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Creating problem-solution scenarios by using Future Wheels and OTSM-TRIZ: Enhancing drone application in wildfire problems in Chile.

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***Abstract:** This research proposal integrates two innovative methodologies—The General Theory of Powerful Thinking (OTSM-TRIZ) and the Futures Wheel, a tool for analyzing various scenarios—to provide decision-makers with new insights into future developments. The objective of this study is to propose a novel, combined methodology that offers a more holistic approach to resolving conflicts and planning for various situations. By merging inventive problem-solving techniques (OTSM-TRIZ) with scenario analysis (Futures Wheel) for a single event, change, or situation, this integration enables simultaneous and strategic application across different industrial contexts. The validation of this combined methodology is demonstrated through a case study: the development of an intelligent multimodal vision system using drones for real-time monitoring and mitigation of wildfires across extensive, unstructured territories. This approach highlights the potential for these integrated methodologies to enhance strategic planning in complex and dynamic environments.*

Keywords—OTSM-TRIZ, Future Wheels; Vester Matrix

I. INTRODUCTION

The strategic planning research field in several companies is constantly searching for more suitable and reliable methods to anticipate or visualize the effects of their decisions or solutions [1]. In many cases, companies frequently rely on the knowledgeable information from their CEOs, industry experts, or even operators [2]. However, the use of expert opinion can be risky for companies because even experts can be biased and may not have an overall framework on how different systems, such as technological, social, environmental, and economic, change [3].

In the literature, various methods are used in planning and strategic analysis that consider expert opinion a key element to better understand the future, such as the Delta Model, Porter Matrix, and SWOT analysis, among others [4-6]. Many of these methods have been improved using the Delphi approach to reduce expert bias [7]. From a practical viewpoint, the previously mentioned methods in terms of forecasting can be considered "static" for some planning purposes. In other words, they do not allow for proper conclusions in some scenarios where a time perspective is required. There are also other methods, such as Focus Groups, Future Wheels, Interviews, and Participatory techniques, that are more prospective (i.e., use knowledge to build scenarios based on stages of analysis) [5,7]. From a practical point of view, these forecasting methods may seem more suitable from a strategic planning perspective [8]. However, these methods also face issues related to the knowledge gathering process, qualitative trend analysis, and cause-and-effect relationships in decision-making.

It is interesting to note that strategic planning and forecasting based on expert opinion lack a systemic process for two main issues. First, strategic planning and forecasting based on expert opinion do not consider emerging problems that can arise during solution implementation as an essential element. Second, these approaches recognize prioritization but do not consider a systematic and structured analysis of the method.

With this premise, some authors have attempted to introduce TRIZ as a key element to develop forecasting analysis [9], stimulating creativity but using a more directional perspective of the problem. The logic of using TRIZ as a forecasting tool is related to: i) bringing new ideas through a systematic approach to technology; ii) using TRIZ postulates to understand benefits and limitations in the decision-making process; iii) using a time perspective while considering both positive and negative effects in short periods for solution development. It is interesting to mention that TRIZ was introduced as a problem-solving theory, but currently, the application of TRIZ in strategic planning has increased considerably [3, 10].

In fact, the evolution of OTSM-TRIZ has been used by several authors to create scenario analysis to obtain a more realistic approach to the situation being planned [11-13]. Nevertheless, OTSM-TRIZ has always been used with a short-term perspective rather than a long-term perspective. Indeed, OTSM-TRIZ can be considered a methodology that generates solutions through fact-based problems to establish future scenarios [11, 12]. Consequently, the anticipation of future scenarios allows for risk reduction through the generation of solutions. However, OTSM-TRIZ needs to be enriched to be more reliable in terms of possible trends that can emerge within the strategic planning view. Given this premise, the following article attempts to improve the application of Futures Wheel by using a more structured approach such as OTSM-TRIZ. Additionally, this integration will be enriched with a more quantitative approach like the Vester Matrix, in order to prioritize the main strategy to follow when several scenarios are created. To validate the authors' contribution, a real case study was implemented using drones to mitigate wildfires and analyze how different scenarios affect the expected solution.

Forest and wildland fires are a global risk, affecting over 350 million hectares annually. As example, in Chile, between 2013 and 2014, approximately 6,335 forest fires burned around 105,992 hectares. A significant event in April 2014 saw a wildfire spread into the city of Valparaíso, resulting in 15 fatalities, over 500 injuries, destruction of 2,900 homes, burning of 1,000 hectares, and displacement of 12,500 people.

In this context, Chile's Forestry National Corporation (CONAF) is the institution responsible for managing forest fires, with the capability to trigger alarms within five minutes of detection. However, limitations exist in monitoring fire evolution and coordinating emergency resources, highlighting an area for improvement to reduce human and infrastructural losses. For instance, limited research exists on automated fire monitoring in large-scale forest fires, making the development of such a system an opportunity to address a critical safety issue and advance research in this area. This proposed methodology aims to envision a more holistic and realistic scenarios in this emerging research field.

II. A BRIEF FRAMEWORK TO UNDERSTAND NEED OF AN ENRICHED FUTURE WHEEL ANALYSIS BASED ON OTSM-TRIZ FOR STRATEGIC PLANNING FIELD.

In this section is presented the main framework to understand the authors proposal.

A. Futures Wheel to envision future scenarios.

Future Wheel analysis was introduced to develop an organized forecasting analysis based on expert scenarios. Pimentel et al. (2011) [13] expanded on this by using the Futures Wheel to enrich goal models, demonstrating how foresight techniques can be applied to requirements elicitation in diverse scenarios. The Futures Wheel technique is traditionally presented through a graphic representation, with the event to be analyzed in a circle (i.e., node) located in the center. This center node represents the first-order consequences (FOC), with the second-order consequences (SOC) in the second node outside the event, and so on, as shown in Figure 1. The main purpose of the Futures Wheel is to propose diverse scenarios and related levels to qualitatively understand cause-and-effect relationships, even if these levels are based on fact-based scenarios.

Frequently, Futures Wheels are presented in a sequential structure around a central theme or topic, which can sometimes be too abstract to effectively identify the risks and complexities of reality [14]. It is important to note that those using the Futures Wheel must be clear in their envisioning process. Consequently, this technique should often be used as one of many sources of information [13;14]. In other words, making decisions based solely on Futures Wheel analysis can be quite risky.

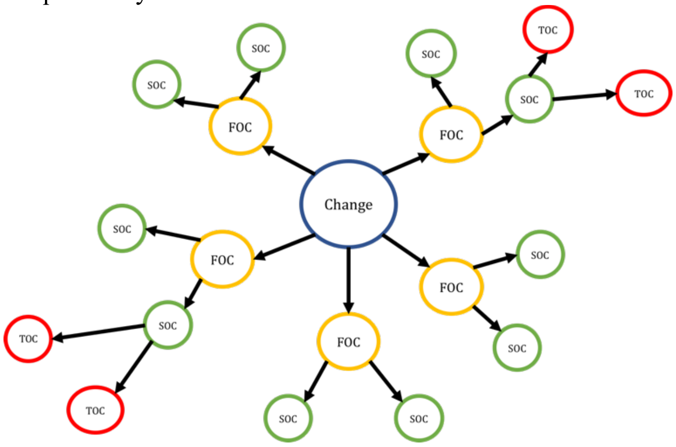


Fig 1: Futures Wheel (traditional graphic representation)

B. OTSM – TRIZ and importance for reduce risk in envisioning process

TRIZ is a methodology that began to be applied more widely from the late 1990s to the early 2000s. Initially, its applications focused on addressing technical problems in design and manufacturing, replacing the traditional trial-and-error method. Over time, the applications of TRIZ have extended to a wide variety of areas.

OTSM-TRIZ is an extension of classical TRIZ, specially formulated by Nikolai Khomenko in 2007[15]. OTSM-TRIZ was developed to increase the efficiency of solutions in complex and atypical problems [15] while allowing for deeper and more detailed problem analysis based on a cause-effect diagram. Its usefulness and effectiveness have been demonstrated in various fields of research, validating the flexibility of OTSM-TRIZ in enriching the analysis of different methods and tools [11-12;16]. One of the most relevant tools of OTSM-TRIZ is the Network of Problems (NoP), which can be useful in many fields of research.

C. Network of Problems (NoP) and similitarity to be used within Future Wheel.

The Network of Problems (NoP) is a diagram that attempts to represent how a solution can generate partial problems and how these partial problems can be solved with partial solutions [15]. Consequently, the Network of Problems aims to create the most plausible scenario of solutions based on the elicitation of potential problems. The application of NoP in risk analysis has been presented in various studies, specifically in anticipating problems and helping to mitigate them [11]. The Problem Network is represented by nodes, where each node can have two representations:

- Representation of a problem (Pb).
- Representation of a partial solution (PS), which can be obtained through the application of classic TRIZ or from another tool used in the problem-solving process.

The line that links each problem with a partial solution represents a causal link, which must be strongly related. According to TRIZ theory, this link between problems and solutions is useful for identifying contradictions. The graphic representation of the main components of the Network of Problems is shown in Figure 2.

From a more strategic and planning perspective, the Network of Problems allows users to generate and visualize several scenarios simultaneously, providing a much broader vision of the problem under analysis [12].

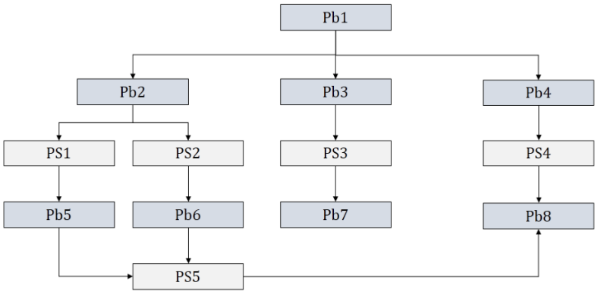


Fig 2: Traditional OTSM - TRIZ Network of Problems

In general terms, the integration of Future Wheels appears to be quite intuitive. However, the Network of Problems (NoP) emphasizes the concept of contradiction, making the links between different levels seem quite direct. Nonetheless, even if the links are direct, it does not mean that their relevance will be the same at all times. Therefore, a systematic approach to prioritize the problems and different levels of the NoP in a proper manner is required.

D. Vester Matrix to identify relevance of scenarios.

The Vester Matrix can be considered a planning instrument that is particularly useful for prioritizing problems [17]. The Vester Matrix is characterized by a double-entry format where the previously identified problems are placed, allowing for the establishment of a hierarchy among them. In general, the assessment is made according to the investigator's judgment, as follows [18]:

Table 1: Vester Matrix Qualification of cause and problems.

Qualification	**Description**
0	Not a cause
1	Indirect cause
2	Very direct cause

One advantage of using the Vester Matrix is that it operates within a logical framework approach, allowing for a systematic analysis. In this case, the Vester Matrix will be applied following eight steps, which are outlined in Table 2.

Table 2: Steps for application of Vester Matrix

Steps	**Description of steps**
1	Determination of problems (variables)
2	Draft the problem, so it is understandable
3	Assessing an identifier for each problem
4	Locate the problems in the matrix
5	Rank the problems
6	Adding of rows (influence / cause) and columns (dependency / effect)
7	Graphic of problems
8	Graphic classification

The Vester Matrix characterizes problems as "active" or "passive" using the following categories, which are described below and facilitate the process of problem evaluation [17]:

- Active Problems: These problems influence others but are not caused by others; in other words, they are cause-problems.
- Passive Problems: These problems do not have a significant influence on others but are caused by the majority; in other words, they are consequence-problems.
- Critical Problems: These problems are causes that generate other causes and are themselves caused by others.
- Indifferent Problems: These problems do not have any cause-effect relation; in other words, they are neither caused by nor affect other problems.

The Vester Matrix representation of problems according to their categories is presented in Figure 3.

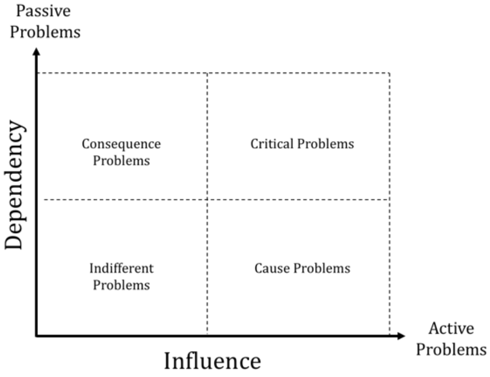


Fig 3: Vester Matrix representation for problem classification.

III. METHODOLOGICAL PROPOSAL

The diagram associated to the methodology proposed for the combination of both OTSM – TRIZ and Futures Wheel it is presented next. In it, six steps to be followed are presented in the shape of a systemic algorithm soon to be detail. Each stage will generate its own outputs, which will contribute as inputs to the next step of the algorithm and so on:

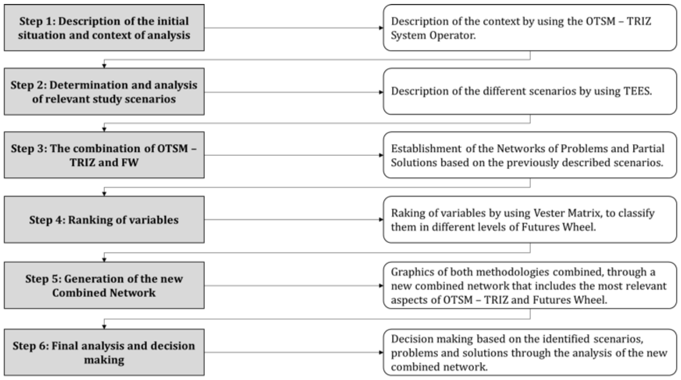


Fig 4. Diagram of the proposed methodology

Step 1: Description of the initial situation and context of analysis

The first step involves the study of the situation to be analyzed and the gathering of information in order to have a general idea of the scenario and the available and useful data. For this purpose, a thorough study of the treated scenario should be conducted, obtaining the complete framework of the situation In this case, the System Operator (SO) is one of the tools that stimulates the analyst's thinking. At the same time, SO aims to obtain information at different levels of detail, allowing to contextualize the situation that is being studied. The output for Step 1 will be a qualitative analysis of the system, sub – system and super – system as well as an understanding of how these different levels have been changing over time [19].

Step 2: Determination and analysis of relevant study scenarios

The second step involves the analysis of the gathered information in the previous step and the use of this knowledge to set the limits that will guide the research. To fulfill this purpose, the following steps should be followed:

- Determine specifically in which aspects of the general scenario the research will be conducted.
- Define the main variables that impact beyond to the problem, in this case is recommended to use at least 4 relevant dimensions such as Technological, Economical, Environmental and Social.
- Research the required data to document the previously defined variables.
- Introduce the required changes to the defined variables according to the available data obtained.
- Define the time frame for the envisioning process.

Step 3: The combination of OTSM – TRIZ and Future Wheels

In this step, the representation of the Network of Problems aims to understand the causal relationships among Partial Solutions and Sub-Problems. Indeed, these descriptions must be presented as conflict situations to stimulate the establishment of causal relationships, as proposed by OTSM-TRIZ. The described situation should also be studied from the perspective of the four scenarios mentioned earlier.

Using the logic of OTSM-TRIZ to define the causal relationships, analysts first have to establish relationships between the already identified problems (Pb). Through this methodology, it is possible to obtain a semantic network [15] because it applies a deductive process to obtain both problems and partial solutions. Given the four main contexts, different Networks of Problems (NoP) will be generated, one for each proposed study scenario (Technological, Economic, Environmental, and Social). These NoPs will later be transformed into the sequences of direct and indirect consequences proposed by the Futures Wheel. At this point, it is also possible to determine if two problems from different study scenarios are related.

As an output from Step 3, the analysts obtain one NoP for each scenario under study. These networks will be classified according to different levels of the Futures Wheel once their relevance to the problem has been established. These networks will allow for a more detailed contextualization of the situation, using a deductive causal relationship applied to the different specific scenarios.

Step 4: Ranking of variables

By using the Network of Problems, we can generate extensive lists of parameters for its graphic structure. This is why ranking the parameters becomes a crucial and useful tool, as it allows us to identify those partial solutions that address the most relevant problems found in the network.

Similarly, the number of direct and indirect consequences obtained using the Futures Wheel can be extensive. For this reason, ranking the parameters helps to create a simpler, more representative model of the problem being studied. This approach also ensures that the model is indeed useful.

A tool that can be effective in ranking the parameters is the Vester Matrix, which is highly useful in prioritizing problems. Through the assignment of ratings, the Vester Matrix helps establish the level of causality between problems. The use of this matrix integrates well with the procedure because the problems have already been defined in previous steps. Now, we only need to determine the level of causality between problems (as well as partial solutions) to establish the hierarchy.

To assign the corresponding scores to the problems of the different scenarios, we consider all four separately. Then, we position the problems in the Matrix according to their scores, following the stages already described.

To create a common point between the Vester Matrix hierarchy and the Futures Wheel, we designed the following classification according to the type of problem. This classification, derived from the Vester Matrix procedure, will now be expressed in Futures Wheel terms:

Table3: Ranking based on Vester Matrix and Futures Wheel

Type of Problem according to Vester Matrix	**Type of consequence according to Futures Wheel**
Active Problems: These are the ones that influence other problems but are not caused by any of them. They are also known as "cause problems".	Direct Consequence of First Order (CFO)
Critical Problems: Problem (usually one) that is the appreciable cause of others and that is caused by others.	Indirect Consequence of Second Order (CSO)
Passive Problems: These problems do not have an important influence on others, but they are caused by the majority. They are also known as "consequence problems".	Indirect Consequence of Third Order (CTO)
Indifferent Problems: These problems do not have any effect of causality on the analyzed set and they are also not caused by either.	Indirect Consequence of Inferior Order

The output of Step 4 is one Vester Matrix for each scenario. These matrices indicate the relevance of each problem in relation to the others. Therefore, after Step 4, all the problems will be ranked according to the Vester Matrix and the Futures Wheel, resulting in their respective positions within the Futures Wheel levels included in the new Combined Network. It should be noted that the problems ranked in this step correspond to those identified in the previous step, using the OTSM-TRIZ Network of Problems.

Step 5: Generation of the new Combined Network

Based on the ranking from the previous step, which considered the problems or variables proposed in Step 3 and the choice of study scenarios made in Step 2, the new Combined Network is graphically generated with the support of TEES and the Vester Matrix. A proposal of the Combined Network is shown below:

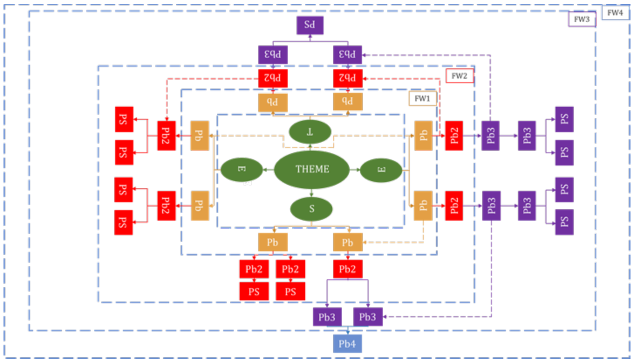


Fig 5: New Combined Network prototype

Each color in the network will represent a different level of hierarchy for the Futures Wheel. These levels will be delineated by segmented lines. At the center of the new Combined Network is the primary problem under study. The four scenarios associated with TEES are also represented.

From the center outward, the problems and consequences are ordered from the immediate direct ones of the scenario to the most indirect ones (SOC, TOC, and others), with their respective partial solutions linked. If two problems from different study scenarios are related, they will be connected by segmented lines of the same color as the corresponding Futures Wheel level.

The output for Step 5 is the graphic Combined Network. It must be easy to read and interpret for those making decisions within the organization or project analyzed. This network includes the most relevant OTSM-TRIZ tools, in conjunction with the pertinent Futures Wheel scenarios and their different levels of hierarchy.

Step 6: Final analysis and decision making

At this point, decision-makers can more objectively evaluate how their upcoming decisions might impact the future. By using the New Combined Network, they can graphically visualize the strategies they choose to implement and their effects on each of the different scenarios, as well as on the primary critical event. The New Combined Network effectively integrates the OTSM-TRIZ and Futures Wheel methodologies into a single, cohesive graphical representation.

IV.CASE STUDY

In this section, a real case study is presented to demonstrate the application, applicability, and viability of the proposed algorithm. The case study involves the use of drones to address wildfire problems. Our aim is to validate the proposed methodology and explore its practical benefits and limitations by applying it to a collaborative drone system and multimodal vision for monitoring wildfires within the national territory.

The proposed algorithm is applied as follows:

Step 1: Description of the initial situation and context of analysis

We conducted a retrospective analysis of recent years to determine if there are recurring patterns or behaviors that should be considered. Contextualizing the current scenario is crucial for understanding the potential future scenarios

According to General Directorate of Humanitarian Aid and Civil Protection of the European Commission, in collaboration with ONEMI, UNDP, UNESCO, and the Red Cross, earthquakes and tsunamis have had the greatest impact in Chile's history due to the number of people affected and economic losses [20]. However, Chile also faces other disasters like floods, eruptions, fires, and droughts due to its diverse geography and climates.

The National Forestry Corporation of Chile (CONAF) defines a forest fire as an uncontrolled fire in rural areas that threatens people, property, or the environment. On average, Chile experiences 6,000 forest fires annually, affecting approximately 50,000 hectares [21]. Environmental conditions, such as lack of rain, high temperatures, and south wind flows between spring and autumn, favor the ignition of combustible vegetation. Human activity is the primary cause of these fires, accounting for 99% of all forest fires, with intentionality reaching up to 90% in some regions [22].These fires are closely linked to agricultural activities, population growth, increased connectivity in urban-rural areas, and a higher presence of people in rural areas during the summer (November to April) [20].

Effective response to forest fires involves several steps: notifying the CONAF Regional Coordination Center (CENCOR), analyzing the situation, dispatching ground and air combat resources, and fighting the fire. Quick detection is crucial for successful fire management and minimizing damage. Detection involves resources, procedures, and activities to discover, locate, and report fires promptly to the CONAF Coordination Center, which then dispatches necessary resources [23-24].

In Chile, drones have primarily benefited agriculture by monitoring fields, crops, applying chemical products, and facilitating reforestation [Innovation Center of the Catholic University of Chile]. Now, we proceed to organize the information using the System Operator of OTSM-TRIZ.

Table 4: System Operator analysis

Level of the SO	PAST	PRESENT	EXPECTED FUTURE
Climate context: Chile (SUPER-SYSTEM)	Seasons of the year well marked, rainy winters, south wind flows and increase of air temperature in summer. Greater concentration of people in rural areas. Less regulation in agricultural and pollution activities.	Lack of rain, higher air temperature and the South wind flows, between spring and autumn, favor the ignition of combustible vegetation due to a source of heat provided by humans. The main cause of the generation of wildfires in the country corresponds to human action and its activities (99% out of 100%).	Agricultural activities, population and connectivity in urban-rural areas increases. It is expected that critical environmental conditions persist, and that intentionality and human action in the generation of forest fires decreases, with greater control in the activities that generate them.
Catastrophe at a regional level (SYSTEM)	In the last two decades, between the regions of Valparaíso and Los Lagos, 313,921 hectares of native forest were lost. Between 2013 and 2015, more than 335,000 hectares of forests were burned.	Forest fires affect more than 45% of the national territory. It is estimated that reforestation after a fire entails an investment of between 197 and 275 million dollars. 99% of wildfires start for human causes.	It is expected that the issue will become more relevant in the preliminary phases and in prevention. It is also expected a more severe regulation and a decrease in the percentage of intentionality (which currently reaches 90%).
Parties involved in wildfires (SUB-SYSTEM	Unstructured process, without distinction of roles. Oral transfer of information in a more immediate environment. No storage or data registration. Little access to technology.	Observers in the field. Central Coordination in charge of dispatching resources according to the detected need. Brigades in the field. There is a registry of data and statistics of accidents (but not in real time).	Overflight drones systems to replace observers in the field, covering large areas of territory and unstructured scenarios, with data collection and transfer of information to the Coordination Center in real time for the adequate distribution of resources for combat.

Through the System Operator analysis, we obtain a summarized qualitative assessment of the system, subsystem, and super system associated with wildfires. The System Operator helps us understand how these elements have evolved over time. Based on the expected future scenarios, it becomes clear that there is an urgent need to address the conflict with technological and innovative solutions to mitigate its impact from the earliest stages.

Step 2 and Step3: Determination and analysis of relevant study scenarios

The analysis of these four scenarios focuses on drones. This information was compiled from various sources, with the most important being face-to-face interviews with the engineer in charge of the drone systems project. To summarize the case study, we will focus on just one scenario, with the remaining three provided as annexes.

First Scenario: Technological scenario

A drone (UAV), considered as a technical system, is designed to operate within a natural environment, either flying or submerging within the sea to gather information. The drone's functions are controlled remotely through a mobile application, remote control, or other means that communicate with the control unit. Drones are powered by electricity. Over time, UAVs have evolved with better technology in control instruments, flight mechanisms, engines, and propellers, incorporating new electronic instruments and support structures that have diversified their use.

Drones can be classified into three primary types: recreational, research, and audiovisual. Each type can use either open technology, which is publicly available, or closed technology. For this research, we focus on open technology, which is continuously updated and improved by experts worldwide. Drones are expected to perform tasks autonomously and ensure their sensors capture the immediate environment accurately.

Drone operators on the ground can control them using remote control or software. The aircraft is programmed to respond to both forms of command, and with the latter option, it is possible to control up to three drones simultaneously. This also aims to give autonomy to the drones, automating the monitoring (not preventive) of forest fires.

This raises a new question: how to protect the drone while it is flying. For this purpose, the original design of the drone is modified to incorporate a camera. The camera, in coordination with the sensors, provides real-time feedback on the drone's status when sending photographs. Thus, it is possible to work with multiple drones in a complementary manner, performing different functions simultaneously, such as analyzing the smoke column to predict fire behavior.

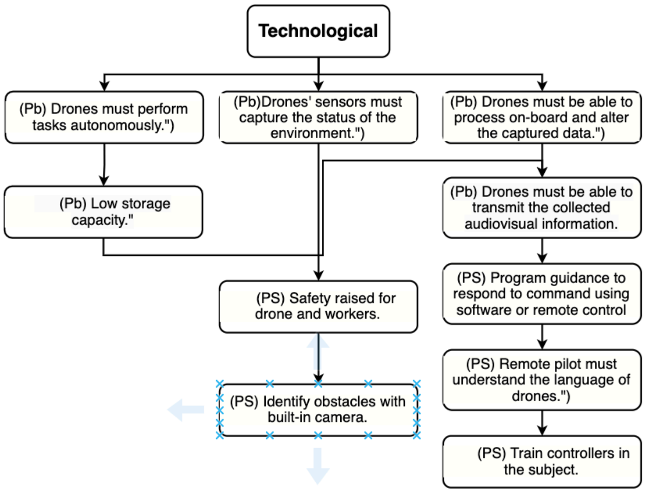


Fig 6: Network of Problems using OTSM – TRIZ for Technological scenario()

Step 4: Ranking of variables

After identifying the most relevant problems through previously established networks, the variables need to be ranked. We used the Vester Matrix to achieve this, obtaining the following results:

First Scenario: Technological Scenario

Considering the Network of Problems (NoP) for the structured technological scenario, the corresponding score assignment using the Vester cross matrix is shown below:

Vester Matrix - Technological													
Code	**Variable**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T 10**	**T 11**	**INF (X)**
T1	Drones must perform tasks autonomously	0	0	1	2	1	1	1	2	1	1	1	11
T2	Drones' sensors must capture the stimuli of the environment	0	0	1	2	1	1	1	2	1	1	1	11
T3	Drones must be able to process on land and air the captured data	0	0	0	0	2	1	0	0	0	1	1	5
T4	Safety risk of drone and workers	0	0	0	0	0	1	0	0	2	2	1	6
T5	Drones must be able to transmit the collected audiovisual information	0	0	0	0	0	1	0	0	0	2	1	4
T6	Remote pilot must understand the language of drones	0	0	0	0	0	0	0	0	0	0	2	2
T7	Low storage capacity	0	0	2	0	1	1	0	0	0	1	1	6
T8	Incorporate a "brain" to the drone (card)	0	0	1	0	1	1	2	0	0	1	1	7
T9	Identify obstacles with built-in camera	0	0	0	0	0	0	0	0	0	0	0	0
T10	Program drones to respond to command using software or remote control	0	0	0	0	0	2	0	0	0	0	1	3
T11	Train controllers in the subject	0	0	0	0	0	0	0	0	0	0	0	0
Dependency (Y)		0	0	5	4	6	9	4	4	4	9	10	55

Fig 7: Vester Matrix for Technological Scenario

Once the maximum values for the dependency (Y) and influence (X) axes have been determined, each problem is plotted on a graph representing the Vester Matrix. This allows for the classification of the problems into different types based on the position of each variable as an ordered pair, as illustrated in the following figure

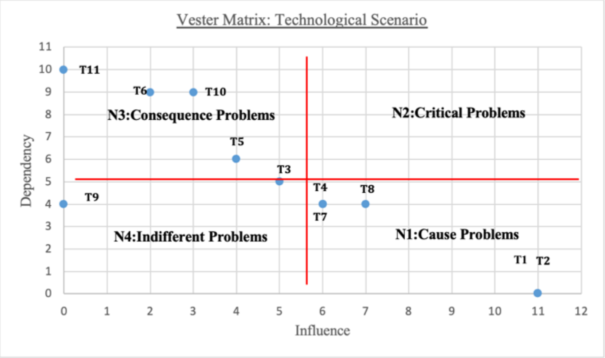


Fig 8: Vester Matrix for the Technological Scenario

Once the category of each problem has been identified, the equivalence is determined according to the levels of the Futures Wheel classification. This is shown in the following table 5, which includes the Network of Problems (NoP) now separated by levels of hierarchy in the new Combined Network:

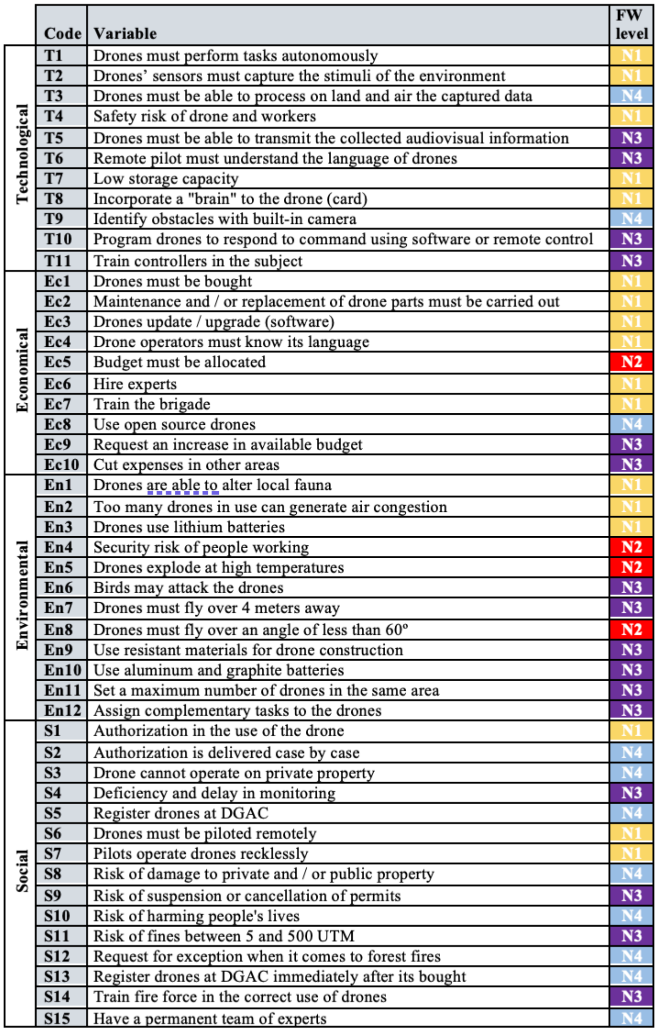
Table 5: Classification of Problems according to Vester Matrix and Futures Wheel for the Technological Scenario

Type of Problem according to Vester Matrix	**Type of consequence according to Futures Wheel**
Active Problems: T1, T2, T4, T7, T8	Direct Consequence of First Order (FOC), level 1
Critical Problems: None	Indirect Consequence of Second Order (SOC), level 2
Passive Problems: T5, T6, T10, T11	Indirect Consequence of Third Order (TOC), level 3
Indifferent Problems: T3, T9	Indirect Consequence of Inferior Order, level 4

Step 5: Generation of the new Combined Network

We now present the Combined Network graphically. It is designed to be easy to read and interpret for decision-makers within the organization or project being analyzed, incorporating the main elements of OTSM-TRIZ and the Futures Wheel.

For practical purposes, the new Combined Network is configured based on the codes assigned to each problem and partial solution, as detailed in Figures 9 and 10.



	Code	Variable	FW level
Technological	T1	Drones must perform tasks autonomously	N1
	T2	Drones' sensors must capture the stimuli of the environment	N1
	T3	Drones must be able to process on land and air the captured data	N4
	T4	Safety risk of drone and workers	N1
	T5	Drones must be able to transmit the collected audiovisual information	N3
	T6	Remote pilot must understand the language of drones	N3
	T7	Low storage capacity	N1
	T8	Incorporate a "brain" to the drone (card)	N1
	T9	Identify obstacles with built-in camera	N4
	T10	Program drones to respond to command using software or remote control	N3
	T11	Train controllers in the subject	N3
Economical	Ec1	Drones must be bought	N1
	Ec2	Maintenance and / or replacement of drone parts must be carried out	N1
	Ec3	Drones update / upgrade (software)	N1
	Ec4	Drone operators must know its language	N1
	Ec5	Budget must be allocated	N2
	Ec6	Hire experts	N1
	Ec7	Train the brigade	N1
	Ec8	Use open source drones	N4
	Ec9	Request an increase in available budget	N3
	Ec10	Cut expenses in other areas	N3
Environmental	En1	Drones are able to alter local fauna	N1
	En2	Too many drones in use can generate air congestion	N1
	En3	Drones use lithium batteries	N1
	En4	Security risk of people working	N2
	En5	Drones explode at high temperatures	N2
	En6	Birds may attack the drones	N3
	En7	Drones must fly over 4 meters away	N3
	En8	Drones must fly over an angle of less than 60°	N2
	En9	Use resistant materials for drone construction	N3
	En10	Use aluminum and graphite batteries	N3
	En11	Set a maximum number of drones in the same area	N3
	En12	Assign complementary tasks to the drones	N3
Social	S1	Authorization in the use of the drone	N1
	S2	Authorization is delivered case by case	N4
	S3	Drone cannot operate on private property	N4
	S4	Deficiency and delay in monitoring	N3
	S5	Register drones at DGAC	N4
	S6	Drones must be piloted remotely	N1
	S7	Pilots operate drones recklessly	N1
	S8	Risk of damage to private and / or public property	N4
	S9	Risk of suspension or cancellation of permits	N3
	S10	Risk of harming people's lives	N4
	S11	Risk of fines between 5 and 500 UTM	N3
	S12	Request for exception when it comes to forest fires	N4
	S13	Register drones at DGAC immediately after its bought	N4
	S14	Train fire force in the correct use of drones	N3
	S15	Have a permanent team of experts	N4

Fig 9: Futures Wheel equivalences from Vester Matrix

With the foregoing as a reference, the new Combined Network is presented as follows:

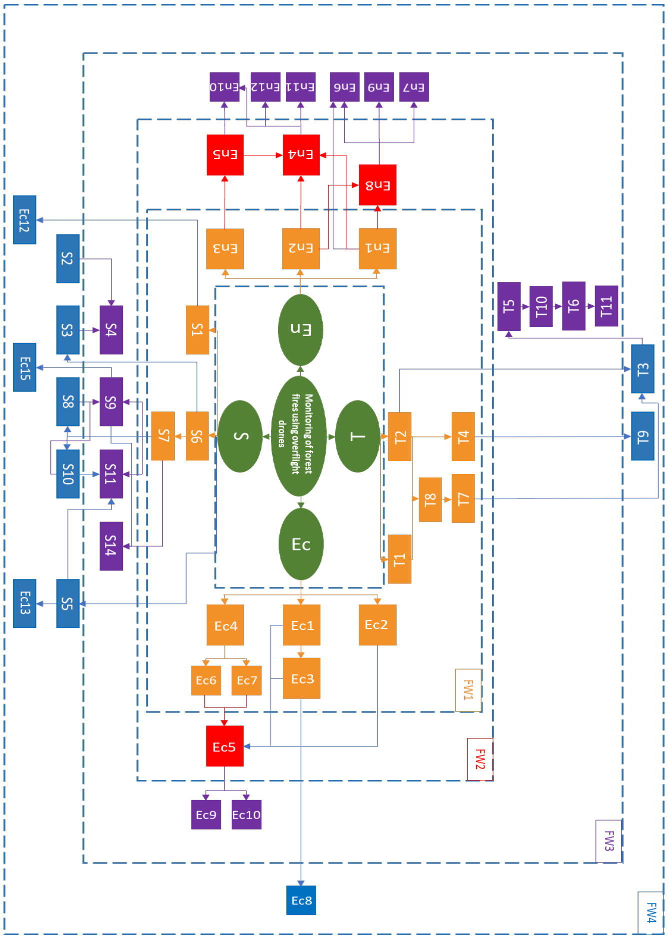


Fig 10: Futures Wheel equivalences from Vester Matrix

Step 6: Final analysis and decision making

Decision-makers can now evaluate more objectively how their decisions regarding a specific topic will affect the situation and how the strategies they choose to implement will impact each of the different scenarios and, subsequently, the critical event.

Based on the Combined Network, it is possible to identify critical problems, such as the safety of personnel and operators exposed to the drone's range of action and the financial resources required. Considering the four relevant scenarios analyzed, the next step is to conduct strategic planning to address the problems according to their relevance. The new Combined Network serves as a tool to organize information and derive useful conclusions and strategies for both the short and long term.

For this particular case, it is proposed to carry out time-based planning in stages, establishing operational plans for short, medium, and long-term objectives. A priority is to set a budget for investments and expenses if drones are to be used as a solution.

It is recommended to assemble a group of experts in drone use and operation and to train brigadiers and workers in the two modes of drone monitoring after acquiring the equipment. This approach reduces the likelihood of reckless behavior in handling the aircraft and minimizes the impact on native fauna within the operational radius. Additionally, it enhances the safety of field personnel.

Special emphasis should also be placed on complying with bureaucratic procedures early, ensuring that the aircraft are legally approved for use in case of fire. While project decision-makers have limited control over regulations and public policies, they can exert pressure to have the aircraft legally approved and registered and to accelerate the approval processes for overflight in special situations such as wildfires.

V.DISCUSSION

The proposed combination of methodologies, through the algorithm presented, helps to add a causality factor to Futures Wheel, as well as a hierarchy to each one of its parameters that can be, in a way, more objective and quantitative. During the case study an expert on the matter was interviewed to obtain most of the information, but it took time to order, analyze and to conclude from it.

From this point of view, decision makers should know that it takes a bit of time and a lot of information to apply this methodology, and that for urgent topics that needs to be resolve in a short period of time it may not be the best answer. However, the proposed methodology is an algorithm that works well in reality, and for really specific problems, as we could see throughout the case study. Although it is a very friendly combined methodology, the difficulty of its use relies on the fact that it needs to have someone who knows how to use OTSM – TRIZ, its nomenclature and method for its correct application. It is also a methodology that keeps being a qualitative way to analyze situations, still based on the experience of the people interviewed or involved on the matter, but with a more quantitative way of determining the relevance of the issues involved.

VI. CONCLUSION

The Futures Wheel makes a valuable contribution to the methodology proposed by OTSM-TRIZ by systematically ranking the problems and partial solutions identified for different scenarios. However, it requires support from an external tool like the Vester Matrix to quantitatively rank each variable. The New Combined Network offers a more comprehensive and global approach, considering multiple scenarios simultaneously and establishing relationships between problems and partial solutions across different scenarios and levels of relevance.

While the Combined Network can sometimes be confusing or difficult to read when an excessive number of variables are considered, it remains an effective tool for decision-makers to establish strategic plans. This allows prioritization of variables over time, thus determining future steps.

A limitation of the proposed integration of methodologies is that OTSM-TRIZ requires familiarity with its structured rules and specific nomenclature for proper use and application. The Vester Matrix provides flexibility in ranking parameters, allowing the use of up to four scores (e.g., from 0 to 3). The decision on the level of detail or difficulty rests with the model developer.

Although the proposed methodology is a six-step systemic algorithm, the use of OTSM-TRIZ and the Futures Wheel involves expert opinions, introducing a degree of subjectivity. This subjectivity affects problem identification, solution ranking, and the configuration of the Combined Network, as determined by the consulted experts' knowledge and relevance. The case study demonstrates the importance of proposing innovative measures to resolve and prevent events like wildfires, using technology-based solutions such as drones. Drones, being highly modifiable and adaptable, can be tailored for specific tasks and research fields, making them favorable for developing innovative solutions to recurring problems.

Socially, although Chile is a pioneer in regulating unmanned aircraft, there is still progress to be made in preparing public policies to improve the acceptance of technological solutions in dangerous environments like wildfires. For example, the amount of paperwork required before deploying these aircraft in the field needs to be streamlined.

Trained professionals and experts are essential for developing technological solutions and understanding the drone's language and immediate context. Ensuring the safety of those controlling and working around drones is crucial.

Given their minimal environmental impact, drones offer an innovative and technological alternative for mitigating and monitoring forest fires. They are non-invasive to the local flora and fauna and use electrical energy. However, a disadvantage is the use of lithium batteries, a topic under discussion with alternative substitutes in development.

Although implementing a drone monitoring system requires a significant initial investment in equipment, software, and expert training, it is a highly effective, safe, and intelligent prevention and monitoring alternative. It is undoubtedly less expensive than dealing with the recurrent forest fires that affect the country each summer season, for which complete solutions have not yet been established.

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