXT}$ *is a set of organizations that have institutional relations with, but are not controlled by, o, i.e. the* external organizations *of o.*

We will often use a more functional notation, i.e. given an organization $o = \langle \mathcal{OBJ}, \mathcal{STR}, \mathcal{REL}, \mathcal{EXT} \rangle$, we will say that:

- $\mathsf{obj}(o) = \mathcal{OBJ}$; (the objectives of o)
- $\mathsf{dsb_i}(o) = \mathcal{STR}$; (the (direct internal) sub organizations of o)
- $\mathsf{isett}(o) = \mathcal{REL}$; (the institutional setting of o)
- $\mathsf{ex}(o) = \mathcal{EXT}$. (the external organizations of o)

2.1 Internal and external sub organizations

Our model is based on the idea that an organization can be specified at different levels of detail. Given an organization o, the next design step is represented by the structure of o, i.e. how o is 'decomposed' in institutionally linked sub organizations. A clear definition of organizations' *structure* is provided in section 2.3. For the moment, it is enough to observe that the institutional relationships among the sub organizations of o are only *indirectly* represented in o, i.e. they are encoded in the institutional relationships included in the specifications of the direct internal sub organizations of o (see definition 10). The same happens for the (direct) external sub organizations involved in the structure of o, i.e. they are not explicitly represented in o, but they can be collected via its direct internal sub organizations looking at their external organizations.

Definition 2 (Direct external sub organizations). *The* direct external sub organizations *of an organization o is the union of the external organizations of the internal sub organizations of o*:

$$\mathsf{dsb_e}(o) = \bigcup_{x \in \mathsf{dsb_i}(o)} \mathsf{ex}(x).$$

Given an organization o is then possible to define the set of all its sub organizations that are used in the *direct implementation* of o, i.e. in the next step of the design refinement.

Definition 3 (Direct sub organizations). *The set of the* direct *sub-organizations of an organization o is the union of the sets of the* internal *and* external *sub organizations of o*:

$$\mathsf{dsb}(o) = \mathsf{dsb_i}(o) \cup \mathsf{dsb_e}(o).$$

The internal direct sub organization relation (as well as the external one) can be generalized taking into account finite chains of internal direct sub organizations.

Definition 4 (Internal sub organizations). *The* internal sub organizations *of an organization o are the organizations that are linked by a finite chain of direct internal sub organization relations*:

$$\mathsf{sb_i}(o) = \{x | \exists o_1, \ldots, o_n (o_1 \in \mathsf{dsb_i}(o) \wedge \cdots \wedge o_n \in \mathsf{dsb_i}(o_{n-1}) \wedge x \in \mathsf{dsb_i}(o_n))\}$$

Right now we have analyzed how the internal and external (direct and indirect) sub organizations of a given one can be identified. But, what is the reason, the rationale, underlaying the distinction between internal and external sub organizations?

The main motivation is relative to the possibility of precisely modeling the institutional setting of organizations. The designer could understand the organization o under development as necessarily engaged in a institutional network of organizations, i.e. the institutional setting/environment, in which o will 'live'. Some of the organizations linked to o are 'under the control' of the designer (the *internal*, with respect to o, organizations), i.e. s/he can more or less directly influence their design, other organizations are 'out of the control' of the designer (the *external*, with respect to o, organizations).[6] Internal organizations exist because of the design of o, while, in general, external organizations exist independently from o, but o depends on them to achieve some goals, to be controlled, etc.[7] The difference can be explained by establishing a parallel with the design of physical artifacts: internal organizations correspond to functional parts of an artifact, *explicitly designed* for it, while external organizations correspond to functional parts that are *reused* from the design of other artifacts, i.e. they are 'available in the market.

The notion of *top organization*, i.e. an organization that is not a sub organization, and the one of *role*, i.e. an organization without sub organizations, can be easily defined on the basis of the $\mathsf{dsb_i}$ relation (or, equivalently, on the basis of $\mathsf{sb_i}$).

[5]Note that here we assume that $o \notin \mathsf{sb}(o)$, i.e. o cannot be included as part of the design of o, even though, as we will see in section 2.3, some institutional relationships from organizations at a given level of design to organizations at a coarser level can be useful and admitted.

[6]Note that external organizations too are designed.

[7]Probably it is also possible to have a sort of mutual dependence. We don't have analyzed this aspect yet.

Definition 5 (Top organization). *An organization o is a* top *organization,* $\mathsf{org}_{\mathsf{T}}(o)$*, if and only if it does not exist any organization o' such that* $o \in \mathsf{dsb}_{\mathsf{i}}(o')$*.*

Definition 6 (Role). *An organization o is a* role*,* $\mathsf{role}(o)$*, if and only if it is unstructured, i.e.* $\mathsf{dsb}_{\mathsf{i}}(o) = \emptyset$*.*

In other approaches, roles are considered as the basic building blocks of complex organizations. These views seem to imply a sort of *bottom-up* approach. In our model, roles are just the result of a step by step process of design. Our view on organizations design is more *top-down* oriented. Clearly, also in our approach roles (and in general organizations) can be reused[8] in other organizations, but the starting point is always the top organization we want to design.[9]

Most approaches reduce complex organizations to compositions or sets of roles that can be linked together. As we will see in the following, in our approach we want to check whether the *implementation* of a complex organizations o (i.e. the way o is structured in its direct sub organizations) is correct, i.e. we want to compare the objectives, the structure, and the institutional setting of o with the composition (dependent on the structure of o) of the objectives, structures, and institutional settings of the direct sub organizations of o. This check is possible for each design step until roles are reached. In this way, the top organization is not completely reducible to the composition of its sub organizations (and, in particular, its roles) and the distinction between the composition of the sub organizations and the original top organization makes possible to consider incorrect or 'dangerous' (with respect to a specific aspect) implementations. In particular, this aspect is very important if security needs to be taken into account.

2.2 Levels of design

As stated before, the idea of layering/stratifying the whole design is central in our approach. On the basis of the sub organization relations introduced in the previous section, we can define in a precise way when two organizations are at the same level of design, and we can also introduce a (partial) order

[8] In the sense that they can be 'imported' as external organizations.

[9] In OperA a role is identified by a set of objectives. In the proposed approach, in addition to objectives, the institutional setting is considered. Further extensions, like the introduction of the available resources of an organization, can be easily taken into account in the model for establishing the identity of organizations (section 2.3 gives more details on this point).

between the levels. Note that the notion of level we are interested in is dependent on a specific top organization, i.e. it makes sense to compare only sub organizations of the same top organization. This is motivated by the fact that reused organizations can appear at different levels of design in different top organizations.

Definition 7 (Same Level of design). *Two organizations o and o' are at the same level of design with respect to the top organization o_T,* $\mathsf{IdL}(o, o', o_T)$*, if and only if there are two chains of internal sub organizations of the same length, respectively from o_T to o and from o_T to o'*

$$\begin{aligned}\mathsf{IdL}(o, o', o_T) \triangleq \mathsf{org_T}(o_T) \wedge \exists o_1, \ldots, o_n, o'_1, \ldots, o'_T(\\ o_1 \in \mathsf{dsb_i}(o_T) \wedge \cdots \wedge o_n \in \mathsf{dsb_i}(o_{n-1}) \wedge o \in \mathsf{dsb}(o_n) \wedge \\ o'_1 \in \mathsf{dsb_i}(o_T) \wedge \cdots \wedge o'_n \in \mathsf{dsb_i}(o'_{n-1}) \wedge o' \in \mathsf{dsb}(o'_n))\end{aligned}$$

With respect to a top organization o_T, the set of all the organizations at the same level of a given sub organization o, is defined as:

$$\mathsf{idl}(o, o_T) = \{x \mid \mathsf{IdL}(x, o, o_T)\}$$

Note that the definition 7 does not consider the structure of *external* sub organizations of the top organization o_T, i.e. the internal sub organizations of external organizations are never considered in the set $\mathsf{idl}(o, o_T)$. This is represented by the fact that the two chains considered in the definition of IdL are chains of internal direct sub organizations. Yet external organizations can belong to the set IdL, and this is represented by the last step of the chain that allows for both external and internal organizations.

This difference better characterizes the distinction between internal and external organizations. From the point of view of o, its external organizations and sub organizations are 'seen' as unstructured, i.e. their structure is opaque from o.

On the basis of the notions defined in definition 7, a partial order can be introduced.

Definition 8 (Lower Level of design). *With respect to the top organization o_T, the organization o is at a* lower level of design *than o',* $\mathsf{LwL}(o, o', o_T)$*, if and only if o is a sub organization of an organization at the same level of o':*

$$\mathsf{LwL}(o, o', o_T) \triangleq \exists o_1, o_2(\mathsf{IdL}(o_1, o', o_T) \wedge o_2 \in \mathsf{sb_i}(o_1) \wedge o \in \mathsf{dsb}(o_2)).$$

In the following we will assume that each organization that is not a top organization has a unique top organization, in the sense that it is an internal sub organization of only one top organization. More formally:

$$\neg \mathsf{org_T}(o) \rightarrow \exists! o'(\mathsf{org_T}(o') \wedge o \in \mathsf{sb_i}(o'))$$

Note that, given this assumption, it is possible to reconstruct the external organizations of an organization o by looking at the institutional relationships of o, i.e. $\mathsf{ex}(o)$ could be defined as the set of all organizations involved in $\mathsf{isett}(o)$ minus:

- (if o is a top organization) $\{o\}$;
- (if o is not a top organization) the set of all the organizations at the same level of o (with respect to the top organization of o) that are internal to that top organization.

Following this definition, all the organizations that are at the same level of o and are not internal to the top organization of o are automatically considered as external. From a conceptual point of view this is not a problem, but from a practical one, the model proposed at the beginning that explicitly represents external organizations allows for a direct check of the consistency of the organizations involved in the institutional relationships of the internal sub organizations of o and the organizations that are direct (internal or external) sub organizations of o. For this reason we prefer the original formulation.

2.3 Institutional relationships and structure

As already explained, the (next design step) implementation of one organization o is specified by the institutional relationships among the direct sub organizations of o. By iterating the design process step-by-step until reaching the roles of o we can obtain the 'final implementation' of o. In order to understand the implementation process it is important to clarify what we intend by *institutional relationship*.

Let us consider a (finite) vocabulary of institutional relations: $\mathcal{V}_{\mathcal{R}}$[10]. We already provided some example of these relations: *dependence*, *trust*, *delegation*, etc. In general, in addition to organizations, the arguments of these relations can be objectives, states of affairs, actions, etc. For example, o_1

[10]We exclude from $\mathcal{V}_{\mathcal{R}}$ the *direc sub organization* relation that is encoded directly in the 4-tuple by the set $\mathcal{STR}$. The same for the indirect sub organization relation.

could delegate just a specific objective to o_2, or o_1 could trust o_2 for performing specific (kind of) actions, etc. In order to illustrate our framework in a simply way, in $\mathcal{V}_{\mathcal{R}}$ we consider institutional relations with only organizations as arguments. This does not prevent us to extend the framework with additional kinds of parameters, but this requires further investigation.

Definition 9 (Institutional relationship). *A institutional relationship is an atomic formula $Rel(o_1, \ldots, o_n)$ such that:*

- *$Rel \in \mathcal{V}_{\mathcal{R}}$ is an n-ary predicate;*
- *$o_1, \ldots, o_n$ are organizations such that:*

$$(a.)\ \exists o_T(\mathsf{org_T}(o_T) \wedge o_1 \in \mathsf{sb}(o_T) \wedge \{o_1, \ldots, o_n\} \subseteq \mathsf{idl}(o_1, o_T)) \vee$$
$$(b.)\ \exists o_i \in \{o_1, \ldots, o_n\}(\mathsf{org_T}(o_i) \wedge \{o_1, \ldots, o_n\} \subseteq (\{o_i\} \cup \mathsf{ex}(o_i)))$$

In definition 9, the condition $(a.)$ requires that all organizations involved in one institutional relationship are sub organizations at the same level of design. Therefore we need a special condition for institutional relationships of top organizations. The condition $(b.)$ does the work by requiring that, in this case, all the arguments of a institutional relationship are either the top organization or its external organizations.

The institutional setting of an organization o describes how o is related to all the (internal and external) organizations introduced at the same level of design, i.e., it completely describes the institutional network in which o lives in the context of the design of the top organization of o[11].

Let us suppose that $o \in \mathsf{sb_i}(o')$. In our framework it is possible to check the *compatibility* between the institutional relationships of o and the ones of o'. For example, if o' is obliged to acquire data only from the external organization o_e, and o is the only sub organization of o' in charge of data acquisition, then, in $\mathsf{isett}(o)$, we need to find the dependence between o and o_e, otherwise the implementation does not satisfy the institutional constraints expressed at the higher level of design. Similarly, let us suppose that $\{o_1, o_2\} = \mathsf{dsb_i}(o)$, $\{o_{11}, o_{12}\} = \mathsf{dsb_i}(o_1)$, $\{o_{21}, o_{22}\} = \mathsf{dsb_i}(o_2)$, and there is a institutional relationship $Rel(o_1, o_2)$. Now, if there are no institutional relationships linking at least one organization in $\{o_{11}, o_{12}\}$ and one organization in $\{o_{21}, o_{22}\}$, then an error can be detected. On the other side, at a

[11] Note that if o is reused as an external organization in the design of the top organization o', then $\mathsf{isett}(o)$ does not give any information about the institutional setting of o in the design of o'. We can extend the notion of institutional setting to any reused organization o, but, in this case, we need to specify the top organization that is reusing o.

lower design level, it is not necessary to find exactly the *Rel* relation: more specific relations can be considered, or *Rel* can be decomposed in a complex network of relations. Relying on this additional information about the links between different relations it is possible to perform a very powerful check on how the institutional setting is maintained across design levels.

Alternatively, it is possible to think that some institutional relationships are semi-automatically *down-propagated* to (some) sub organizations. Distinguishing different kinds of institutional relationships, it is then possible to associate to these kinds different down-propagation mechanisms. This is a very interesting topic that can help a lot the designer in order not to introduce design mistakes, but we will not address this topic here.

The structure of an organization o is represented by the union of the institutional settings of its direct internal sub organizations, i.e. it is described as the institutional relationships that take into account organizations introduced at one step deeper in the design detail.

Definition 10 (Direct structure of an organization). *The direct structure of an organization o is the union of the the institutional settings of the internal sub organizations of o:*

- $\mathsf{str}(o) = \bigcup_{x \in \mathsf{dsb_i}(o)} \mathsf{isett}(x)$.

Note that the institutional relationships in the direct structure of o can also involve organizations in $\mathsf{dsb_e}(o)$ but they cannot involve *only* organizations in $\mathsf{dsb_e}(o)$, i.e., at least one argument in the relations needs to be an organization in $\mathsf{dsb_i}(o)$. It is possible also to extend the notion of direct structure of o by including also the institutional relationships of the direct external sub organizations of o, i.e. $\mathsf{str}(o) = \bigcup_{x \in \mathsf{dsb}(o)} \mathsf{isett}(x)$. We prefer here to consider the more restrictive definition because this is more in line with the previous observation that the external organizations are more 'opaque', but, in any case, nothing prevents us to have both definitions if they are useful in practical cases.

As in the case of the sub organization relation, the (indirect) structure of an organization can be defined by finite chains of nested direct structures.

2.4 Objectives

From the design (designer) perspective, objectives are very important to specify why one organization is created, i.e. they characterize the teleological dimension of that organization. They represent the intended (by the

designer) objectives for the organization 'under development'. This is quite similar to the process of design of a physical artifact where the designer specifies the functionalities the artifact is supposed to have.

The structure of the organization allows the designer for choosing a specific way of 'implementing' these objectives. The designer can establish how the objectives declared for the whole organization can be 'decomposed' into simpler objectives attributed to simpler organizations in the structure and the way these organizations are linked by means of institutional relations. In general this can be a much more complex decomposition than the *and/or* one considered in the majority of existing approaches.

As in the case of the structure, the decoupling of the objectives of the whole organization o and the objectives of the institutionally structured sub organizations of o constitutes the basis for making possible the checking of the 'correctness' of the implementation.[12] Having a function that composes the objectives of the structured sub organizations of o, is then possible to check whether these composed objectives coincide with the objectives directly assigned to o. This function is quite complex to build and here we do not consider this aspect, but our framework lays the basis for the objectives' checking at the design level.

Another important aspect that we do not address in this deliverable is the ontological status of objectives, i.e. we do not analyze which kind of entities objectives are. They are just considered here as labels. Clearly, in order to build the composition function, relations between these objectives are necessary (e.g. refinement, compound, etc.). We leave this aspect for future work.

2.5 Abstracting from organizations

The previous definition of an organization o includes the direct sub organizations of o, therefore the structure of o contributes to the characterization of o: an organization o' with the same objectives and the same institutional setting of o but with different structure is necessarily different from o.

It can be useful to have a more general notion of organization that abstracts from the specific implementation. To illustrate the general idea, let us go back to the parallel with artifacts' design. In the case of artifacts, it is quite common to say that the same functionality can be achieved in different ways. For example, if the required functionality is "writing on paper",

[12] The external organizations at the same level of o, i.e. $\mathsf{ex}(o)$ can also be considered to check some constraints, i.e. for example if the links o has with these external organizations are not in contradiction with the objectives of o.

then we can rely on ballpoint pens or fountain pens. The design of ballpoint pens is different from the design of fountain pens but both of them satisfy the requirement. In this case we can say that the functionality of "writing on paper" is relative to a more general kind of artifact, the kind *pen*, and *ballpoint pens* and *fountain pens* are just two specific implementations of pen, and therefore they are two specific kinds of pens. To understand how the design of *ballpoint pen* (and *fountain pen*) is linked to the design of *pen* is a quite delicate problem that we don't want to address here. We want just to observe that there are at least two possible ways to interpret the previous example: (*i*) the functionality of *ballpoint pen* is more specific that the one of *pen* and, because of that, the structure of *ballpoint pen* is different form (and not necessarily a specification of) the structure of *pen*; (*ii*) the functionality is the same but the structure of *ballpoint pen* is different from the structure of *pen*.

Our approach allows both kind of abstractions. The second one is quite simple:

$$|o| = \{x \,|\, \mathsf{obj}(x) = \mathsf{obj}(o)\}$$

while the first one requires a *refinement* relation between objectives. Clearly, less open abstractions can be considered; for example:

$$|o| = \{x \,|\, \mathsf{obj}(x) = \mathsf{obj}(o) \wedge \mathsf{isett}(x) = \mathsf{isett}(o) \wedge \mathsf{ex}(x) = \mathsf{ex}(o)\}.$$

2.6 Realizations of organizations

In the previous section we have seen that an organization is characterized by its specific implementation. But, right now, we have not considered how an organization can be and act in the physical world. Roles are still organizations, i.e. they are not specific agents, but they offer the natural interface with agents.

Similarly to other approaches, we consider here a temporary *plays* relation between agents and roles. When all the roles of a top organization are played by agents then we will say that the top organization is *realized*, and the set of all players is called the *realization* of that top organization. If we dispose of a model of agents that realizes an organization, the same kind of check of the correctness of an implementation can also be considered for the correctness of a realization.

The fact that at different times the realization of an organization can change is largely accepted. More problematic is the possibility that, at the same time, the same organization has different realizations. Note that in

the case of artifacts this is not a problematic situation: different pens of exactly the same model can simultaneously exist (they are spatially distinct). In some cases, for organizations, the uniqueness of the realization seems to be assumed. For example when we think about the design of FIAT, we are inclined to exclude that different realizations of FIAT exist at the same time (while we accept quite easily that the realizations of FIAT at different times can be different). We can interpret this reluctance just saying that the structure (plus the objectives and the institutional setting) of FIAT is unique to FIAT, but this is a quite strong assumption. Another possible interpretation consists in thinking at FIAT as an extension of our notion of organization. For example, in addition to objectives, structure, and institutional setting, the legal registration or the legal representative of FIAT can be considered. In this sense FIAT is in the middle between the design level (our organizations) and the realization level, because it is not necessary that all its roles are realized, only some specific ones, or maybe a sort of 'setting instantiation' relation is necessary. We think this is a very important point to be clarified.

Linked to this point there is the possibility for organizations to be players. Do we assume that only realized organizations can be players? In this case, what kind of entity is a realized organization? Why and with respect to what are they different from organizations or realizations? What about the external organizations? Are these really organizations in our sense, or are we thinking about realized organizations or realizations? The situation is still more complicated if we try to establish a clear difference between external organizations and organizations that plays a role at the same level of design. What is the difference?

Despite all the open questions and the generality of the model, we think that it clarifies the basic 'ingredients' of the design of an organization. In the following section we will illustrate the model taking into account a case study coming from the PAT.

3 Case study

Our model is also driven by a case study that comes out from the collaboration with a company, Business Process Engineering[13] (BPE, in the following) that delivers application to manage business and administrative processes. The application that BPE proposes has as its main goal to give to the legal office of the province of Trento (PAT - *Provincia Autonoma di Trento*)

[13] http://www.bpeng.com

a unified view of the informative sources involved in the management of administrative procedures.

The primary goal is to link each administrative procedure with the organizational structures, norms and deadlines it refers to. The reason for expressing these relations is to find – for example – the list of procedures that are assigned to each unit of the PAT or to check if there are conflicts among different competences.

Accomplishing these tasks without building an *ad hoc* application is a very ambitious goal. In order to do this we believe that it is mandatory to start from the elicitation of the organization's structural design before getting into the analysis of procedures: procedures are meaningless without specifying the complex network of relationships underlying each organizational unit.

To show the usefulness of our approach we decided to analyze the design of a segment of the province of Trento: the department of culture (*Dipartimento Beni e Attività culturali*). Before getting into the core of the case study we will explain briefly how in general the PAT works.

The PAT is governed by an executive committee (the *Giunta Provinciale*) that is led by a president (the *Presidente della Giunta Provinciale*). The province is divided into several departments with specific competences: health, school, culture, welfare, infrastructures and so on. Each department is divided in different units called *Servizi* and each *Servizio* is further divided into other units called *Uffici*.

The PAT, as every italian province, is administratively regulated in accordance with the Italian law. But, with respect to other provinces, it enjoys a large autonomy from the general government and differently from other provinces its structure is designed by its own executive committee. This allows us to take into consideration just the norms that come out from the decisions of the *Giunta Provinciale*.

Roughly, the normative layer of the PAT is divided in different kinds of norms. The relevant kinds of norms for our case are: *Statuto*, *Leggi Provinciali*, *Declaratorie*. The *Statuto* is the core law for the province. It is a sort of constitution and, from a legal point of view it is at the same level (it has the same legal validity) of the Italian Constitution. It describes the fundamental principles and the fundamental structure of the province.

The *Leggi Provinciali* (provincial laws), besides the other general functions they have, assign general objectives to the province itself and then specify the structure of the province in order to pursue these objectives. In the *Leggi Provinciali* it is possible to find the institution of the various departments and the assignment of the competences to them.

The *Declaratoria* (declaratory judgement) is a sort of summary (that has nonetheless legal force) of the various administrative provisions that assign competences to the more specific structures of the PAT as, for example, services and offices.

3.1 Department of Culture – case study

After this very brief and rough explanation we are ready to go into our case study: the Department of Culture (*Dipartimento Beni e Attività Culturali*) of the province of Trento. For the sake of simplicity in this case we take into account the latter two types of norms (*Leggi Provinciali* and *Declaratorie*) and we try to show how this part of the province is designed starting from the department level down to the offices level.

In the provincial laws the province establishes as one of its objectives "the protection of the cultural goods and the development of culture". In order to pursue this goal a special department is instituted by law: the Department of Culture (*Dipartimento Beni e Attività culturali*), with a director who supervises it. At the same time provincial laws give structure to the department in question, by dividing it into different services:

- Service for Cultural Activities;
- Superintendency of Historic and Artistic Goods;
- Superintendency of Archaeologic Goods;
- Superintendency of Architectural Goods;
- Superintendency of Librarian and Archival Goods.

In the declaratory judgments there is additional specification about how to pursue these objectives. This is mainly done by giving more structure to the various services and by specifying their different objectives and competences. For the sake of brevity we will focus on the first service, the Service for Cultural Activities (*Servizio Attività Culturali*). The main objective of this sub-department (that has its own responsible) is "to promote the development of culture by taking care of the various provincial institutions dealing with culture, especially libraries and museums". The Service for the Cultural Activities has also to relate to another service, the Superintendency of Librarian and archival Goods, "in order to guarantee a proper action in the matter of the preservation of the archives and books".

This services is decomposed into two different offices, with a responsible for each of them:

- Office for the Librarian System of Trento (*Ufficio per il Sistema Bibliotecario di Trento* - SBT);
- Office for the Promotion of Culture (*Ufficio Amministrativo per la Promozione Culturale*).

The SBT office has to, by declaratory judgment, among its main objectives, "guarantee the right of the citizen to information, documentation and cultural update by the good managing of the librarian resources". In order to pursue its goals this office has not only to manage its own libraries but also to deal with the libraries of other institutions, that are external to the province itself, as for example the National Librarian Service (*Servizio Bibilotecario Nazionale*, SBN). SBT relies on SBN especially for the cataloguing system.

It is easy to see how the design of the structure moves in a step by step modality. Firstly, there are general, statutory norms that establish what the organization in question has to do, what are its objectives (in this case the development of culture), then these objectives are described more in details by providing more specific structure to the organization services and offices.

This is done, in a sense, by a sort of delegation: the executive committee delegates at different moments and to different figures the design of a structure that allows the pursuing of its general objectives. In fact PAT norms allow some roles – for example the director of the department – to design in a more detailed manner some aspects of the services or of the offices by means of directives.

Social control is another important aspect of delegation in the design process that emerges from the analysis of this case study. Once this complex chain of nested units is in place, the need of a way to know whether the whole project is achievable arises. In order to achieve the objectives of the organization the designer has to rely on people. The whole system is dependent for its functioning on people who play roles in the units: things as contracts signed by these agents are a means the organization has to force people to pursue its objectives. As we have seen before, for each unit there is a role, as a director or a responsible who has this function. His/her commitment to a contract acts as a "social glue" for the organization.

3.2 Formal analysis of the case study

This section is intended to give a flavor of how our model may be used to (partially) represent the structure of a real and complex organization. For this purpose, the formalization of the design of the Department of Culture of

PAT is presented below. More specifically, we would like to show how and what formal aspects of that organization can be captured by the 4-tuple introduced in the definition 1 and how the design layering works.

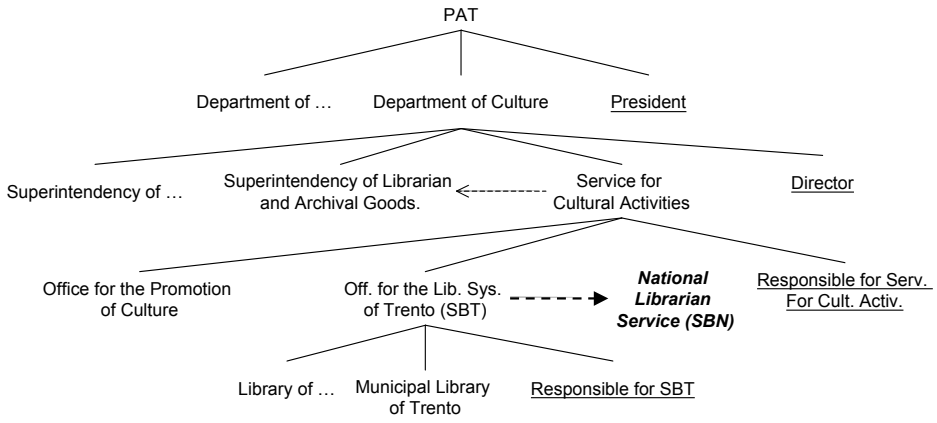

Figure 1: The (partial) structure of the Department of Culture of PAT. Roles are underlined. There is only one external organization with respect to PAT, namely, National Librarian Service (in bold).

Provincia Autonoma di Trento (PAT) itself is not a main interest in this case study. So, the institutional setting in which it is and its objectives are not under consideration. We start introducing the sub-organizations of PAT

$$\mathsf{dsb_i}(\text{PAT}) = \{\text{Department of Culture, President, Department of... }\};^{14}$$

and the structure and objectives of one of its department, namely the *Department of Culture*:

- $\mathsf{dsb_i}$(Department of Culture) = {Service for Cultural Activities, Director, Superintendency of Librarian and Archival Goods, Superintendency of...};
- obj(Department of Culture) = {"Protection of the cultural goods", "Development of culture"}.

[14] By "Department of ..." we mean the departments that are sub-organizations of PAT and which are not taken into account here. Similarly in the case of "Superintendency of..." and "Library of ...".

Then we focus on the characterization of one specific sub organization of the Department of Culture, namely the *Service for Cultural Activities*:

- $\mathsf{dsb_i}$(Service for Cultural Activities) = {Office for Promotion of Culture, Office for the Librarian System of Trento (SBT), Responsible for Service for Cultural Activities};
- obj(Service for Cultural Activities) = {"Promote the development of culture"};
- isett(Service for Cultural Activities) = {$\mathsf{HasObligation}$(Service for the Cultural Activities, Superintendency of Librarian and Archival Goods)}.

The structure, objectives, external organizations and the institutional relationships of Office for the Librarian System of Trento (SBT):

- $\mathsf{dsb_i}$(SBT) = {Municipal Library of Trento, Responsible for SBT, Library of...};
- obj(SBT) = {"Guarantee the right of the citizen to information, documentation and cultural update by the good managing of the librarian resources"};
- ex(SBT) = {National Librarian Service (SBN)};
- isett(SBT) = {$\mathsf{Depends}$(SBT,SBN)}.

SBN is a direct external sub-organization of Service for Cultural Activities:

- $\mathsf{dsb_e}$(Service for Cultural Activities) = {SBN};

therefore its direct sub-organizations are (they clearly are all at the same level of design):

- dsb(Service for Cultural Activities) = {Office for Promotion of Culture, SBT, Responsible for Service for Cultural Activities, SBN}.

Looking at the PAT, we can say that it is a top-organization, $\mathsf{org_T}$(PAT), and its internal sub-organization and roles are, respectively:

- $\mathsf{sb_i}$(PAT) = {Department of Culture, President, Department of ..., Service for Cultural Activities, Director, Superintendency of Librarian and Archival Goods, Superintendency of..., Office for Promotion of Culture, SBT, Responsible for Service for Cultural Activities, Municipal Library of Trento, Responsible for SBT, Library of..., ...};
- {President, Director, Responsible for Service for Cultural Activities, Responsible for SBT, and other Responsibles}.

We say also that the Office for the Promotion of Culture and the SBT are on the same level of design with respect to PAT:

- IdL(Office for the Promotion of Culture, SBT, PAT).

With respect to PAT, the set of all the organizations at the same level of SBT is:

- idl(SBT, PAT) = {Office for Promotion of Culture, SBT, Responsible for Service for Cultural Activities, SBN};

and, with respect to the PAT, the SBT is at a *lower level of design* than the Department of Culture:

- LwL(SBT, Department of Culture, PAT).

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