



Análise Operacional e Engenharia Logística: Apoio à Decisão

Estruturação da alocação de recursos na fase de resposta à catástrofe natural utilizando o Pensamento Focado em Valores (VFT)

Structuring the resource allocation in natural disaster response phase using the Value-Focused Thinking (VFT)

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Resumo

Muitos países vivenciam todos os anos várias catástrofes naturais ou catástrofes humanas que levam milhares de milhões de almas. Mecanismos para prever vários tipos destes desastres naturais foram desenvolvidos na tentativa de minimizar o número de vítimas, tendo atingido um nível de sucesso bastante elevado. No entanto, mesmo com todos estes sistemas de previsão, as catástrofes naturais ainda acontecem e continuarão a acontecer. Depois de uma catástrofe ter ocorrido, a fase de resposta é a principal forma de salvar as pessoas afetadas. Muitos países, organizações e outros atores envolvidos nesta fase trabalham de forma isolada e geralmente de forma desordenada. Desta forma, a fase de resposta torna-se uma atividade difícil e dispendiosa. Este artigo pretende sugerir um ponto de partida para estruturar e organizar a fase de resposta de uma catástrofe, com uma aplicação sistemática de um dos Métodos de Estruturação de Problemas (PSM), centrada na alocação de recursos para o salvamento das vítimas.

Abstract

Many countries experience every year several natural disasters or human catastrophes that take thousands of millions of souls. Many mechanisms to predict these natural disasters have been developed to minimize the number of victims, reaching such a successful level. However, even with all these predictive systems, natural disasters still happen and will continue to occur. After a catastrophe occurred, the response phase is the primary way to save affected people. Nowadays, many countries, organizations, and other actors involved in this phase work alone without integration. This way, such a phase becomes expensive and challenging work. This paper aims to suggest a start point to structure and organize the response phase of a disaster, with a systematic application of the Problem Structuring Methods (PSM), focused on the resource allocation for victims rescue.

I. INTRODUCTION

According to the Centre for Research on the Epidemiology of Disasters (CRED), our planet suffered 1.939 natural disasters in the last five years, like floods, droughts, and earthquakes. The total number of affected people reached almost nine hundred million, between killed, injured, and homeless, resulting in approximately US\$ 820 billion of material damages [1], observed in Table 1.

A disaster is a sudden, catastrophic event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using their resources [2]. Though often caused by nature, disasters can have human origins. A disaster occurs when a hazard affects vulnerable people or when the combination of threats, vulnerability, and inability to reduce the potential negative consequences of risk results in disaster.

TABLE I. EM-DAT: THE OFDA/CRED INTL DISASTER DATABASE SOURCE: ADAPTED FROM EMGY EVENTS DATABASE EM-DAT

Period	2009 /2013
Disaster	Natural
Disasters	1.939
Killed	398.246
Injured	1.026.546
Affected	891.411.731
Homeless	6.086.486
Total affected	898.524.763
Total Damage	\$ 816.781.617.000

Such events, defined by [3], consist of a disaster management cycle composed of four distinct phases: mitigation, preparation, response, and recovery. The first and second phases are positioned before the disaster, while the response and recovery phases happen after the occurrence. That disaster management cycle is shown through Fig 1.

This work deals with the response phase that begins after the disaster and can execute help and support actions. As a result, the number of dead and injured people can be reduced by a fast and more efficient rescue.

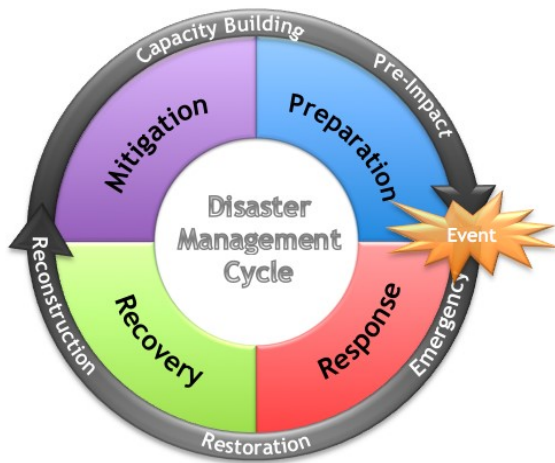


Fig. 1. Disaster management cycle

In many places and regions, it is observed low or absence of capabilities to execute these fast and efficient actions. They have not even an efficient system of rescue and support. Many goodwill people, organizations, or institutions are trying to help, disorderly and singly, using excessive or insufficient resources to provide an efficient service.

It is possible to extract some characteristics from this problematic situation because there is a complex problem with multiple actors, many uncertainties, and even some conflicts of interest.

Such characteristics give a perfect environment for the application of Problem Structuring Methods (PSM)

This paper contains five sections. The following section presents a review of the PSM applied in the resource allocation problem in the natural disaster response phase. Section 3 gives an example of the application of such methodologies. Section 4 the expected result from the previous section, and the paper is concluded in section 5.

II. THE PROBLEM STRUCTURING METHODS

According to [4], the problem structuring methods (PSMs) arise from managers and researchers' necessities to face some new problems that could not be solved using such existing quantitative OR methods, known as Hard OR.

The traditional or classical Operational Research (Hard OR) was an excellent way to solve well-structured problems in organizations or systems with a tight hierarchy and a well-defined and repetitive task generating reliable data and a consensus of priority [5]. Nevertheless, these traditional methods could not support problems that did not have measurable units perform data or a well-defined problem, which constitutes some categories of decision problems involving politics, power, and social demand of organizational life [4].

So, Soft OR school came to deal with the whole laid by the Hard OR and can be characterized by the stipulations of the usage of the Systems Age Thinking principles for problem structuring, Hermeneutic-Phenomenology principles for the qualitative modeling, and used for an organization or system where all the actors participate actively in the problem structuring and problem-solving process [6].

PSMs can be conceptualized as a set of Soft OR approaches for proper construction and resolution of a problematic situation [6]. [7] give some characteristics of these methods, based on systems thinking, with primarily qualitative constructed models that may take account of several criteria without tradeoffs for optimization and can be integrated with hard and soft data.

The general idea of the PSM is to reach a complete situational awareness about the problematic situation to capture and express it in some form (cognitive maps, rich pictures, casual maps, and decision graphs). From this representation, the situation will be explored, using techniques/analyses to development of an enhanced understanding, to enable a shared language to be developed, and through using the representation(s) to act as transitional objects helping a group negotiate towards a set of improvements and actions to resolve the situation [4].

The problematic situations for which PSMs aim to provide analytic assistance are characterized by multiple actors, differing perspectives, partially conflicting interests,

In 1996, under a Soft OR context, Ralph L. Keeney stated that the conventional way to solve a problem situation nowadays (decisionmaking) focuses on alternatives. Therefore, when facing a decision problem, it is natural to think first about the alternatives to solve it and only after, to think about our values to choose among these.

Decisions situations usually arise from others actions: enemies, government, stakeholders, friends, and anyone else; or by circumstances: recessions, opportunities, and natural disasters. Faced with these decision problems and forced by the time pressure, we make the "best" choice among some that we have at hand. Such a situation is referred to by [8] as alternative-focused thinking and is a reactive way to face the problem.

A proactive way to solve a problem situation is to think about values first because it matters in any situation. Then, after defining these values and finding the "fundamental objectives", only later is supposed to think about alternatives, which are means to achieve the objectives arisen from the values [9].

With these concepts in mind, Ralph L Keeney developed Value-Focused Thinking (VFT) to identify desirable decision situations and then reap the benefits of this situation by solving them. The VFT makes use of the individual's values and judgments to extract important types of objectives. Then, after the statement of these objectives (strategic, fundamentals, and means ones), it is possible to think about alternatives to achieve them.

Another essential concept about VFT is that the hard thinking focused on values will bring up better alternatives and guide identifying desirable decision situations, which are known as decision opportunities.

Significant effort is allocated to articulating values. This articulation of values in decision situations comes before any other activities. The articulated values are explicitly used to identify decision opportunities and to create alternatives. With this concept in mind, value-focused thinking help to create better decision situations with better alternatives, leading to better consequences.

[9] use some "steps" for structuring a problem where the first one is to identify objectives, using some techniques like thinking about objectives without limitations, thinking on a "Wish List". It is possible to use alternatives - asking about desirable and undesirable alternatives for a stated objective, and it will become a new source of objectives. Another way to identify an objective is to use consequences, where consequences that matter are pretty easy to identify associated objectives. The Keeney complete list of techniques to use in identifying objectives can be viewed in Table 2.

TABLE II: TECHNIQUES TO USE IN IDENTIFYING OBJECTIVES

<p>1. A wish list. What do you want? What do you value? What should you want?</p> <p>2. Alternatives. What is a perfect alternative, a terrible alternative, some reasonable alternative? What is good or bad about each?</p> <p>3. Problems and shortcomings. What is wrong or right with your organization? What needs fixing?</p> <p>4. Consequences. What has occurred that was good or bad? What might occur that you care about?</p> <p>5. Goals. Constraints and guidelines. What are your aspirations? What limitations are placed upon you?</p> <p>6. Different perspectives. What would your competitor or your constituency be concerned about? At some time in the future, what would concern you?</p> <p>7. Strategic objectives. What are your ultimate objectives? What are your values that are absolutely fundamental?</p> <p>8. Generic objectives. What objectives do you have for your customers, your employees, your shareholders, yourself? What environmental, social, economic, or health and safety objectives are essential?</p> <p>9. Structuring objectives. Follow means-ends relationships: why is that objective important, how can you achieve it? Use specification: what do you mean by this objective?</p> <p>10. Quantifying objectives. How would you measure the achievement of this objective? Why is objective A three times as important as objective B?</p>
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The VFT makes use of three different kinds of objectives, always focusing on values. They are the strategic objective, the fundamental objective, and the means objective.

The objectives are not fixed concepts, and they may change depending on which decision context it refers to. For example, the most "valuable" or the first principle of some person or organization in one specific context will be the strategic objective, the highest fundamental objective level, the one who will guide all of the others objectives.

The fundamental objectives are specifications of the immediately upper-level fundamental objectives, and they are the end, the mission to be achieved.

To achieve the fundamental objectives: there are some means, ways, or methods to do it, known as means objectives.

Almost all experts on decision-making say that it is crucial to list your objectives. However, they are not specific about how to do it or how to use the objectives to guide your thinking. Value-focused thinking includes numerous procedures to assist in this way: First, several techniques help compile an initial list of objectives; Second, these objectives are categorized as means or ends objectives and logically structured; Third, several procedures assist in using the objectives to create alternatives. Fourth, the objectives are examined to identify valuable decision opportunities.

Identifying objectives; The most obvious way to identify objectives is to discuss the decision situation. The process requires significant creativity and hard thinking, and you begin by asking the decision-maker, "what would you like to achieve in this situation?" The responses provide a list of potential objectives and a basis for further probing.

There are several techniques listed in Table 1 that stimulate the identification of possible objectives. These techniques provide redundant guidance for identifying objectives, but redundancy is not a shortcoming. It is much easier to recognize redundant objectives when explicitly listed than to identify missing objectives.

When asking an individual to express objectives, clarify what is needed is a list of objectives without ranking or priorities. To expand the list, you may ask, "If you had no limitations at all, what would your objectives be?" Similarly, you may ask what elements constitute the bottom line for the decision situation and the decision-maker.

Many words, such as tradeoffs, consequences, impacts, concerns, fair, and balance, should trigger questions to make implicit objectives explicit. If a decision-maker says, "Tradeoffs are necessary", ask tradeoffs between what and what. If a decision-maker says, "The consequences should be fair", ask fair to whom and what it means. If the decision-maker (DM) seems to stop and think, ask what the thoughts are. Responses to these questions may lead to other queries as appropriate.

Often one begins to think hard about a decision situation only after some alternatives become apparent. Articulating the features that distinguish existing alternatives provides a basis for identifying some objectives. For example, in considering alternative sites for an airport, one feature that differentiates the alternatives might disrupt citizens due to high noise levels. It suggests the apparent objective of minimizing disruption from noise. You might ask respondents to list desirable and undesirable features of alternatives and use these to stimulate thought about objectives.

To find fundamentals objectives: it is suggested to make use of strategic objectives carefully considering how alternatives in the current decision context may contribute to the strategic objectives. The response indicates potential fundamental objectives for the problem at hand.

The use of generic objectives different from strategic objectives because it refers to the concerns for ALL decision-makers in a SINGLE decision situation or one decision context, where major categories of objectives matter, for example, economics, health, safety, and environmental impacts. Discussion about each type should lead to the development of specific objectives. (Strategic Objective = single DM for all situations).

After objectives identification, the second step should organize these objectives, structuring objectives - after all, objectives are defined, separate the fundamentals from the means objectives.

The WITI test (Why is this objective important in the decision context) is used to separate fundamentals and means objectives. If the answer is that the objective is one of the fundamental reasons for interest, it is a candidate for the fundamental objective. Whereas the answer is essential because of its implications for some other objective, it is a means objective. Attempt to control the consequences in identifying key objectives, which must be in the same decision context.

In a fundamental objectives hierarchy, the lower-level objective is a part of a higher-level objective. The higher-level objective is defined by the set of lower-level objectives directly under it in the hierarchy. This lower-level objective should be mutually exclusive and collectively should provide an exhaustive characterization of the higher-level objective. There should be at least two (max four) lower-level objectives connected to any higher-level objective.

Deciding what is essential requires value judgments. Value judgments are necessary to construct fundamental objectives hierarchy. In a case of public problems, the public's values, or values expressed by representatives (such as legislators or regulators), are those appropriate to construct the fundamental objectives hierarchy [9].

The means-ends objectives (means-ends network), on the other hand, may have complex relationships (lower-levels may conduct many others higher-levels, not only to its immediately upper-level above). Therefore, it should answer the question, "What would you like to achieve in this situation".

Deciding how to achieve a higher-level objective requires factual knowledge. Judgments about facts are needed to construct means-ends networks. So in the upper case, individuals with expertise about technical or factual aspects of the decision situation are often much better qualified than the public or its representatives to construct the means-end objectives network [9].

It is also vital the measure the fundamental and means objectives to enhance the process and benefits of value-focused thinking. The measurements of their achievement can provide valuable insights and clarify its meaning. Moreover, it may create desirable alternatives, maybe even an obvious "solution" to a problem.

[9] use the attribute concept meaning the degree to which an objective is achieved is measured. Like the objectives, the assignment of attributes to measure them always requires value judgments that can lead to important insights from value-focused thinking. He specifies three types of attributes, i.e., natural, constructed, and proxy ones.

The natural attribute usually has a familiar and direct sense. For example, if an objective is minimizing cost, the attribute "cost measured in dollars" is a natural attribute. Likewise, the objective of reducing fatalities has the "number of fatalities" as a natural attribute.

A constructed attribute is developed specifically for a given decision context, in which there is no natural attribute. Eventually, by the time and use, a constructed attribute may tend to take on the features of natural ones, i.e., Richter scale for earthquake magnitudes. Sometimes, it is challenging to identify or find natural or constructed attributes. In this case, will be needed the development of an indirect attribute, known as proxy attribute.

Another interesting approach from the Soft OR is cognitive mapping (CM). It is a technique that explores individuals' perspectives about a situation, extracting their world viewing and representing them on a map, which will help operational researchers work on various tasks. These tasks include; providing help with structuring messy or complex data for problem-solving, assisting the interview process by increasing understanding and generating agendas, and managing large amounts of qualitative data from documents. While Cognitive Mapping is often carried out with individuals on a one-to-one basis, you can use it with groups to support them in problem-solving [10].

Cognitive Mapping is a technique used to structure, analyze and make sense of accounts of problems. These accounts can be verbal - for example, presented at an interview or documentary. Thus, cognitive mapping can be used as a note-taking method during an interview with the problem owner and provides a useful interviewing device if used in this way. Alternatively, you can use CM to record a transcript of interviews or other documentary data in a way that promotes analysis, questioning, and understanding of data [10].

The technique is founded on George Kelley's theory of persona. The theory suggests that we make sense of the world to predict how, all things being equal, the world will be in the future, and decide how we might act or intervene to achieve what we prefer within that words - a predict and control view problem-solving [10].

III. THE PSM AND THE RESOURCE ALLOCATION PROBLEM

The decision problem in this paper, which is analyzed, is the natural disaster rescue victim's resources allocation on its response phase. According to [6], the first step to structure a problem in a problem decision is recognizing a decision problem. Then, we extract the strategic objective from the decision context, which will guide all decisions and decision opportunities. An essential part of the decision problem is the definition of the decision context, which is the response phase of a catastrophe.

Dealing with a public interest problem, the adequate stakeholders to evaluate and create the fundamental objectives are the own public (or their representatives).

Here, we have some valuable tools, like separated interviews to compound a congregate cognitive map or a workshop, enabling the discussion about the decision situation.

To the present, the author conducted some separate interviews with different people, composed and validated a congregated cognitive mapping to illustrate the public opinion about the decision context values and fundamental objectives.

So, this step, which requires a group of public representatives, was concluded to specify values or objectives. As suggested by [9], a simple question is used to initiate this process (identify objectives): "What would you like to achieve in this situation?" For our problem, the group readily agreed about the identification and specification of two values: 1. Save the maximum number of human lives; 2. Reduce to a minimum the cost of the response phase. These values may be viewed as the fundamental objectives that are supposed to conduct to accomplish the strategic objective.

The time of response is a fundamental task to save lives in the response phase. So, the same group, thinking about value number 1, designated as a fundamental objective, agreed about these others still fundamental objectives, which may also be viewed as better "specifications" of the value number 1 and so on: 1.1. Maximize the number of rescued victims and 1.2. Minimize rescue team fatalities. Exploring 1.1, they thought about: 1.1.1. Rescue injuries; 1.1.2 Rescue homeless (the ones who have conditions to move) people and 1.1.3. Extraction of the deaths (to avoid epidemics). The number of alternatives may vary and depend on the creativity of the group.

Working on fundamental objective number 2 (Reduce to a minimum the cost of the response phase) the same way as did with number 1, we have 2.1 Optimize the resources allocation; and 2.2. Improve voluntary participation.

We can observe that when working with value-focused thinking, it is necessary to think about values. It means that, sometimes, we need to take a step back to look at the origins of the decision problem. Then, to find out the true value that will guide our present objectives and alternatives, instead of going direct to the possible constrained-free alternatives we already know.

We may observe that the fundamental objectives are specifications from the immediately upper-level objective, always with the strategic objective as the highest fundamental objective. These lower levels are essential to clarify and even discover new other objectives.

For example, the fundamental objective 2.1 (Optimize the resources allocation on response phase) was divided as 2.1.1. Minimize the rescue activities cost; and 2.1.2. Optimize the victim's support cost. Table 3 lists some possible fundamental objectives for the resource allocation problem at the response phase.

This step may continue until the group feels comfortable that all alternatives (or objectives) about the values of the strategic decision context were exposed, covering all the fundamental objectives for this specific decision context.

The process of structuring objectives results in a deeper and more accurate understanding of what one should care about in the decision context. It also helps to clarify the decision context and to define the set of fundamental objectives. Finally, it leads to a more apparent distinction between fundamental and means objectives.

Structured objectives provide the basis for any use of quantitative modeling. The fundamental objectives hierarchy indicates the set of objectives over which attributes should be defined.

TABLE 3: FUNDAMENTAL OBJECTIVES HIERARCHY FOR RESPONSE PHASE RESOURCE ALLOCATION

1.	Save the maximum number of human lives.
1.1.	Maximize the number of rescued victims.
1.1.1.	Rescue injuries
1.1.2.	Rescue homeless.
1.1.3.	Extraction of the deaths
1.2.	Minimize rescue team fatalities.
2.	Reduce to a minimum the cost of the response phase.
2.1.	Optimize the resource allocation.
2.1.1.	Minimize the rescue activities cost.
2.1.1.1.	Maximize victims search system.
2.1.1.1.1.	Minimize information speed.
2.1.1.1.2.	Maximize victims search speed.
2.1.1.1.3.	Maximize victims search speed.
2.1.1.2.	Minimize victims rescue system costs.
2.1.1.2.1.	Minimize rescue unit's allocation speed.
2.1.1.2.2.	Maximize rescue unit's allocation efficiency.
2.1.1.2.2.1.	Maximize rescue unit's availability.
2.1.1.2.2.2.	Minimize rescue unit routing time.
2.1.1.2.2.3.	Minimize rescue units routing distance.
2.1.1.2.2.4.	Maximize the number of victims rescued/rescue units.
2.1.2.	Optimize the victim's support cost.
2.2.	Improve voluntary participation.

An example of the fundamental objectives hierarchy may be seen in Fig 2.

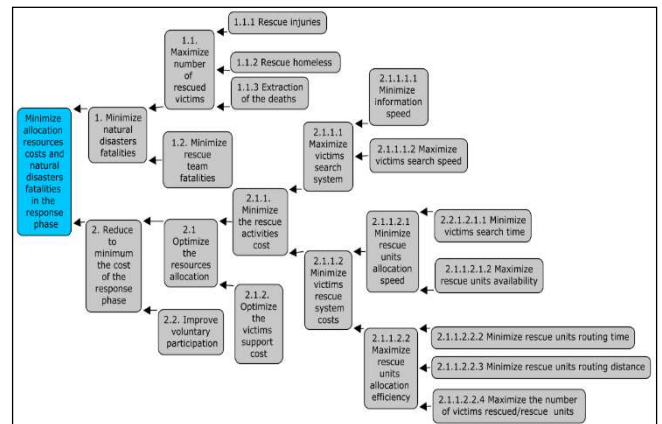


Fig. 2. Fundamental Objectives Hierarchy

With the fundamental objectives in hand, form a second group to deal with the means objectives. It is supposed to join the best and more experienced individuals, from all stakeholders involved, with expertise about technical or factual aspects in the decision context. Therefore, members from fireman, police, rescue-teams, army, navy, air force, and any other organization or institution with active participation in the specific decision context. In addition, it should have pilots, medics, rescuers, investigators, guards, among others.

Each fundamental objective should be exposed at one time. First, the facilitator should explain the aim of the meeting and stimulate the group to think with no limit and no constraints to enable the most significant number of creative ideas. Then, collect all the alternatives indicated by the individuals for each objective to form the means-ends objectives networks.

As an example of this step, we could begin putting in a debate the first fundamental objectives, from Fig.2, asking "how do we minimize natural disaster fatalities in a response phase of a catastrophe?". Then, naturally, alternatives will come, like: a) It is desirable a swift execution of the rescue; b) It must be allocated the maximum number of rescue-teams/units; c) It must be allocated a safe and adequate place to receive the deaths, injuries, and homeless.

Explore new alternatives to form lower-levels means objectives through the question of "how do we ...?". For example, following the option "a)", "how do we execute a swift rescue?". The answers should come like a.1) we must have a very efficient system to activate and designate the rescue units when needed; a.2) we must have an always-ready rescue unit to be designated; a.3) minimize de rescue units routing time; and so on.

Exploring "a.1)", how do we make a very efficient system to activate and designate the rescue units? For example, we may have: a.1.1) having a command-and-control center; a.1.2) having an algorithm (software) to support the decision about what unit-rescue will be designated to what; and so on. This step is observed in Fig 3.

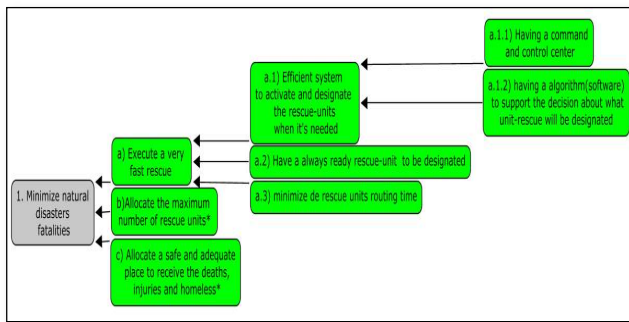


Fig. 3. Means-ends Objectives Network

With these examples, we already have a well-structured problem, well-defined fundamental objectives, and means objectives that will guide how to achieve the formers.

Fig 4 shows the relationships between several objectives hierarchies and an objectives network for the resource allocation problem in the natural disaster response phase.

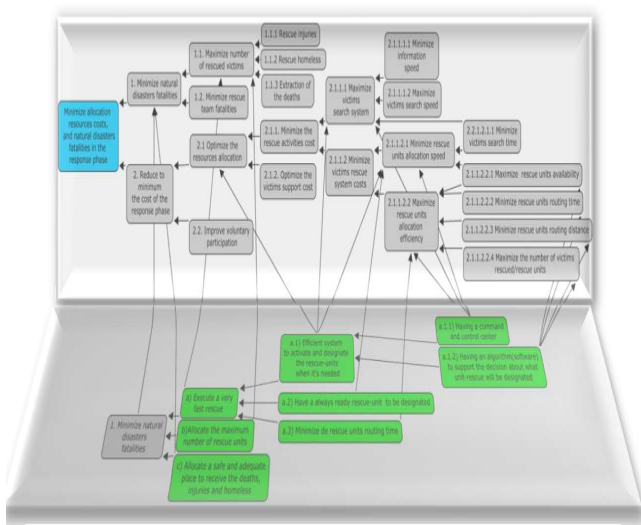


Fig. 4. Relationships between objectives hierarchies and an objectives network for resource allocation problem in the natural disaster response phase.

The application of Value-Focused Thinking (VFT) enables the use of quantitative techniques (use of attributes and quantifying objectives with a value model), which will clarify the objectives already expressed by the previous qualitative ones. However, this paper's purpose deals only with problem structuring, and we are focusing on the Soft OR. Therefore, we stop at this point with the reached objective of structuring a complex problem with multiple actors, differing perspectives, partially conflicting interests, significant intangibles, perplexing uncertainties [5].

IV. EXPECTED RESULTS

As said before, this paper aims to suggest a way to structure such a complex problem like a resource allocation on the natural disaster response phase using value-focused thinking (VFT).

It is expected to provide a guideline or a starting point to interested organizations, institutions, or anyone who works with natural disasters management to improve, review, or begin planning, organizing, or structuring a system or a command and control center for crisis management.

We wish to support the decision-maker to take a fast and effective decision to minimize the number of victims from a natural disaster, enabling improved rescue services and more safety for the population.

V CONCLUSIONS

The PSM arose to support and try to solve some problematic situations where the traditional or Hard OR could not be applied. This complicated situation, also known as a "messy", is usually characterized by the presence of a complex problem, with multiple actors, eventual interest conflict, significant intangibles, and uncertainties.

The solutions provided by the PSM usually refer to the clarification, identification, or characterization of a problematic situation.

Such a method from the Soft OR (PSM) focuses on structuring, finding, and defining objectives. It is possible and recommends using one but several methods, methodologies, tools, or techniques of PSM in some situations. For example, for any particular complex problem, which is supposed to contain many stakeholders and uncertainty, there is likely to have a dynamic system composed of many small systems (problems) in a significant decision context. Each of these small "pieces" will require some specific method, methodology, tools, or technique of the PSM.

After that, with these objectives in hand, we can apply some Hard OR to find any best local solutions to achieve these objectives. This mixture of Soft-Soft OR and Hard-Soft OR methods to find and probably solve (or improve) a problematic situation is known as Multimethodology.

Applying this Multimethodology, using the Soft-Soft OR methodology of value-focused thinking and the cognitive maps tool, we designed a guideline or a starting point to organize, plan, structure, or improve resource allocation in the natural disaster response phase.

With such a complex problem, we can work as deep as we want, even with every particular operation and procedure details definition. So, this improvement is one opportunity for future works.

For future works, it is also possible, thinking about Soft OR and PSM, applying other multimethodology combinations as the use of Soft System Methodology, SODA maps, and Future Scenarios.

Another interesting multimethodology approach should aggregate Hard OR as linear programming to network optimization and transportation assignment problems to rescue unit allocation, goods delivery, drug distribution, and medical services allocation.

This Soft-Hard OR mixture should be a powerful application of Operations Research to reach the best and most complete solution and decision analysis tool to a complex problem that could not be solved entirely with individual Soft or Hard OR analysis separated.

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