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Linguistic and Semantic Layers for Emergency Plans

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Abstract. Plans for emergency response are complex collaborations in which actors take roles and responsibilities. They are generally long textual documents containing practical instructions, in natural language, for hazard responses. A more rigorous structured-text would be useful for a twofold audience. From one side, it can be useful for quickly understanding the plan and on the other side it can be used to improve the modelling phase and delivering an automatic emergency-support system. This paper proposes an approach, conceived for humans, for converting a free-form plan document into a structured version of the same document. The approach is based on a linguistic and a semantic analysis that are strictly correlated and materialize in a metamodel. It contains the essential elements of an emergency plan, and aids in interpreting the input document also reducing inconsistencies, redundancies, and ambiguities.

Keywords: Emergency Plans, Metamodel, Free-form to Structured Text,

1. Introduction

Worldwide, emergency response plans describe complex processes involving collaboration and interaction of multiple roles and departments. In Italy, the definition of emergency plans is ruled by a normative layer that provides a national standard for managing emergencies. This rules originated by the Emperor Octavian Augustus who firmly believed that "the value of planning diminishes with the complexity of the state of affairs". In the first century before Christ, he put the basis of modern planning strategies that are now collected into the "Augustus Method" [19], introduced in 1997. This document proposes an uniform planning approach that is, at the same time, simple and flexible where the key idea is to overcome the classical approach based on the bureaucratic census of equipment used in civil protection interventions with a new focus on assets availability.

In the context of the project N.E.T.TUN.IT[1], we are working on a fully operational platform for cross-border data collaboration to cope with shared risks and disasters due to emergency scenarios. The project objective is that the Italian and Tunisian sides collabo-

[1]Net de l'Environnement Transfrontalier TUNisie-ITalie (N.E.T.TUN.IT), Cross-border Cooperation Programme of the EU Community, Italy-Tunisia 2014-2020

rate in the response to a simulated accident impacting nearby population health risks as well as atmospheric and marine pollution.

Emergency response plans are typically expressed as informal documents written in natural language. This represents an obstacle for applying a systematic modeling as well as for automatic verification and runtime adaptation. Nonetheless, understanding a free-text document (e.g. with the purpose of extracting fundamental information) is a challenging task that requires skills and domain knowledge.

In [6], we started a preliminary work for identifying a number of keywords in the free-text version of the paper, collecting and sorting their specific meanings. These words are so recurrent in the text that suggested us to be representative for describing organizational patterns during emergency response activities. The work concluded that some keywords in the text could be used as a pivot for extracting the intricate meaning of an emergency plane.

Now, building on those basis, this paper addresses the problem in a more systematic way by establishing a semantic layer for emergency plans. We work under two basic assumptions: i) we limit the scope of the study to Italian plans, and ii) the study specifically focuses on organizational patterns that emerge from plans. The objective of the work is to provide a set of guidelines for manually converting a free-form text into a structured one, in which semantics is made explicit. The present work presents three novelties with respect to the previous paper [6], as listed below.

- The first novelty is a clear separation of the linguistic and semantic aspects through the concept of lexicon. A linguistic analysis is proposed as preliminary activity with the aim of reducing flaws due to the natural language. This activity helps in reducing errors in the further extraction of the embedded meaning.
- The second contribution is the metamodel for modeling an organization for emergency response. Differently, by other approaches in literature [3, 42], our proposed metamodel originates from the empirical study of existing emergency plans, and it is well grounded on the linguistic analysis of the text.
- The third contribution is a list of linguistic issues that we recognized in emergency plan documents. Even if in this paper we only reason about their possible presence in the input text, their categorization represents a first step towards a subsequent work of delivering a (semi-)automatic transformation from free-text to structured-text documents.

The rest of the paper is structured as follows: Section 2 provides an overview of the long term agenda on which the current work relies, and it provides a motivating example for justifying the importance of the proposed approach. Section 3 introduces the Italian landscape in the definition of emergency plans and illustrates the state-of-the-art about ontology and metamodels for emergency management. Section 4 presents the result of a linguistic analysis of the selected corpus of documents we used for empirically define our semantics, that is materialized in a metamodel, presented in Section 4.2, actually the core of the paper. Section 5 offers several examples for providing a gradual understanding of how to use the metamodel. Section 6 provides a discussion of limits of the current approach whereas some conclusions are drafted in Section 8. Finally, two appendixes report in details property tables for the elements of the metamodel and sentence templates for rewriting in a structured way the input text.

2. Motivation: From Free Text to Structured Plans

The objective of this section is to provide motivations for the current work. To this purpose, we illustrate, by means of an example, the need for a semantic layer when dealing with emergency management plans. Along the whole paper, we report many examples of sentences taken from real emergency plans. It is worth noting that, despite the original sentences being in Italian, we report translations, as accurately as possible.

An emergency plan is usually provided in free-text form according to a generic format as prescribed by national laws. As an instance, we report below an excerpt from a plan [13, p. 93,94][10, p. 55] conceived to deal with a fire emergency and involving the civil protection agency, some volunteer organizations, and the police:

"`[...] The head of civil protection agency activates its cartography support service at the civil protection headquarters to prepare useful maps for the management of the emergency and the subsequent phase of return to normality. [...]`"

This kind of documents may present flaws due to the natural language such as redundancy, ambiguity, and the use of synonym; moreover, different authors may express the guidelines by using their own sensibility and linguistic skills thus introducing an undesired alteration of the intended plan. As an example, one of the issues is the use of different words (synonym) to address the same event or the same action. It is common, when writing, the voluntary use of synonyms for the sake of elegance and for avoiding word repetitions. Even if this custom leads to more elegant documents for humans, it carries uncertainties that may cause ambiguities in the interpretation of the plan, and it represents an obstacle for a software-based automation.

To this purpose, we highlight the need to convert informal documents to more rigorous models in which semantics is highlighted and uncertainty is removed. We suggest a two-steps approach, in which the first point is resolving linguistic issues and the second one is identifying essential elements to reveal the document structure. The first challenge is to construct a linguistic layer for analyzing an input emergency plan text, with the aim of dealing with the uncertainty of the natural language and resolving linguistic flaws.

The linguist analysis, will be connected to a semantic layer, intended to analyze the structure of sentences to make the meaning hidden across the document evident in small and compact semantic networks. Here, the challenge is focusing on organizational structures that are recurrent in many (Italian) emergency management plans. The use of a metamodel facilitates the reader generating a well-structured version of the same documents.

The expected result a semantic network like the one shown in Figure 1, built starting from the previous exemplar sentence. The underlying semantic of the nodes and relations of this diagram will be clear later in this paper. Here, it is worth noting how the same sentence is structured by assigning precise meaning to the various components of the discourse.

Despite the existence of automatic tools for interpreting the natural language, it is worth highlighting the role of manual translations of free-text in the context of emergency plans. This is a requirement that has its roots in the particular nature of the domain and in specific requirements of the project.

A recent study, mainly focusing on Chinese emergency plans, proposes automatic extraction of business process models from textual descriptions [21]. Despite the great advantage in terms of time and resources, the authors recognize a lower quality with respect to manually processed texts.

Interestingly, semantic role labeling systems [26,32] proved to perform reasonably well in some controlled experiments. However, the degradation of performance has been demonstrated when a supervised system is faced with unseen events or a testing corpus different from training [26]. Therefore, applying semantic role labeling to the crisis management plan domain could represent a big challenge, surely out the scope of the NETTUNIT project.

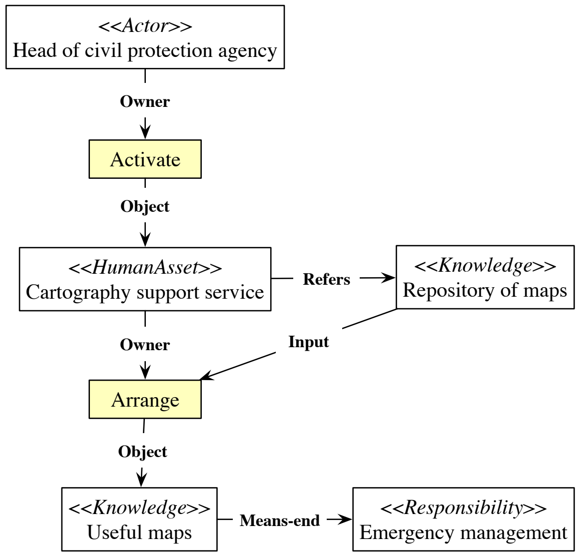

Fig. 1. Instance of the metamodel for Sentence 4.

In addition, manual translation is motivated by the central role of the humans in crisis management. This occurs at different levels of the process, starting from the responsibility to set and approve the emergency plans, till the need of maintaining complete control of the ongoing activities [7]. In this context a totally automated approach will break the precise distribution of responsibilities, mandatory by laws. Clearly, this point does not exclude future semi-automatic approaches could facilitate this translation.

Another interesting point to clarify is how the resulting semantic networks (like the one in Figure 1) could be usefully employed in an emergency management. In our vision, the structured version of the input corpus of documents will support further phases of conceptual modelling and, consequently, an execution layer. Just to provide an intuition of this phase, let us consider the previous emergency plan as an example of transformation from structured-text to modeling notation. For the sake of simplicity, we adopt the very well-known BPMN notation to represent in a visual format the same corpus of information (a see Fig. 2).

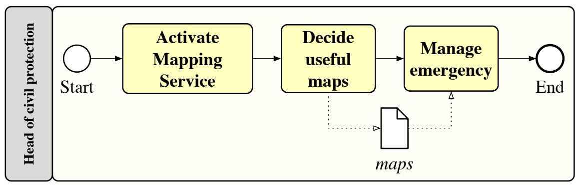

Fig. 2. A fragment of BPMN derived from the exemplar sentence.

To conclude, Section 7 provides an intuition of the long-term agenda, related to the N.E.T.TUN.IT project, in which the final objective is to exploit a framework for the adaptive execution and management of emergency plans.

3. State of the Art

In this Section we first provide a bird-eye view of the Italian landscape about emergency management, with a specific focus on national norms and regulations. In the second part, we review some of the existing approaches to highlight the semantic of an emergency plan.

3.1. The Italian Landscape

In Italy, the structure of emergency response plans follows the so-called "Augustus Method" [19]. This method was developed by the Italian Civil Protection Agency and officially adopted by the Italian Ministry of the Interior in 1997. In the perspective of the Augustus Method, the competences and the intervention areas are defined with a set of Support Functions, each of which has a specific Manager who is in charge of keeping their plan up to date, also through exercises and updates. In times of need, the Support Functions are called upon to deploy their skills and are coordinated to respond effectively to emergencies.

The Support Functions are defined both at municipal (4) and regional level (5). They include, inter alia, technical advisory and planning services, social and health care, veterinary services, media and information, voluntary organisations, traffic control and transport. In this way, the roles and responsibilities of the different operational centres are defined. The heads of the Support Functions actively participate in the operational centres, each for their own competence, ensuring their cooperation and the availability of the resources at their disposal should it be necessary to deal with an emergency situation.

The structure of any emergency plan according to the Augustus Method has three basic parts: *(i)* General part, *(ii)* Outlines of Planning, *(iii)* Model of intervention.

The General Part includes all the information related to the knowledge of the territory, the existing monitoring networks, the risks of the area and the related possible incident scenarios (fires, floods, earthquakes, toxic smoke pollution). The Outlines of Planning describe the objectives to be achieved in response to a specific emergency. Finally, the Model of intervention defines the responsibilities and the chains of command and control for all actions necessary to deal with and resolve civil protection emergencies. This also requires a constant exchange of information between the central coordination system and the peripheral system of the civil protection agencies on the updated availability of resources in terms of men and means to adequately deal with emergency situations.

A directive of the President of the Council of Ministers in 2005 has perfected the structure of the plan that in the new version includes the following sections: General Part, Incident Scenarios, Organisational Model of Intervention, Information to the Population, and Cartography.

In this article we report the results of the analysis of several emergency plans [17],[12],[13], [10] that were selected because they represent different examples in terms of scope, size and responsible institution (author of the plan). These are reasonably recent plans, some of which have been updated over the last five years, and clearly we have considered only the most recent versions. In particular, we have focused on the active part of the contingency plan, i.e. mainly the Organisational Model of Intervention.

Interestingly, the considered plans show two different outlines for this section: some adopt a 'phase-based' structure, while others a 'role-based' one.

The document [17] includes the intervention plans for each alert level (Warning, Pre-alarm, Alarm) and the role of all the actors involved through a chronological description of the tasks and functions of all the entities involved for each phase. This kind of structure is not very direct on who has to fulfil a specific task and depends on an attempt to avoid many repetitions in the text.

Instead, the plan in [12] describes which events trigger the transition from one alert level to another and then lists the description of individual roles and their responsibilities and actions to be implemented directly or to be activated in the form of a single list for each plan that discusses the tasks of the roles in all phases.

The second type of structure is found in the longer documents, probably because in this way it is easier to locate the information concerning each stakeholder, thus facilitating access to information in case of urgency.

The distinction between these two types of structure is relevant to our study because we found that the two structures generate different types of ambiguity. While plans in the first category are sometimes vague about who is responsible for a specific task, plans in the second category eliminate this risk but are less clear in reporting the relationship between each stage and the tasks to be performed within it.

3.2. Semantic Approaches for Emergency Plans

A major problem in collecting, representing and integrating information from several heterogeneous sources can be simplified by an adequate conceptualization of the Emergency Management domain. An ontology, in fact, can provide a unified explanation of concepts and the relationships between them. Thus, it makes knowledge sharable among different users and also allows automatic data processing.

In the scientific literature, there are various studies and proposals of ontologies for the management of various types of emergencies (fires, explosions, terrorist attacks, natural disasters, humanitarian emergencies) which can have serious consequences on the well-being of the population. For example, [23] reports an extensive analysis of scientific articles in the literature. They discuss a classification of ontologies according to common concepts (people, organizations, resources, disasters, geography, processes, infrastructure, damage) and less common ones (topography, hydrology and meteorology).

In [20], the authors propose to integrate many ontologies and vocabularies found in the literature into a unified structure. The authors have followed the principles of ontological methodologies such as NeON [39] and Methontology [18] which encourage the reuse of existing ontologies. Furthermore, in order to have a quantitative assessment of the quality of their proposal, they designed an evaluation survey based on 17 questions concerning hierarchical, relational and lexical aspects.

Unfortunately, very few ontologies originally designed for crisis management are formally represented and accessible to the public. Moreover, there are no ontologies that cover all aspects of the emergency management domain and, above all, contingency plans are hardly ever written on the basis of an internationally accepted domain ontology.

The main issue that hinders the applicability of such ontologies in the context of the N.E.T.TUN.IT project is they focus more on the description of the kind of event, resources and messages, whereas they lack in describing the kind of human organization, goals, tasks and responsibilities that are designed to front the crisis.

This aspect is partially noticed in [3] the authors present a metamodel for modelling a crisis situation from an analysis of the domain of interest with the aim of generating an interoperability layer (Mediation Information System, MIS) between the information systems of the organisations involved in responding to a crisis. In their metamodel, authors introduce Risk and Crisis elements. Risk models the conjunction of the possibility to have an event with negative consequences. The degree of risk is related to the probability of the event and its potential effects. A Crisis is the realization of a risk and therefore it is related to its event and dangers. The presence of these elements is a direct consequence of the will to model the current emergency (Crisis in their metamodel).

In [42], the authors propose an Emergency Response Organisation ontology to overcome semantic ambiguities due to differences in emergency systems between different countries, regions and organisations. Authors focus on the emergency response organisation with the aim of resolving semantic conflicts in the development of emergency response information systems or the elaboration of emergency plans.

This work goes in a direction that is promising from the N.E.T.TUN.IT project. They focus on (and detail very much) the concept of human organization and roles, but despite they introduce the concept of goal, it is quite marginal in their metamodel. According to our experience, we want a better integration of goals/responsibilities with actors and tasks.

4. Linguistic and Semantics

This section describes the semantic layer that is the ground for producing structured-text plans. This layer extends a preliminary work on lexical semantics (i.e. investigates word meaning) done in [6] and refines the conceptual semantics by means of a metamodel, thus explaining properties of argument structure.

We started from a set of lexicons [2] identified through a linguistic analysis for building a metamodel. A lexicon is a representative word that assumes a specific meaning for a class of synonyms. Identifying this meaning enables a further modelling phase.

4.1. Linguistic Analysis

One of the cornerstones of this work is defining the way in which a structured-text plan (a knowledge model) can be connected with its linguistic formulation, i.e. the free-text version of the plan. In practice, we need to analyse linguistic information thus to properly assign a specific meaning to words [2,5].

To write the present work, we studied and analysed a number of Italian Emergency Plans [10,12,13,17] to compare the different approaches, styles and terminologies. The major issue we discovered is that each author uses to express the guidelines by using his own sensibility and linguistic knowledge; this often leads to the use of different words (synonyms) to address the same concept. Sometimes, the use of synonyms simply occurs for reasons of elegance and to avoid repetitions in close sentences.

In order to avoid to over-simplify the problem, we think a good strategy would be to accept the richness of natural language, even if that means dealing with more complex inputs. In dealing with natural language documents, we delineate a clear separation between the linguistic and ontological levels, However, a close collaboration between these two levels may help to better manage linguistic flaws (in particular, synonyms). An instrument to connect linguistic and semantic layers is the lexicon. In literature, a lexicon is defined as a vocabulary of words (in a language) along with the knowledge of how each word is used. The concept of lexicon gathers the linguistic properties of terms and their syntactic relations, differently from an ontology term that focuses on a conceptual element.

In order to identify these linguistically different but semantically similar words, we have defined a lexicon table, shown in Table 1. Table 1 currently counts thirty three terms referring to seven lexicons. In the first column the reader can see the main word (i.e. the lexicon) chosen as representative of all the terms (synonyms) listed in the second column. In the third column we specify the precise meaning we associate to the lexicon. Finally, in the fourth column, we show a sentence taken from an Italian plan and translated into English that contains one of the synonyms.

Table 1

List of Lexicons and their Synonyms.

Lexicon	**Synonym Terms English (Italian)**	**Meaning (for disambiguation)**	**Example**
Order	Orders (Ordina)	Give an authoritative instruction to do something	The prefect disposes a continuous monitoring of air quality in relation to wind direction, intensity and altitude
	Disposes (Dispone)		
	Provides (Provvede)		
	Sends (Invia)		
Inform	Informs (Informa)	Give someone facts or information	The Manager shall update the Prefect and other interested parties by means of messages using the template specified in the attachments
	Updates (Aggiorna)		
	Communicates (Comunica)		
	Notifies (Notifica)		
	Signals (Segnala)		
	Reports (Relaziona)		
Gather Data	Monitors (Segue)	Collect various types of information	The mayor monitors the development of the situation and informs the population that the state of external emergency has been lifted.
	Acquires (Acquisisce)		
	Observes (Osserva)		
	Carry out (Effettua misure)		
Activate	Activates (Attiva)	Turn something to active or operative	The Technical Rescue Director sets up an Advanced Command Post
	Sets up (istituisce)		
	Implements (pone in essere)		
	Adopts (Adotta)		
	Actuates (Attua)		
	Applies (Applica)		
Decide	Decides (Decide)	Come to a resolution in the mind as a result of consideration	Mayor locates safe area for setting up a first accommodation facility
	Locates (Individua)		
	Marks (Caratterizza)		
	Establishes (Stabilisce)		
	Defines (Definisce)		
	Authorises (Autorizza)		
Arrange	Arranges (Predispone)	Make instructions or preparations for an event or activity	The mayor makes use of the municipal voluntary association
	Coordinates (Coordina)		
	Organises (Organizza)		
	Makes use (Si avvale)		

Discovering synonym is significant because it limits the arbitrariness in interpreting the free-text plan and it also allows moving from it to the structured-text version of the same plan. Moreover, it aids in creating linguistic categories that converge in the specification of lexicons [5] that are the representatives for all the contained words.

The Table 1 could grow, in the future, in order to better cover all the particular cases that yield in the whole corpus of national emergency plans. To this aim, it will be necessary to consider a larger number of emergency plans with the purpose of extending the current list of synonyms for each lexicon thus gradually reducing possible cases of ambiguity.

However, besides the problem of synonym, that we partially solved here, we also encountered other linguistic issues that we noted for future investigations and are listed in Section 6. Given the objective to manually convert a document from a free-form text to a structured one, in most of the cases, humans are able to solve these flaws and take the correct decision by deducing from the context. Indeed, these flaws represent a big limits when moving from human to machinery interpretation of the text. After creating a semantic layer, the next natural step that comes in mind is to move towards an automatic support for extracting an ontology from the input text. Natural language processing is a fast-paced research field that may provide an important improvement to the automatic management of emergency management [8,9,41]. This is actually out of the scope, but we are moving forward with this objective in mind.

4.2. *The Proposed Metamodel*

It is now necessary to clarify some rules we adopted in defining the elements of the metamodel:

- We are interested in lexicons because we want to connect the use of the metamodel to linguistic information embedded into the free-text plan [5].
- We focus on a general structure of emergency response plan: this means that domain actions related to the management of a specific accident (even if common to other cases) are out of the scope. The reason for this choice is to limit the number of elements of the metamodel and to remain general by leaving apart domain-dependent terms that change with the kind of emergency or that may depend on the adoption of new strategies and new technologies.
- Typically, the elements of the ontology explicitly appears in the free-text version of the plan as lexicons (or synonyms). Our idea is to respect the problem knowledge and comprehension that the writer of the plan has. However, we extended the metamodel with some terms, e.g. decisions, and responsibilities, that do not explicitly appear as words in the plan's text, but they are deducible from the document's structure. An example of that will be provided in Section 5.

The rest of this section discusses the proposed metamodel whereas the next section will put the metamodel in practice for building some parts of a structured-text plan.

In literature, many ontologies exist for each specific category of emergency (natural disasters [1], explosions [23] and terrorist attacks [24], just to mention some of these). As already discussed, our proposed semantics aims at highlighting collaboration patterns that appear within an emergency plan. For this reason, it does not focus on domain-specific actions used to solve some kind of accident rather than another one.

From the linguistic analysis, we discovered several elements that could be clustered in five categories: actors, events, actions, responsibilities and resources [6]. These elements constitute the basis for building a metamodel that enriches the previous work by detailing and relating these categories. This approach ensures a link to the linguistic level.

Actors are relevant because of the human-intensive nature of the response organization. Events yield to be modeled because they trigger changes in the current situation, delivering the different stages of the plan (for instance, moving from pre-alert to alert). Actions are of paramount importance in the metamodel because they represent the building block of any emergency plan. In the vision of adopting a goal-oriented self-adaptive systems, identifying responsibility as goals is necessary for studying how the system will adapt to unexpected accident evolution. To this purpose, responsibilities specify why a specific actor is involved in the emergency management plan, what he/she should care and pursue, and who could be considered accountable for a possible failure. A specific attention is given to delegation (term that originated from goal-oriented methodologies), that here refers the 'principle of expected result'. Finally, resources are relevant, in the context of an emergency, because they provide means for addressing objectives in emergency plans.

In the following subsections, we will detail the fundamental aspects of these categories, and of the elements within them.

4.3. Actors

A fundamental aspect of the innovation proposed by the Augustus method consists in clearly assigning responsibilities. For this reason, it becomes very relevant to create a list of actors involved in the execution of the plan.

In the numerous plans we studied, we found many actors, often referred to with acronyms. We noted that the ambiguity allowed by the Italian language sometimes creates some indecision on identifying who is the actor responsible for performing a specific action. This indecision mainly happens in plans where the description is ordered using time or event-related criteria. Plans, where activities are clustered according to actors, do not present this ambiguity, of course.

We differentiate between individual actors and collective actors. With the term individual actor, we will address the common-sense meaning of a participant in an action or process. Collective actors represent a more refined concept where according to [34] collective actors perform a coordinated and collaborative decision-making process where one individual speaks for the group. Collective actors share the same interests, integration mechanisms, an internal and external representation of the collective actor and an innovation capacity.

Examples of individual actors include some already cited authorities: Mayor, Prefect, chairs and participants of committees (that are collective actors), for instance, the Responsible for the Town Operating Center or the Civil Protection Officer on duty.

Examples of collective actors include the operation room of the Metropolitan Police, the Rescue Coordination Center, the Regional Agency for Environment Protection, the Integrated Regional Operation Room, and so on.

As reported in the metamodel (see Figure 3), an actor may perform actions on its own (as the owner of the action), or it may assist another actor; this entails that the actor is the owner of responsibilities associated to the result of the action, i.e. she is accountable for the expected result; emergency plans lie in a knowledge-intensive field, for this reason the metamodel prescribes that the actor owns some knowledge useful for performing its duty. Another interesting aspect is that the action may be performed (by the owner or assistant) on behalf of someone else (after a delegation), finally, the actor may be either producer or consumer of events.

4.4. Responsibility

As issued by Italian laws, an emergency plan assigns specific responsibilities to the participant actors. For instance, according to the Augustus Method, each Support Function

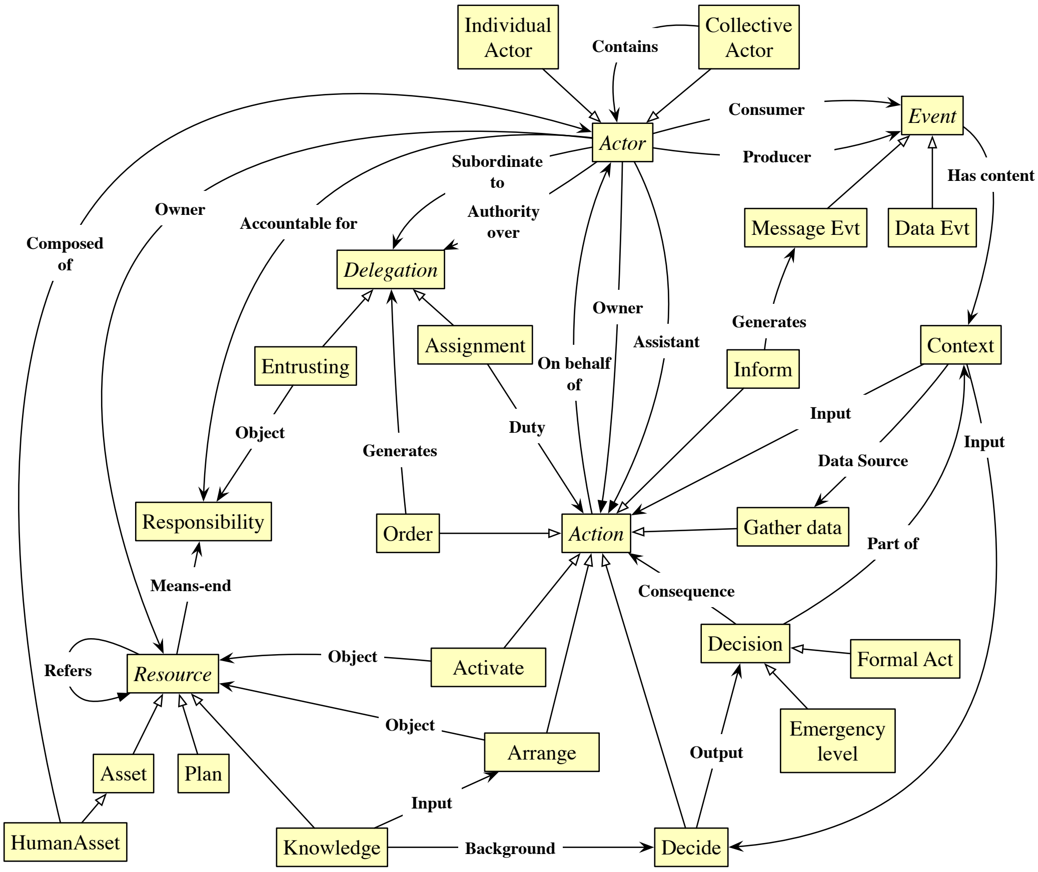

Fig. 3. The proposed metamodel for emergency plans

manager is in charge of a specific responsibility such as ensuring health-social assistance, managing mass media and information, coordinate voluntary organizations, controlling circulation and traffic, and so on. A Responsibility implies a commitment to address an objective under the criterion of personal responsibility and accountability also by law.

- during the Alarm Phase, the Chief of the Provincial Fire Brigade is responsible for coordinating the technical and scientific staff;
- the Provincial Health Agency General Manager is responsible for activating the necessary organisation for the specific type of accident;
- the Chief of the City Brigade Fire is responsible for coordinating all operative structures forming the Rescue Coordination Centre.

We implicitly related the concept of responsibility to that of *Goal* because we intend to create a correspondence with strategic actor relationships that originate from social modelling [16] and Goal-Oriented requirements engineering [40] and to pave the way for a multiagent system automatic support [7]. In this perspective, responsibilities lead to either direct actions or delegations to other parties.The metamodel expresses this aspect by specializing the generic concept of delegation in two subclasses: *Entrusting* moves one responsibility from an authority to a subordinate actor thus the latter becomes accountable for the expected result. Conversely, an *Assignment* implies that an activity is delegated, whereas the responsibility remains to the authority actor.

An interesting relationship is 'means-end' that connects a resource to a responsibility, thus modeling that the related resource is needed to fulfill the given responsibility.

4.5. Events

Emergencies exist because negative events compromise the environment, changing its state; this is a simple fact that justifies the importance of modelling events in an emergency. In our analysis, we always found events that are produced or consumed by actors (it is a sort of knowledge of the external event).

We identified two types of relevant events for the structured representation of the plan: *Data Events* and *Messages*. A Data Event represents data obtained from monitoring activities and the acquisition of information from any possible source. The Message event represents an intentional exchange of data (see the Inform action) that is related to the emergency, for instance, a phone call from the responsible manager of a plant affected by a significant fire blast.

Everything can be the content of a Message Event, however for simplicity we classify two subcategories of message: *Informal* and *Formal*. Informal messages refer to phone calls, media diffusion of news, and so on. The essential feature of an informal message is that it does not have any kind of template specified in the emergency plan. Formal messages are delivered using traceable communication means (emails, other types of computer-based messages, telegrams,…). An essential feature of formal messages is the adherence to a format specified in the plan. Frequently, formal messages are encoded using some emergency communication protocol, like the Common Alert Protocol (CAP) [30].

4.6. Actions

Actions are the essential brick of an emergency plan. The Action is an abstract category that is specialized by different subclasses delivering different organization patterns (that we identified in the linguistic analysis): order, activate, arrange, gather data, inform, decide.

All the actions are related to an owner actor who is up to execute them (sometimes on behalf of an authority), and optionally, some assistant actors helping in addressing the result.

Order. The first subclass we specialize from Action is *Order*, suitable for situations in which an authority actor sets an order to a recipient actor. The order typically generates a delegation (either Entrusting of responsibility or the Assignment of duty).

Examples from the plans we examined are:

- The Prefect orders to the commissioner the actuation of the traffic deviation plan.
- The Mayor orders the police to evacuate the zone.

Activate. Another subclass is *Activate* that covers situations where a resource is made available for being used within the emergency. Here, resource is a general term used to indicate three categories of elements that may be activated: Plan (typically a sub-plan ready to be enacted), an Asset (e.g. an individual, an office that provides a function, a machinery, and so on) and a Knowledge (e.g. a document, a law, some kind of information source).

Examples:

- The Civil Protection Office Head activates the weather monitoring team.
- The emergency manager activates the External Emergency Response Plan.
- The civil protection activates its Cartography Support Service.

Arrange. We also considered the *Arrange* subclass that implies some kind of coordination, organization and planning before a Plan may be enacted. This is a frequent occurrence in the emergency plans we studied. Examples:

- The police arranges the monitor of the emergency site to ensure the fast evacuation of the population.
- The head of the Town Protection Agency arranges watch duties in the Town Operation Room.

Gather data. The *Gather Data* subclass refers to the act of acquiring data, and it is very significant in dynamic emergency responses.

The Gather Data action is always performed over the current situation (data source) via direct/indirect observation, by remote sensors, experts operating on the field, and, sometimes, by citizens. It is also used for checking the operational state of resources.

Examples:

- The Regional Civil Protection Agency gathers data about the accident.
- The head of the Resources Department gathers data about the status of resources and personnel.
- The head of the Civil Protection Agency gathers data about suitable places to shelter displaced persons.

Inform. *Inform* represents the act of sending messages to a recipient. The message may be a formal act, following a structured protocol, or an informal communication like a phone call. The action may be one-shot or repeated with a frequency (e.g. when updating the current state of something).

- The head of the Civil Protection informs the commander of the Municipal Police about the emergency status
- The civil protection informs the volunteer service to activate volunteer organizations

Decide. *Decide* is a type of action requiring information, quick access to knowledge (such as maps, technical schematics of plants, norms) or expertise (i.e. support from technical staff). The output is a *Decision* i.e. the (typically formal) act that has consequences over the plan. Consequences are generally provided in terms of other actions to be performed.

- The Mayor decides to move from the pre-alert phase to the alert phase
- The Civil Protection decides the useful maps for the management of the emergency

Decisions in the plans are often described in terms of the actor who has to take them and the possible alternatives (i.e. trigger alert, or deactivate the pre-alert phase). Sometimes some supporting actors are also listed. Decisions are the part of the plan that we have often found lacking relevant details; for instance, criteria for deciding may remain blurred and are rarely formalized. Often, plans do not explicitly use the ‘Decide’ lexicon; they instead address the concept of a decision to be taken by someone by describing the incoming events and expected decisions in terms of orders issued or actions undertaken. Sometimes, events may be related to the emergency development, and decisions are about the actions that are required to face the new event.

5. Extracting Emergency Plans

This section presents the method we conceived for manually analyzing a free-text emergency plan with the aim of generating its structured version. The section exploits several excerpts from the studied emergency plans, also presenting the corresponding instance of the metamodel.

In the following list we report the steps used to transform emergency plans from free-form text into structured text. We suppose to fragment the plan in sentences or group of sentences that are logically related in terms of actions to perform, objective to achieve, timeframe specification, and so on. Each fragment will be processed with the following procedure:

1. Highlight candidate keywords (subjects, verbs, complements).
2. Identify Actions (verbs of the metamodel or their synonyms from the Synonyms list, see Sect. 4) in the highlighted keywords.
3. Verify that Actions used in the fragment match the semantics adopted in the proposed approach by considering that:
   - The semantics underpinned by the metamodel (see Fig. 3) is the same (particularly significant are the relationships with other metamodel elements).
   - Verbs in the analyzed fragment of text are used in the same way the corresponding Actions are used in proposed templates (see Appendix).
   - Items listed in the property table of the verb match what can be extracted from the studied fragment (carefully verifying the presence of all the required properties).
   - Examples reported in the Synonyms list (Sect. 4) address the same meaning.
4. Rewrite the fragment of text by using the templates proposed in Appendix (the result is the structured text version of the fragment).
5. Compile the property table of all the metamodel elements used in the structured text.
6. Verify that all words in the fragment have been properly considered and converted in structured text if they are worth of.[2]

[2]It is worth noting that the proposed approach still does not manage some portions of the plan text, for instance adverbs expressing causal/temporal relationships (we plan to deal with them in a future work), and accident-specific actions and terms (too many and too specific for being part of the metamodel).

The application domain of the proposed metamodel is quite specific (civil protection emergency plans), so it is possible to empirically verify the coverage of the metamodel with respect to its scope. Moreover, despite emergency plans follow norms and laws that can vary significantly in different nations, the elements presented in our metamodel seem general enough to cover most of the cases. Within the N.E.T.TUN.IT project, we will have the opportunity to compare this metamodel with plans used in the countries of other partners, so to obtain a further validation. Indeed, this is one of the reasons we preferred to identify only a few (quite general) lexicons and to complete the coverage with a list of synonymous. It is sufficient to map the proposed lexicons to those used in another language for having a reasonable starting point for the analysis of a plan in another language. A similar issue regards the actions that are specifically adopted for countering each different accident. They are accident-specific and of limited interest for the scope of this paper, but they can easily be deducted from the reading of each specific plan and identified throughout that. The reuse of these terms in other plans is, anyway, limited when we change the accident at hand.

We will now provide some examples of sentences extracted from real emergency plans. The sentences are originally in Italian, translated in English trying to maintain the original meaning, but this may introduce some flaw. Examples are introduced adopting a precise structure:

1. The rationale behind the selection of the sentence as an example, we also cite the document where the sentence has been found.
2. The sentence in natural text, as found in the emergency plan.
3. An analysis of the text and some considerations arising from that.
4. The instance of the proposed metamodel springing from the sentence.
5. The properties tables for the metamodel elements identified in the sentence.
6. the structured text version of the sentence obtained by using the templates reported in Appendix.

Example 5.1. *The objective of this example is to smoothly introduce the reader to the proposed method. The following fragment of plan, actually a simple sentence extracted from [11, p. 42], is a case of Actor-Action-Subject phrase with a straightforward interpretation.*

Sentence 1 — "`The municipal police arrange the assigned roadblocks`"

This sentence is characterized by a subject (*the municipal police*) a verb (*arrange*) and a noun (*the roadblock*). The *Arrange* action is a lexicon of the metamodel that refers to something that must be planned/organized/adapted at runtime. This perfectly matches with the very nature of putting roadblocks in the area to be secured. Fig. 4 shows an instance of the portion of the proposed metamodel, representing these three elements and their relationships.

By using the property table of the element Arrange (see the Appendix), we analyze the input text for further details. Table 2 shows a minimalist table where only non trivial rows are filled with values (for convenience we omitted optional fields).

Finally, from the Appendix we also get that the sentence template for the Arrange element is something like: `[owner] Arranges [object]`.

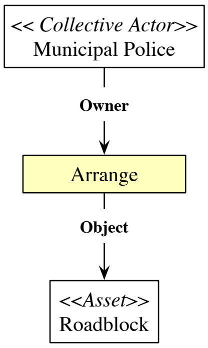

Fig. 4. Instance of the metamodel for Sentence 1.

Table 2
Properties of Arrange activity for Sentence 1.

Arrange	
owner	`Municipal police`
object	`Assigned roadblocks`

Therefore, we positively verified that the *Arrange* action is used in the meaning addressed by our metamodel and now, by using the proposed sentence template, we obtain the following output structured sentence:
Structured Sentence 1 — "`[Municipal police] arrange [Assigned roadblocks]`"

Example 5.2. *The next sentence is a more complex case; it is extracted from [13, p. 93], and it includes two actors, two actions, and an event that will be decomposed into two correlated parts.*

Sentence 2 — "`The head of the civil protection agency alerts the director of the volunteer service for the activation of volunteer organizations from neighboring provinces.`"

Sentence 2 involves two actors: the head of the civil protection agency and the director of the volunteer service. The former pursues the primary activity of ordering something, the latter pursues the order by activating a resource. The order generates an assignment. When an order is dispatched, a duty is assigned, in this case the activation of the volunteer organizations. We model this using the '*Order-Assignment-Activate*' block. The director of the volunteer service owns the assigned activity '*Activate*'. Fig. 5 shows the instance of the metamodel for Sentence 2.

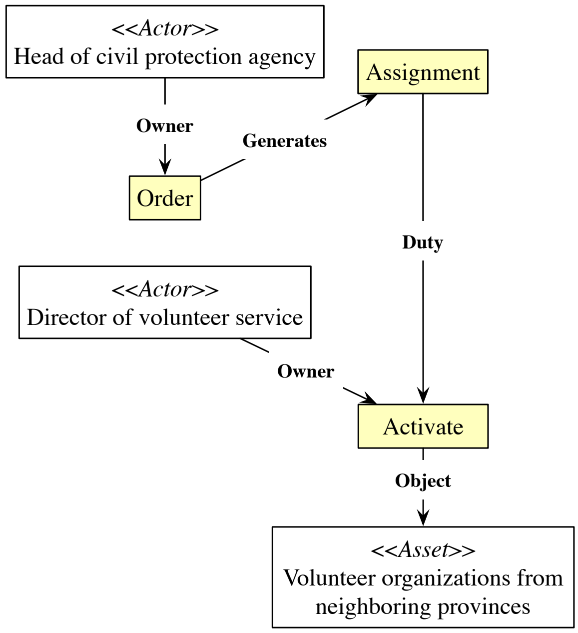

Fig. 5. Instance of the metamodel for Sentence 2.

Table 3 lists the properties related to activity '*Order*' in Sentence 2 (for convenience, only non-optional fields):

Table 3
Properties of Order activity for Sentence 2

	Order
owner	`Head of civil protection agency`
generate	`Activate`
target	`Director of volunteer service`

Table 4 lists the properties related to activity Activate in Sentence 2 (for convenience, only non-optional fields):

Table 4
Properties of Activate activity for Sentence 2.

	Activate
owner	`Director of volunteer service`
object	`Volunteer organizations from neighboring provinces`
on-behalf-of	`Head of civil protection agency`

According to the templates the activities characterizing Sentence 2 (see Appendix), the instance of the metamodel is the following:

Structured Sentence 2 — "`[Head of civil protection agency] orders [Director of volunteer service] to [activate] with assignment [Volunteer organizations from neighboring provinces]. Consequently, [Director of volunteer service] activates [Volunteer organizations from neighboring provinces].`"

6. Study of the Validity of the Proposed Approach

This Section presents an experiment to validate the proposed approach and discusses limits and open problems.

6.1. Experimental Phase

Goal definition. We set up an experiment to evaluate the appropriateness of the proposed approach. In the following, we want to analyze the linguistic and semantic layers for the purpose of translating some target emergency plans with respect to validity from the point of view of a potential user in the context of researchers.

The experiment has been designed to evaluate three aspects:

RQ 1: the appropriateness of the synonymous table

RQ 2: the completeness of the metamodel

RQ 3: the usefulness of the tables of property.

To respond to RQ 1 we asked to annotate all the words that do not match with any of the lexicon (including synonymous) of the synonymous table. We also asked to double-check (and count) possible wrong associations (occurrences of polysemy).

To respond to RQ 2 we measure the cases in which the metamodel is sufficient to model the target sentence.

To evaluate RQ 3, we asked subjects to respond to which extent filling the table of properties helped in the disambiguation of an element of the metamodel.

After building the approach, we selected a team of 4 researcher. Two of them were not involved in the research, therefore their knowledge of the proposed approach (and of the emergency domain) was limited.

Therefore we selected two documents containing two emergency plans of different type. The first document (Siracus) is 120 pages with about 44.000 words. The second one (Ragusa) is 45 pages with about 35.000 words.

Given the input document, we designed the experiment operationalization by two tasks.

Task 1 - From these documents the first task was to identify the relevant sentences that describe some kind of reaction to an emergency event.

Task 2 - Translating the sentence by using the proposed approach.

We can classify the experiment as 1 factor with 2 treatments, given that the same task is operated by a subject with background knowledge and by another subject without background knowledge.

Stage 1 - all the subjects were involved in teamwork for processing documents to identify the relevant sentences (Task 1). After completing this task over the two documents, the list of sentence is randomized and distributed to the 4 subjects.

Stage 2 - each subject, working individually, processes its own queue of sentence in order to instantiate the metamodel (Task 2). This stage is double checked, in the sense that every completed sentence is published in a shared document, where all the other subject can access. To complete the stage, every instance of the metamodel must be revised and marked as reviewed.

Due to full agendas, we did not assigned limited time for the exercise, and we let subject to work in different moments. The only synchronization point was the end of stage 1 and the beginning of stage 2.

From the experiment running, we obtained some preliminary findings about the quality of the proposed approach. The most important result concerns RQ 2, i.e. the completeness of the metamodel. Indeed, from a semantic point of view, the metamodel resulted enough complete to cover all the cases of the input documents. Therefore, we we can reject null hypothesis and accept RQ 2.

A different result occurred for the linguistic layer. Subjects annotated different cases of not considered synonyms and many cases of polisemy. We can not conclude about the appropriateness of the synonym table and must reject RQ 1. The problems encountered during this phase are discussed in the following.

Finally, the four subjects agree about the usefulness of the table of properties as complementary tool for build the semantic structure of a sentence. Consequently, RQ 3 is accepted.

For what concern the validity of the experiment, we can surely refer about the low statistical power due to a limited number of participating subjects, that is compensated by a large size of input documents. Moreover, the usefulness of the tables of property is demanded to a subjective perception of the involved personnel that may suffer of fishing and error rate. A factor that may affect the internal validity of the experiment was the synchronicity of scheduled tasks due to personal agendas. This modality could have generates some interactions among personnel, therefore treatments could influence one the other.

6.2. Open Linguistic Problems

The approach we propose in the paper has several advantages: it allows disambiguation of the text, it enforces the clear identification of responsibilities, and the delegation of tasks/responsibilities. The structured form of the text may be used for the generation of a workflow corresponding to the plan.

Nevertheless, connecting the semantic layer to a linguistic analysis produces a well-grounded set of lexicon that are represented into a metamodel. However, practical usage of the semantics is actually hindered by a number of linguistic issues that we discovered, but not all of them are yet solved. In the following, we provide a list of linguistic challenges that we raise, in order to move from a manual to automatic text conversion.

Another relevant consideration is that, despite the fact a semantic layer reduces the effort required to manually convert the free-text form of the plan to the structured one, we are aware that a manual conversion is too demanding. For this reason we are also considering the adoption of an automatic text conversion approach on the basis of existing contributions in literature like [9][41][8].

In the following, we provide a classification of some linguistic issues that we encountered during the preparation of this work (this is a preliminary and not exhaustive list).

Polysemic words. Words in this category have several possible meanings [33]. Let us consider the following example: "The head of the Civil Protection Agency identifies suitable places to shelter displaced persons"; it shows the use of a synonym ('identifies' in place of 'gathers data') in the proposed sentence. This is an intriguing case of ambiguity that may be solved through the context. Indeed, the term 'identify' could also be intended as a decision to be taken about what are the best places to shelter displaced persons. However, we deduced that the sentence refers to a 'gathers data' act by looking at the rest of the sentence, where the delivered meaning is to collect geographical data for future use.

Another frequent case of polysemy concerns the word 'alert' that can be used with the intended meaning of Informing someone about an event, or it can be used to express an Order as reported in Sentence 2 (see previous section).

The problem of polysemy is frequent when interpreting natural language text, and it is amplified in an emergency plan due to the super specialized vocabulary that is used with the purpose of writing plans. This is a big issue to the objective of automatic translating the text. State of the art in automatic sense disambiguation is to date considering this a task of immense difficulty [35]. An interesting claim comes from [15] where the author observes that polysemy is easier to handle at a conceptual level, and proposes a frame-based methodology that exploits domain ontologies for reducing the negative effects of polysemic words.

Composed lexicons. We also discovered some particular cases in which the same term refers to a composed meaning, i.e. it may be expressed by composing other lexicons. An example is the term "evaluate"; let us consider the sentence:

– "Fire brigade <u>evaluates</u> possible need for resources"

this one corresponds into the following actions:

– Fire brigade <u>gathers data</u> about existing resources;
– Fire brigade <u>decides</u> on the need for additional resources.

In the example above the word in the free text "evaluates" requires two successive actions which in our structure are represented by the lexicon "gather data" and "decide".

To the best of our knowledge, literature does not report contributions that identified such a category of linguistic issues. Our agenda already contains an empirical study to be performed over a large number of emergency plans with the intent of discovering the highest number of words with a composed meaning.

Normalization via pre-treatment. There exist words in some sentences of emergency plans that at a first analysis seem to be uncovered by the proposed metamodel. Let us consider the following sentence: "The Municipal Police implements the directives of the Commissioner in any Public Order activities". The metamodel does not support the action Implement. The term is reported among the synonyms of Activate in the table of Lexicon (Table 1), however, 'Activate the directives' does not make sense and it clearly does not match with the intended meaning of the sentence.

This actually is not a limit of the approach, but rather it is a limit of the linguistic analysis. Indeed, the same sentence could be rewritten as "The Commissioner orders the Municipal Police to implement . . . ". In this case, the sentence could easily be treated by our approach, because the Order lexicon is well suited into the metamodel.

We classified this issue as a problem of 'pre-treatment' of the input text. We are convinced that several rules could be defined to solve problems in this category. For instance, switching subject and direct object of the previous sentence allows to discover that the Implement action is related to an Order.

Another relevant example concerns the Assist verb that is not covered by any of the lexicons. However, the metamodel includes Assistant as one of the properties of Action. This means that a sentence like "The Forestry Corps cooperates with the Fire Brigade in extinguishing a fire" could be normalized as "Fire Brigade have the responsibility to extinguish a fire with the support of The Forestry Corps".

We are currently working on identifying a set cases and the corresponding rules to be applied for obtaining a normalized version of a sentence. This is an ongoing work that has already provided preliminary results, and it will be completed in future works.

Relationships between sentences. As a matter of fact, a plan is not composed of a mere list of atomic sentences, rather, it is ideally a workflow including alternative branches, and, within them, sets of instructions that could be executed in parallel, in a specific order (mandatory or not), and according to predefined temporal constraints (also including temporal intervals/deadlines).

Usually, such specifications are delivered, in the free-text form of the plan, by using elements of the text (such as adverbs), or text structures (like numbered/dotted lists, and so on).

Disambiguation of such constrains is often a hard task. Just to provide an example, let us consider a bullet list of actions to be performed to mitigate the consequences of some accident (a very common situation in many plans). Is the list prescribing a mandatory order, or may the actions be executed even in parallel? We often found this is left to a common-sense interpretation of the work to be done, and therefore it strongly depends on the knowledge and skills of the reader. It is always worth remembering that in stress conditions such abilities may be altered and this may lead to a misinterpretation of the plan.

Again, we collected a set of examples, and we are deducing some cases that could help in identifying some patterns. We also envisage the need to establish a set of connectors that will be used in the structured version of the text to clearly specify relationships between sentences like: sequence, parallel, time dependencies, deadlines, and so on. Nonetheless, similarly to previous listed linguistic issues, this point remains an open challenge that is worth further studies.

7. Future Works

Worldwide, emergency plans are written in free-text form; this work arises by the need to generate a common and stable understanding of the organizational patterns that are described along several pages of text with all the flaws of natural language.

However, this is the first step of a pipeline for transforming a free-form text into an executable dynamic workflow. Indeed, in the context of N.E.T.TUN.IT, we conceived a three-steps process to address this long term objective (see also Fig. 6). The whole pipeline, together with the envised challenges are described below.

From Free-Text Plan to Structured-Text Plan, that is the focus of this paper. The use of a linguistic and semantic layers is the first step for making explicit the intended meaning of sentences.
Challenge 1. Manual translation is clearly a great burden for the persons who will manually translate these documents. To facilitate their task, we are investigating the use of semi-automatic text conversion techniques from literature [8,9,41], and the evaluation of text complexity for identifying specific parts of a text that can be simplified to support the conversion process from free-form text to its structured version [37]. Surely, instruments like WordNet [27] will play a role in the semantic tagging of input text, whereas other instruments like Bablenet [28] will be useful in the phase of extending the approach to other languages (for example in French).

Representing the Structured-Text Plan with a Modelling Notation.
The first outcome from having a structured text, is the possibility to produce a graphical notation.

This point has been preliminary explored in [29], in the context of Norwegian emergency management. The authors show how authorities and rescuers better understand plans expressed in visual and textual form, and therefore, they can be more proficient in facing unanticipated events. This study also focuses on highlighting roles in the organizations and how they have to interact. The same research recognizes some problems using the BPMN standard: some difficulty to model task duration and in reusing a process diagram from one environment to another.

Our agenda includes devising a specific modelling notation to represent an emergency plan. An essential requirement for this notation is that it will easily support adopting an adaptive middleware for the execution and coordination of the plan's activities. The definition of this notation is still a work-in-progress activity, but we have identified the main contributions it will receive from a few well-known standards. The BPMN notation is a part of that, but not so central as it could be expected. The Italian directives (the Augustus method) prescribe that a plan provides general indications for the management of the emergency, whereas details are to be defined at emergency time. For this reason, we are considering to adopt the Case Management Modelling Notation (CMMN) that allows to represent scenario-based situations, and the Decision Modelling Notation (DMN) that allows to formalize critical aspects of decisions to be taken during the development of an accident, also including decision criteria (like data values reported by personnel on scene) and the reference documents to be consulted. Finally, some parts of the free-text plans naturally convey the opportunity to introduce a model of the goals related to the responsibilities of involved stakeholders (like the authorities and the support functions described in a plan).

Classically speaking, the literature broadly promotes supplementing natural language with standard notations and languages for business processes, such as the Business Process Modeling Notation (BPMN). However, designing high-quality emergency response processes is a great challenge that involves a relevant domain knowledge and the adoption of ad-hoc process modelling techniques. Indeed, BPMN has some limitations when applied to this specific domain, some coming from the intrinsic generality of emergency plans (the details of the accident are not known when writing the plan), others from domain-specific issues (like the relevance of location-related information and the employment of multiple resources [4]).
Challenge 2. A possible to solution seems to be in complementing BPMN with other notations, namely the Case Management Model and Notation (CMMN) [25], and the Decision Model and Notation (DMN) [31]. In fact, while traditional business processes can be described by a priori de-

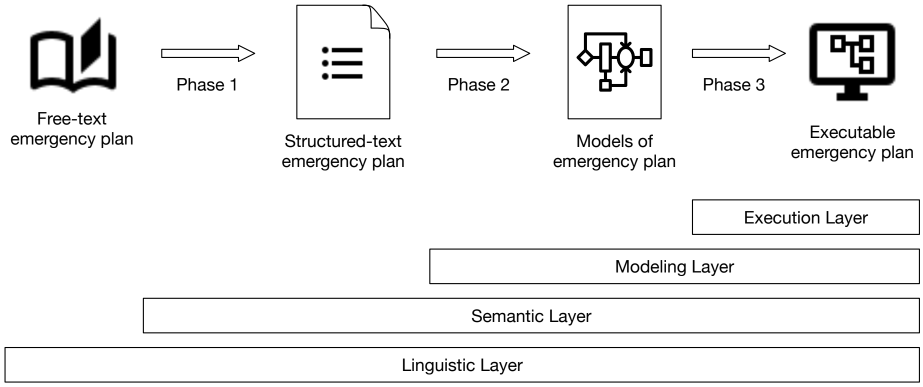

Fig. 6. The proposed process for transitioning from free-text emergency plans to executable plans

fined sequences of activities using the BPMN notation, the CMMN notation (an OMG standard) offers a more natural support for dynamic workflows, while DMN (another OMG standard) allows describing and modelling repeatable decisions within organizations.

This position is also supported by [38], where authors highlight that an emergency response is a knowledge-intensive process, modelling and automating such a process is therefore a challenging task. Authors suggest to use CMMN and build a template model for a generic emergency response process. The adoption of the three modeling notations (BPMN, CMMN, DMN) at the same time is also suggested in [22], where the authors investigate how to use a combination of these three modelling languages in the context of crisis management.

Adaptive Execution and Management of Emergency Plan. We intend to automatically produce executable workflows to coordinate the activities within an emergency plan.
Challenge 3. This is the step of our process towards the introduction of an automatic support for the management and execution of emergency plans is to work on a formal graphic notation that could well represent emergency processes. The idea is that the structured-text document will be the input to model the plan by using a notation that could be injected in some workflow management system, and automatically executed.

The definition of the best notation for such a task is a relevant challenge that is still open, and it will be part of our future research work.
Challenge 4. The context of emergency management is extremely variable and very difficult to forecast. Unexpected events may spoil the validity of pre-defined plan: the actual plan ought to emerge after the consideration of the specific accident, environmental conditions (for instance roads-, weather-conditions, and so on), assets (fuel, food, transportation, and so on), operational capability (assets, numerical consistency of assets, intervention time and need for logistic support).

An accident management system has to include relevant features of adaptive workflows (like MUSA [6,36]) considering the roles of humans, environment data (spatial-referred representation of the environment and involved assets) and finally, laws and regulation.

Just to provide an example, the communication capability is a key element of any emergency. The support to emergency communications is already existing, and great care is devoted to the adoption of standardized content protocols for messages, as the Common Alerting Protocol (CAP) [30] that is an XML-based data format for exchanging public warnings and emergencies. Although that is of relevant value, more is still to be done on the telecommunication infrastructure resilience and the automatic support for alternative delivery channels.

8. Conclusions

This paper focused on inconsistencies, redundancies, and ambiguities that hinder understanding and formalizing emergency plans. The need to convert informal documents to more rigorous conceptual models requires a semantic layer for identifying essential elements of the input text and resolving linguistic issues that may be present. To achieve this result, we extracted essential keywords through an empirical study of several Italian documents reporting different kinds of emergency plans. Our analysis allowed us to discover recurrent structures in these documents. Sometimes, these linguistic structures are evident, other times they are hidden, and some interpretation of the text's meaning is needed. We support identifying them by using a metamodel of lexicons that are detailed by a list of properties. The translation into the structured form of the text is supported by specific templates.

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Appendix A - Tables of Properties

This appendix reports the properties tables detailing the lexicons of the proposed metamodel. Each table of properties has a twofold objective: (*i*) it helps in clarifying the meaning of the word in the free-text version of the plan also disambiguating situations in which the same word fits different keywords (with slightly different meanings); (*ii*) it reports all the available information in the structured version of the text in a clear and compact form, but it remains apart from the structured sentence, and therefore it does not affect its readability.

Because of their object-oriented nature, in this work, the tables of properties specify attributes of the lexicons and may be related by inheritance relationships as descending from the metamodel specification of lexicons. For instance, the 'Order' lexicon inherits some properties from its mother class 'Action' (like precondition, temporal constraints, and so on); notably, as we will report later on, some properties are common to many keywords. Some elements, in a table of properties, are mandatory, this means they play a relevant role in defining the meaning of the corresponding lexicon, whereas others are optional. Graphically, we used an asterisk for labelling prescribed elements.

In the following we cluster the more significant elements of the metamodel in four categories (Actions, Actors, Events, Responsibilities) and we introduce one section for each of them. For the sake of conciseness, we omit some elements whose attributes can be trivially deduced from the metamodel.

I. Actions

Action is the (abstract) mother class for all the elements in this category. They inherit some of their properties from the following table:

Action	
owner [Actor]*	actor responsible for the action that operates for its enactment
on-behalf-of [Actor]	someone who delegated the action to the current owner
assistant [Actor](0..n)	supports the owner in the enactment of the action
precondition	execution context
temporal constraints	start, duration, frequency, and due time
resources	assigned resources
quality requirements	minimal expected quality of service
ack to	when present, a notification is required when completed
input [Context]	expected data from the current context necessary for the action

The following table reports the properties for '*Activate*':

Activate	
Matching with Italian words: attiva, pone in essere	
object [Resource]*	the target to be activated

The properties list for '*Arrange*' is reported below:

Arrange	
Matching with Italian words: predispone, prepara	
object [Resource]*	the asset or plan to be enacted
input [Knowledge](0..n)	expected input knowledge necessary for arranging

The following table lists the properties for '*Decide*':

Decide	
Matching with Italian words: decide, stabilisce, assimila, delibera	
background [Knowledge](0..n)	required background knowledge for taking the decision
criteria	formalized rules as a support for the decision
output [Decision]*	the outcome decision

The following table lists the properties for '*Gather data*':

Gather Data	
Matching with Italian words: raccoglie informazioni, opera monitoraggio	
data source [Context](1..n)*	data, information or event to be acquired/monitored
frequency	specifies the frequency of data acquisition

The '*Inform*' activity models the act of communicating between actors. The following table reports its properties.

Inform	
Matching with Italian words: informa, comunica, aggiorna, mantiene informato	
generate [Message evt] *	sent data, information, or acknowledgement
recipient [Actor](1..n)*	will receive the information
recurrent	when flagged, the activity is repeated every time there are updates
formal deed	legal/official document issuing the order to inform
comm. channel	how the order to inform is notified to the owner actor that will execute it

The properties of the activity '*Order*' are reported below:

Order	
Matching with Italian words: ordina, dispone	
target [Actor](1..n)*	receives (executes) the order
generate [Delegation]*	the entrusting/assignment to be undertaken
formal deed	legal/official document issuing the order
comm. channel	how the order is communicated to the target actor

II. Actor

Actor is an abstract class, Individual and Collective actors inherit some of their properties from this class. The properties list for 'Actor' is reported below:

Actor	
name*	name of the actor
owner of [Action](1..n)*	actions assigned to the actor
accountable for [Responsibility](0..n)	responsibility for which the actor is accountable for
authority over [Responsibility](0..n)	responsibilities that are delegated to a subordinate
subordinate to [Responsibility](0..n)	responsibilities that are delegated from an authority
assistant in [Action](0..n)	action(s) to which the actor contributes
produced [Event](0..n)	events generated by the actor
consumed [Event](0..n)	events received by the actor

The table specializes into two different tables, for individual and collective actors respectively.
The properties list for 'Collective Actor' (which inherits from the properties table for 'Actor') is reported below:

Collective Actor	
members [Actor](1..n)	members of the group
head [Actor]*	head of the group

The property members is not marked as mandatory because there is no need for knowing explicitly the involved members. For instance, municipal police is a collective actor, involving several members, but there is no need for knowing how many members and who are the members.

III. Event

The following table lists the properties for '*Event*' that is an abstract class.

Event	
producer [Actor]*	actor producing the event
consumer [Actor]*	actor consuming the event
has content [Context]*	the information content

Note: it is mandatory to have at least a producer or a consumer actor, having both of them is not mandatory.

The table below reports the properties of a '*Message Event*'.

Message Event	
from [Actor]*	Sender actor
to [Actor](1..n)*	Recipient actor(s)
priority	Priority of the message
comm. channel	The channel used to dispatch the message
template	Reference to the message template from the plan/adopted standard
exception	Description of how to deal with unsuccessful delivery of the message

Significantly, in some plans, we found the explicit indication of how to deal with the impossibility to reach the destination person (for instance, by contacting a specified alternate contact person). For this reason, we introduced the Exception slot in the properties list.

The following table reports the properties for 'Data event':

Data Event	
data source/target	originator of the data (for input data) or the recipient (for output data)
thresholds	thresholds that are to be monitored
values	information enclosed in the event

The 'data source/target' property represents the originator device of the data (for input data) or the recipient (for output data), for instance, a sensor or a computer application. 'Thresholds' specifies the thresholds that are to be monitored, for instance, the level of a river that should not reach one meter. In fact, the reading of the river level is the data event that has some significance for the accident management; 'values' represent the information enclosed in the event; it may include the measuring unit or any other significant information.

The presence of the 'threshold' property may seem odd in this event type since it is necessary to perform some action to compare the actual reading of a sensor with the threshold value. Although formally speaking, this is true, but in the plan, we often found that data readings become significant only when they reach or overcome some specific value (for instance, a pollutant concentration in the atmosphere). All data readings that do not reach the threshold are not significant, and thus they do not generate a 'Data' event (if a threshold is specified).

IV. Responsibility

Properties of the responsibility keyword are reported below:

Responsibility	
responsible [Individual actor]*	responsible for pursuing the goal
objective*	the result that is expected by the responsible
alternate responsible [Individual actor]	responsible when the primary one is not available or reachable
participant [Actor](0..n)	support the owner actor in performing her duty
precondition	precondition to be verified before pursuing the expected result

Several parts of the emergency plan assign responsibilities to actors involved in emergency management. However, as well as happened for decisions, responsibilities are often implicitly defined in some emergency plans. Indeed, the primary responsibilities can be extracted by the Support Functions that are explicitly listed in the plan as the Augustus Method prescribes. Other (finer-grained) responsibilities require an additional effort in the identification.

Appendix B - Sentence Templates

This appendix describes the sentence templates for deploying the lexicons proposed in the metamodel in the structured version of the text. The templates are reported in the same order as the corresponding property tables are in the previous section.

Lexicon	**Template**
Actions	
Activate	[owner] Activates [object]
Arrange	[owner] Arranges [object]
Decide	[owner] Decides [output]
Gather Data	[owner] Gathers Data about [a subject]
Inform	[owner] Informs [recipient(s)] about [message evt.]
Order	[authority] Orders [subordinate] to [do something/address an outcome] with Entrusting/Assignment
Event	
Message Event	[Formal/Informal] Message [content] From [producer] To [consumer(s)]
Data Event	Data Event [content] From [producer] To [consumer(s)] [thresholds] [values]
Responsibility	
Responsibility	When [precondition], [someone] is Responsible for [objective]

Appendix C - Examples

Example 9.1. *The objective of this example from [13, p. 77] is to introduce the concept of delegation of responsibility, and to illustrate how to deal with synonyms.*

Sentence 3 — "`The prefect orders the commissioner to enact the Roadblock Plan`[3]"

In Sentence 3, the prefect, the principal actor, orders the commissioner (the delegate) to stop traffic according to the directives of the Roadblock Plan. The plan contains instructions for blocking the traffic in certain parts of the accident area, also deviating it towards alternative roads [14]. The enactment of the roadblock plan follows an order from the prefect, which generates a delegation of type '*Assignment*'. Because the Roadblock Plan involves blocking the traffic, we explicitly add the related responsibility '*To stop the traffic*' for which the commissioner is accountable. The enactment of the plan implies the activation of the procedures necessary to stop the traffic. Therefore, we identify in '*Activate*' a synonym for '*enact*'. Fig. 7 shows the instance of the metamodel for Sentence 3.

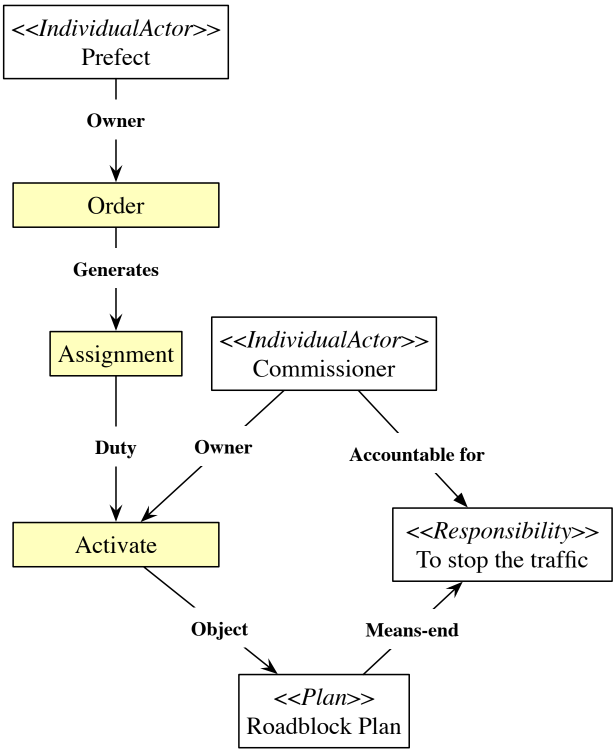

Fig. 7. Instance of the metamodel for Sentence 3.

Table 5 lists the properties related to activity '*Order*' in Sentence 3 (for convenience, only non-optional fields).

Table 5
Properties of Order activity for Sentence 3

	Order
owner	`Prefect`
generate	`Activate`
target	`Commissioner`

Table 6 lists the properties related to activity '*Activate*' in Sentence 3 (for convenience, only non-optional fields).

[3]Freely translated from the Italian 'Piano Operativo Cancelli, POC'

Table 6
Properties of Activate activity for Sentence 3.

	Activate
owner	`Commissioner`
object	`Roadblock Plan`
on-behalf-of	`Prefect`

The main activity of Sentence 3 is *Order*; according to the template of this activity, whereas the second part of the sentence in a dependent phrase that refers to an '*Activate*' action. It is worth noting that the sentence template for '*Order*' (i.e. `[authority] Orders [subordinate] to [do something/address an outcome] with Entrusting/Assignment`) may refer either to an Assignment of a task or the Entrusting of a responsibility. The final part of the template allows distinguishing these two cases, making explicit the intended meaning that was hidden in the original sentence. The result is the following:

Structured Sentence 3 — `“[Prefect] orders [Commissioner] to [stop the traffic] with assignment. Consequently, [Commissioner] Activates [Roadblock plan] ”`

It is worth noting the clause 'consequently' used to start the second sentence. This derives from the fact that the two sentences are related by a cause-consequence relationships. This is intuitively visible in the original sentence, but we are studying how to derive these kinds of relations (causality, temporal and so on...) directly from the metamodel. This aspect will be further explored in future works.

Example 9.2. *This example shows how to deal with a structured sentence where many actions intertwine through the use of a common knowledge asset. The sentence is the following [13, p. 94]:*

Sentence 4 — `“The head of civil protection agency activates its cartography support service at the civil protection headquarter to prepare useful maps for the management of the emergency and the subsequent phase of return to normality.”`

Sentence 4 involves one actor, the head of civil protection agency, and two actions (the verbs in the sentence): activating the cartography support service and deciding which maps to use. Fig. 8 represents these two capabilities as individual activities, the first owned by the head of civil protection agency and the second by a '*HumanAsset*', the operator of the cartography support service. More precisely, we specialize the activities in '*Activate*' and '*Arrange*' respectively, for which there is matching with the metamodel. The head of civil protection agency activates a human resource (the operator of the cartography support service) that is skilled for accessing the repository of maps of the territory. The operator uses the system to select pertinent maps to decide where to (spatially) dispatch the necessary resources for addressing the emergency: we model this by using the '*Arrange*' activity which output is a Knowledge (useful maps). Moreover, given each map in the repository is intended to support for the resolution of the emergency, there is a '*means-end*' relationship towards the 'emergency management' responsibility.

Concluding, we do not model the part of the sentence '*at the civil protection headquarter*' because, so far, the proposed metamodel does not allow modeling the spatial dimension. Nevertheless, we pinned this aspect in our research agenda.

Table 7 lists the properties related to the activities '*Activate*' (for convenience, only the necessary fields).

Table 7
Properties of activity Activate for Sentence 4.

	Activate
owner	`Head of civil protection agency`
object	`Cartography support service`

Table 8 lists the properties related to the activity '*Arrange*' (for convenience, only the necessary fields).

Table 8
Properties of activity Arrange for Sentence 4.

	Arrange
owner	`Cartography support service`
object	`Useful maps`

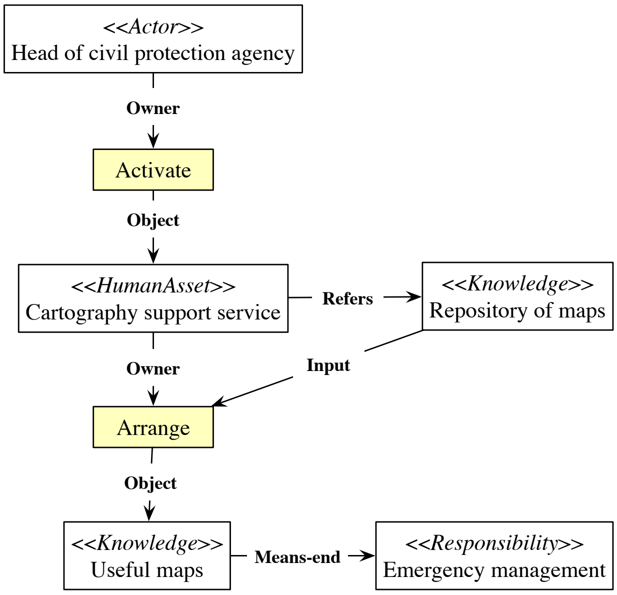

Fig. 8. Instance of the metamodel for Sentence 4.

The activities '*Activate*' and '*Arrange*' have a similar template (`[owner] Activates/Arrange [object]`). By pivoting the sentence on these two activities, we obtain the following structured text:
Structured Sentence 4 — "`[Head of civil protection agency] activates [cartography support service]. [Head of civil protection agency] arranges [useful maps] with a positive contribution to [emergency management]`"

Example 9.3. *This last example aims at illustrating how to use the metamodel and related instruments to identify and deduct missing elements in the text. The sentence, extracted from [10, p. 55], is quite simple:*

Sentence 5 — "`The police take appropriate measures to ensure the rapid flow of emergency vehicles and the fast evacuation of the population .`"

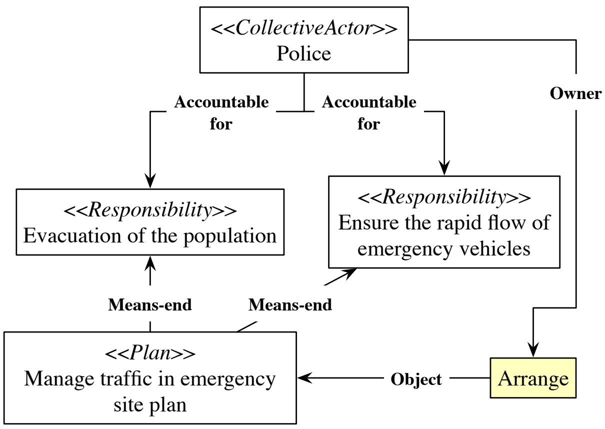

Fig. 9. Instance of the metamodel for Sentence 5.

In Sentence 5, we model the police corp as a collective actor, it has organizational capabilities and can contribute with several activities to the enactment of an emergency plan. We identify in '*Arrange*' a synonym for '*takes appropriate measures*'. The activity '*Arrange*' is linked to the plan that will be conceived and enacted. Sentence 5 presents uncertainty as it is not specified which plan addresses the goals: we solve this uncertainty by introducing a label for the plan: '*Manage traffic in emergency site plan*'. The original meaning of both ensuring the rapid flow of emergency vehicles and evacuating population is represented in the metamodel by two responsibilities associated to the cited plan by a Means-end relationship. Fig. 9 shows the instance of the metamodel for Sentence 5.

Table 9 lists the properties related to the '*Arrange*' activity (for convenience, only non-optional fields):

Table 9

Properties of Arrange activity for Sentence 5.

	Arrange
owner	`Police`
object	`Manage traffic in emergency site plan`

The template of the '*Arrange*' activity is the following: `[owner] arranges [object]`. By using this template, we obtain the following structured text:

Structured Sentence 5 — "`[Police] arrange [Manage traffic in emergency site plan] for [Ensure the rapid flow of emergency vehicles] and [Evacuation of the population]`"