A Case Study for Better Management of Forest Fire Situations using DiCoMa, A Disaster Management Framework

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Abstract

Dicoma is an IT framework providing a list of tools to be used by different parties aiming at reducing the effects of the disaster and recover from the disaster situation. It includes components for analyzing social media, components for detecting forest fires based on complex event processing algorithms applied to data collected from sensors and also components making use of geographical information systems (GIS) for evaluating fighting strategies and decision making.

In recent years the world has seen many dramatic disasters, both natural and man-made. Forest fires are among the most commonly observed natural disasters. They can have devastating results for both the natural environment and the human population. A total of 20,749 million hectares of land area is covered with forests in Turkey, with forest fires, also known as wildfires, frequent in the coastal zones. Istanbul, the most crowded and industrialized city of Turkey, is located in the coastal zone. According to the Turkish General Directorate of Forestry, Istanbul has a high probability of forest fires. Disasters like forest fires are far beyond the ability of a single agency to deal with, and require cooperation between multiple agencies. The purpose of this study is to evaluate disaster preparedness and response of Istanbul in the case of a forest fire situation, and to reduce Istanbul's vulnerabilities with the help of the Disaster Control Management framework (DiCoMa).

Keywords: *Disaster Scenario, DiCoMa, Istanbul, Forest Fire, Complex Event Processing.*

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Vaka Analizi: Orman Yangınlarının Daha İyi Yönetimi için DiCoMa (Afet Yönetimi Platformu) Sisteminin Kullanımı

Özet

Dicoma, Avrupa Birliği ITEA2 çerçeve programı tarafından desteklenen aynı adlı projenin sonuç ürünü olarak ortaya çıkmış, afet durumlarının yönetilmesi, afet etkilerini azaltma ve afet sırasında iletişimin hızlı ve etkin bir şekilde sağlanması için geliştirilmiş olan bir dizi yazılım aracından oluşmaktadır. Dicoma içinde sosyal media verilerinin analizi, sensör verileri üzerinde karmaşık olay işleme teknikleri kullanarak orman yangınlarının tespiti, coğrafi bilgi sistemleri (CBS) kullanarak yangın durmunun güncel halinin görselleştirilmesi ve simulasyonların yapılması, karar alma için coğrafi haritaların kullanımı amacıyla gerçekleştirilmiş yazılımlar yer almaktadır.

Son yıllarda dünyanın farklı yerlerinde çok sayıda afet görülmüş ve afet yönetimin önemi bir kez daha açık bir şekilde görülmüştür. Orman yangınları bu afetlerin önemli bir kısmını oluşturmaktadır. Yangınlar hem doğla çevre için hem de insanlar için çok ciddi sonuçlara neden olabilmektedir. Türkiye'ni yüçölçümünün 20,749 milyon hektar kadarı ormanlardan oluşmaktadır ve kıyı alanlarda orman yangınları sıklıkla görülmektedir. Orman Genel Müdürlüğü verilerine göre İstanbul, orman yangını riskinin yüksek olduğu bölgelerden biri olarak sınıflandırılmaktadır. Afetler tek başına bir kurum tarafından yapılacak müdahalelerden çok birden fazla kurumun birlikte hareket etmesini gerektirmektedir. Bu çalışmamızın amacı İstanbul'un afet durumlarına karşı dayanıklılığını ve hazırlıklılığını irdelemek amacıyla farazi bir orman yangını senaryosu oluşturulmuş, Dicoma araçlarının bu senaryoda nasıl etkin bir şekilde kullanılarak afet müdahalesini kolaylaştırdığını ve yönetime destek verdiğini göstereceğiz.

Anahtar kelimeler: *Afet Senaryosu, DiCoMa, İstanbul, Orman Yangını, Karmaşık Olay İşleme*

1. Introduction

Disaster Management remains to be a major topic of interest for international community as costly disasters continue to be observed around the world. This paper provides a case study and a novel methodology for effectively fighting forest fires. Even if it is not possible to evaluate directly the results of our research, the scenario defined in the case study shows clearly that an effective disaster response methodology has been proposed.

Forest fires are one of the most common disasters observed in Turkey. Thousands of hectares of forest have been destroyed as a result of forest fires. The total land mass of Turkey is 77,079 million hectares (ha), of which 20,749 million ha are forested, representing about 26 per cent of the country's total land area (Ay and Ay, p. 2). Forest fires, also known as wildfires, are very frequent in Turkey's coastal zone, a 1700 km long band stretching from Kahramanmaras to Istanbul. The band that is sensitive to fire is 160 km deep (Forest Fires in Turkey, p. 4), and about 80 per cent of fires occur in these zones. Istanbul, the most crowded and industrialized city of Turkey, is located in

the coastal zone. According to the Turkish General Directorate of Forestry, Istanbul has a high probability of forest fires (Forest Atlas, p. 77).

Forest fires occur throughout the year, but are more frequent and intense in the summer months due to high temperatures and low relative humidity. The period between the first of June and the end of October constitutes what is termed the "Forest Fire Season", with 80 per cent of forest fires occurring during this period (Forest Fires in Turkey, p. 5).

The General Directorate of Forestry conducts forest firefighting in Turkey. These types of tasks are carried out by a Department of Forest Protection and Firefighting at the Central Organization level and by the individual Divisions, attached to the Regional Directorates, at the province level.

1.1. Related works

Disaster management related research is mainly concentrated on improved preparedness and prevention as stated also by [Paton, 2003]. Paton, proposes a social-cognitive model in order to improve preparedness for disasters.

In another study[Rose, 2004], authors tries to create resilience metrics in order to decrease the negative outcomes after the disaster. The metrics proposed are helpful for better management of disaster situation but unlike the proposed method in this paper, they are not concerned with what happens during disasters.

We were not able to locate a disaster management work aiming at using IT systems for improving communication and helping decision makers take fast actions that are decisive for recovering from disaster situation like the methodology proposed in this paper.

Compex event processing is a relatively new approach to solving big data related problems. Recent research paper [Cugola et al, 2014] shows clearly that the best approach to manage uncertainty is to use complex event processing. Managing event context in an uncertain environment like tunnel ventilation through complex event processing rules that are capable of containing uncertainty was an important challenge adressed sucessfully. Disaster situation, addressed in this paper, inherently includes a lot of uncertainty with different degrees which makes it an ideal candidate for application of complex event processing techniques.

Other recent research papers [Terroso-Sáenz et al, 2015], [Dunkel et al 2011], [O'Donnell et al, 2013] have addressed complex event processing in different domains. Common conclusion from all these papers can be summurized as; CEP model facilitates finding solutions for complex problems with complex and temporal inputs.

1.2. Methodology

The first stage of this study is an examination of the general forest situation of Turkey and review of the literature on the incidence of forest fires. After completing this first step, we examine Turkish emergency response organizations and firefighting capacity. Throughout this study period, Istanbul Forest Regional Directorate and Disaster and Emergency Management Presidency (AFAD) assisted us by providing necessary information. Next, we analyzed the hazards for the worst-case scenario by obtaining the

essential information and then beginning the process of creation and development of the relevant scenario.

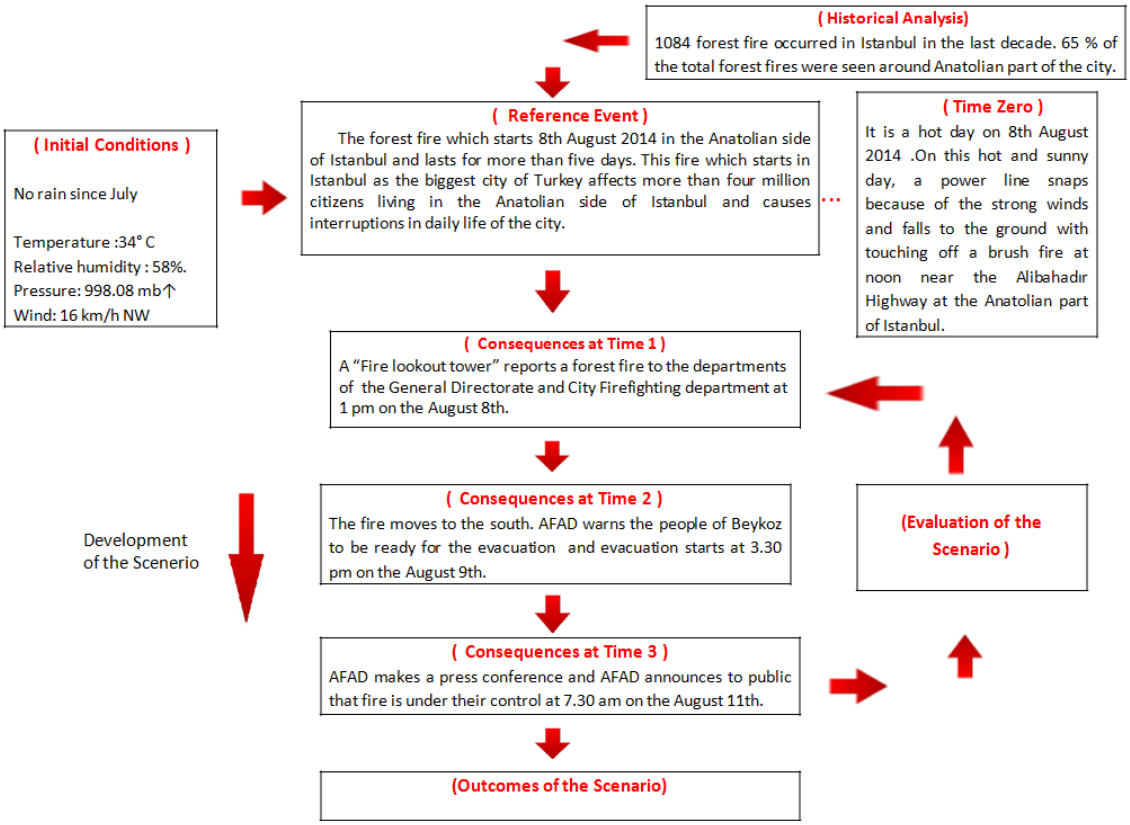


Figure 1: Workflow of the Scenario

The worst-case meteorological conditions were selected as initial conditions for estimating the worst-case scenario. For determination of the least favorable meteorological conditions, a historical analysis was applied. These conditions were then used as inputs to design the evaluation process of the scenario. The worst-case circumstances identified in the scenario are:

- increase in wind speed
- movement of the fire toward the town
- evacuation of settlements
- insufficient capacity of Turkish firefighting and disaster response teams
- citizens in the middle of fire zone require assistance
- multiple deaths and injuries
- unexpected accidents
- interruption of maritime transportation through the Istanbul Bosporus and on the international highway
- burning of thousands of hectares.

Finally, according to the outcomes of the scenarios developed, we began to construct the "DiCoMa" system. For this phase, the basic question was, "How can we prepare for and manage the disaster more effectively?" To answer this question, established DiCoMa systems and tools were used in order to improve the system's capacity. This is shown in Figure 1, following which we present the worst-case scenario in detail.

2. The Worst-Case Forest Fire Scenario for Istanbul

August 8th 2013 (First Day)

1.00 pm

A "Fire lookout tower" reports a fire to the General Directorate of Forestry and City Firefighting departments. The fire then jumps to the Alibahadir County Highway and is within a mile of a new housing development consisting of 20 houses outside of the town of Alibahadir. The nearest fire station is 30 minutes from Alibahadir County. The fire now covers 20 acres, is spreading fast, and is beyond the control of the fire station.

2.00 pm

Incident Commander, observing the fire progress and current situation from decision support system part of Dicoma Framework sends relevant resources to the incident location. Firefighters and the initial attack crews respond to the fire. However, it appears likely that firefighters will not be able to stop the flames from reaching the homes. Meanwhile, the people who live in the outskirts of the Town of Alibahadir begin to evacuate the area.

2.30 pm

The General Directorate of Forestry calls an emergency meeting.

3.00 pm

The General Directorate of Forestry notifies the Governor of the province and thus all state agencies and they generate an Incident Command System (ICS) in AFAD (Government Emergency Control Center).

3.30 pm

The government of the province meets in AFAD and they decide to evacuate the Alibahadir County area to a radius of 20 km.

As the fire grows, an old couple notices smoke below their property further out in Alibahadir County .They call their neighbours and the fire station to find out what is happening. They discover that all the lines are busy or are not answered. Additionally, there is no news on the radio.

4.30 pm

A Task Force of The General Directorate of Forestry arrives in the fire area with trailers, bulldozers and fire trucks. They try to take fire under control. In addition, two fire helicopters take off from Sabiha Gokcen Airport. Meanwhile, news agencies all around the world begin to report the forest fire in Istanbul. Therefore, reporters begin to approach the fire zone.

5.00 pm

The Fire Helicopters come from the Black Sea side of Istanbul and drop water on the fire, then come back to the Black Sea to pick more water up.

The old couple cannot reach any help. The old man's name is Hamit, and he goes out to try and understand the situation. He finds that the fire is quite close to their only road. If the fire spreads, they are trapped. They are not sure if they should stay or leave and wish that they were prepared for either eventuality.

5.30 pm
The fire helicopters continue to drop water on the fire. The process of picking water up from the Black Sea and dropping it on the fire takes approximately 30 minutes, and the pilots continue to follow orders to do this regularly until a new order arrives.

7.30 pm
The old couple is still is in the fire zone and the fire gets closer and closer. The smell of smoke is thick in the air, and occasional ash falls on the ground. The sun starts to glow orange.

7.45 pm
The old couple manages to communicate with the city emergency services and asks for help.

7.55 pm
The task force is warned about the old couple and the Governor of the province commands the forces to rescue these people.

8.30 pm
The Search and Rescue Association joins the task force. They make a plan and decide to try passing the fire zone.

9.00 pm
In an announcement, AFAD declares that the fire is almost under control.

9 .30 pm
The rescue teams pass the fire zone and reach the old couple. They provide first aid to them and connect to the AFAD centre via the escape road.

10.45 pm
The rescue teams arrive in the safe area with the survivors.

11.00 pm
The Turkish state meteorological service reports that the wind has changed direction, now blowing to the South, and increased speed to 20 mph.

August 9th 2013 (Second Day)
4.30 am
The fire begins to grow more and more rapidly in the now 21–23 mph South wind. The firefighters and task force report to the command centre that they have lost control of the fire and they try to upgrade their position.

5.30 am
The Turkish state meteorological service reports that the wind direction will not change for a while and the wind speed will not fall.

6.00 am
When the sun rises, the General Directorate of Forestry and the Governor of the province have another meeting in the AFAD to evaluate the situation. They recognize that they are about to lose control of the fire. The initial attack crews, firefighters and

task forces have worked for 16 hours. Workers are becoming exhausted and they state that they need to take a rest.
The worst news for the responders is that because the wind is now blowing to the south, driving the fire in the direction of Beykoz County, thousands of people who live in Beykoz County are in danger.

Unfortunately, it is recognized that some of the homes have wooden siding or wood shingle roofs. In addition, since schools are closed for the summer holiday, children are at their homes or playing in the neighbourhood.

6.30 am
The General Directorate of Forestry and Governor of Province declare an emergency situation and they ask for support from the military and from the governors of other provinces.

7.15 am
The fire moves to the South. AFAD warns the people of Beykoz to be ready for the evacuation and calls a press conference about the recent events.

8.00 am
The military joins the firefighting efforts. Firefighters and task forces arrive from nearby counties. AFAD calls back the Initial Attack Crews and AFAD begins to change shifts of the firefighters and task forces according to the recent developments.

10.30 am
The Governor of the province calls a meeting to discuss evacuation plans for a wide area. Meanwhile, a C-130 aircraft joins the firefighting efforts.

12.00 am
Two more fire helicopters arrive in the fire zone and they join the firefighting efforts.

1.30 pm
Task force teams report to the AFAD that they have lost contact with two of their members.

1.45 pm
AFAD notifies all units about the two lost staff members. A rescue team is assigned to find the lost staff members.

3.00 pm
AFAD and Governor of Province decide to evacuate the area from Mahmut Sevket Pasa to Polenezkoy to a radius of 30 km. Many people live within the affected area. Therefore, further assistance is required. AFAD asks for support from the Turkish Red Crescent and the Istanbul Metropolitan Municipality.

3.30 pm
The evacuation starts from the point closest to the fire zone. Municipal buses pick the people up and they carry them to the assembly areas. However, some are not prepared. They think they can evacuate at the last minute, not realizing how fast a forest fire can

move and failing to understand that most casualties of forest fires die while trying to evacuate too late. Thus, the military forces begin to check the houses one by one.

6.00 pm
The rescue team finds the bodies of the lost staff members and reports this to the AFAD center.

6.15 pm
AFAD calls an emergency meeting. AFAD evaluates the situation and notifies the families of the staff members. The PIO of AFAD calls a press conference and publicly declares their grief.

9.30 pm
Almost 70% of the evacuation process is completed. However, the fire continues to move to the South and they are quite far away from keeping the fire under control.

August 10th 2013 (Third Day)
1.00 am
Action teams report to the AFAD that the evacuation process is complete. They then begin to withdraw from the evacuated area.

3.30 am
The fire reaches Mahmut Sevket Pasa County and by this time more than 20 houses have already burned. The wind speed is 20–22 mph and the direction of wind is towards the South-South West.

6.30 am
AFAD calls a press conference and AFAD informs the public about the recent events.

7.30 am
TV reporters and journalists build their broadcast centres near the AFAD centre and fire zone. This creates pressure on the workers and negatively affects their performance.

9.00 am
The Prime Minister and the some Members of Parliament visit the AFAD center and request information about fire fighting actions.

11.30 am
The smoke from the fire covers the Anatolian part of Istanbul and affects the daily life of the city. People are scared and prefer to stay in their homes.

1.00 pm
The Turkish Coast Guard Command warns the AFAD and Ministry of transport about smoke. It also reports that because of smoke and fog, visibility on the Istanbul Bosporus is becoming more and more restricted.

2.30 pm
The Ministry of Transport makes an announcement halting maritime transportation on the Istanbul Bosporus.

5.30 pm
The firefighters report that they have brought the fire in Polenezkoy County under control and have stopped the fire moving towards the South. Nevertheless, the fire still progresses in a westerly direction.

8.00 pm
The Turkish State Meteorological Service reports that the wind speed has fallen to 10–12 mph.

9.30 pm
One fire helicopter breaks down and turns back to Sabiha Gokcen Airport.

10.30 pm
The General Directorate of Forestry and Governor of Province meet in the AFAD center. They evaluate the current data and they decide to focus on controlling the westward movement of the fire.

August 11th 2013 (Fourth Day)
3.30 am
The fire fighters report to the AFAD that they have stopped the fire's westward progress.

5.30 am
The fire is taken under control by the fire fighters, task forces and military forces in the fire zone.

7.30 am
AFAD calls a press conference and announces to the public that fire is under their control.

9.30 am
AFAD assigns all units to begin surface cooling actions.

1.00 pm
Severity of the fire decreases and the fire fighters move to the center of the fire zone.

4.00 pm
The Ministry of transport makes an announcement re-opening transportation on the Istanbul Bosporus.

6 .00 pm
The fire fighters find four dead bodies in a forest area 7 km from the village of Ornekkoy and report it to the AFAD.

7.00 pm
The PIO of AFAD calls a press conference and informs the public, declaring their grief upon the deaths.

11.00 pm
The fire fighters reach the evacuated houses in Mahmut Sevket Pasa County.

August 12th 2013 (Fifth Day)
2.00 am
The fire fighters find two more dead bodies in a burned house in Mahmut Sevket Pasa County.

9 .00 am
The PIO of AFAD calls a press conference and informs the public about the latest deaths, declaring their grief.

1.00 pm
The fire fighters reports to the AFAD that 80% of the surface cooling actions are completed.

5.00 pm
The General Directorate of Forestry and Governor of Province meet in AFAD center. They decide to implement early recovery actions.

3. Outcome of the Scenario

The forest fire which started on the Anatolian side of Istanbul and lasted for more than five days has resulted in eight deaths, sixty injured people, the burning of more than 2000 hectares, closure of an international highway, interruption of maritime transportation through the Istanbul Bosporus and physical damage costing hundreds of millions of dollars. This fire, starting in the locality of Istanbul, the biggest city of Turkey, has affected more than four million citizens living on the Anatolian side of Istanbul and caused interruptions to the daily life of the city.

4. Evaluation of the Scenario

While developing the scenario, the worst conditions were selected for the postulated Emergency Operations Centre (EOC) actions/activities. Before estimating the response of the Turkish forest fire teams and disaster organization, the capacities of the teams and organization were considered. During the whole progress of the scenario, some lack of response action capabilities was also observed. The worst-case scenario process revealed new vulnerabilities for Istanbul. These vulnerabilities are:

- For massive forest fires, relief operations are not efficient
- Emergency responses and plans are not efficient
- The assessments of vulnerability of forest ecosystems and communities are not sufficient and not updated
- Performance of monitoring and alarm equipment are not comprehensive
- IT systems are not widely used.

As can be seen from the above, all these vulnerabilities increase the risks for Istanbul, and hence, a new systematic approach is needed.

DiCoMa framework is able to detect and help decision makers to take action for the vulnerabilities listed above through the tools provided. The framework ensures effective

management of large disasters and complex emergencies by providing a set of tools that aim to improve the effectiveness of decision makers.

5. DiCoMa: A Disaster Management Framework

As the project name implies (DiCoMa = Disaster Control Management), the main goal for the DiCoMa project is to provide better tools for disaster control management. Disasters like earthquakes, forest fires, massive storms and floods are far beyond the ability of a single agency to deal with, and require cooperation between multiple agencies.

Moreover, decision makers dealing with such disasters are frequently swamped with massive amounts of – often conflicting – information, on which decisions need to be made in real time. Adding this to the need to take into account, social, political and economic factors, it is no wonder that many incorrect decisions are made, worsening an already difficult situation. On the other hand, effective training for such situations, especially in a multinational setting, requires an enormous effort and thus cannot be used very often.

The DiCoMa project aims to provide a set of tools to improve the effectiveness of decision makers in dealing with disasters by better training and in situ support in the field. This toolset will include:

- **Data Abstraction Tools** – A comprehensive set of tools designed to process and correlate information from a large variety of public and private sources, allowing the creation of a unified data set, which can be easily explored and understood by decision makers.
- **Simulation and Modelling Tools** – DiCoMa proposes to create a suite of simulation tools that model both human behaviour and natural phenomena (i.e. fires, earthquakes, weather patterns).
- **Decision Support and Training Tools** – DiCoMa intends to create applications to be used by decision makers during both real and simulated disasters that present information to the decision maker in a manner that is easily and quickly understood and propose alternative actions, indicating the implications of each alternative.

Figure 2 Shows the communication between different modules in the DiCoMa framework. The decision support system, the component of main interest for this paper, is fed by the data coming from different sources. The complex event processing patterns concerning alarm levels, described below, are activated by the data coming through the Enterprise Service Bus (ESB) of the DiCoMa system.

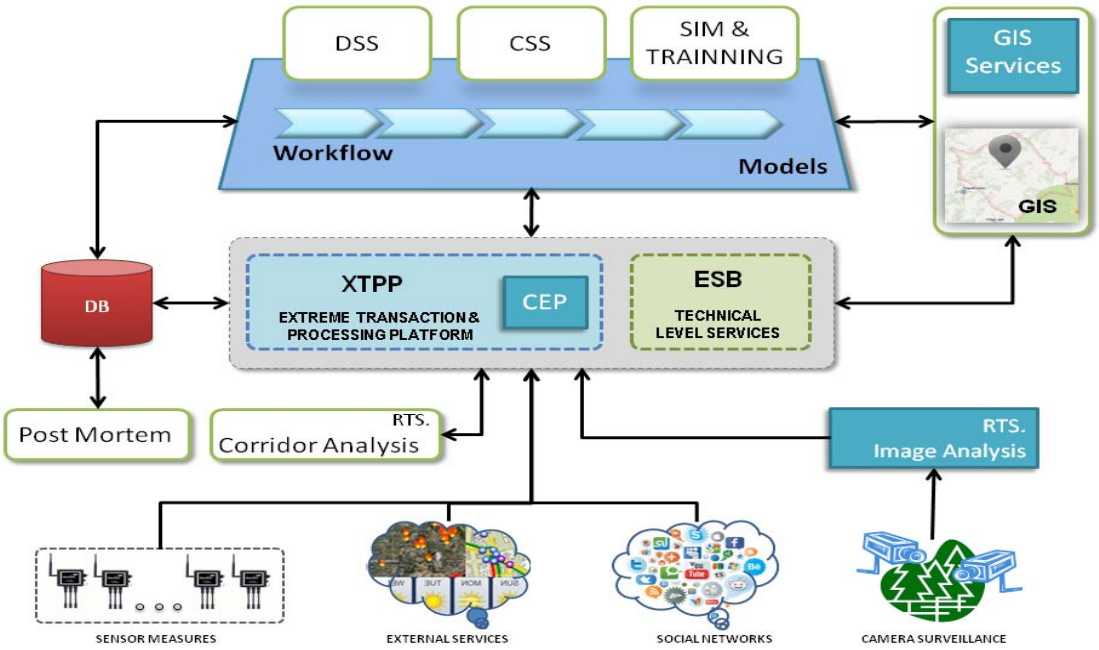


Figure 2: DiCoMa System

DiCoMa Decision Support and Training Tools: Forest Fire Alarm Levels and High Level Operational Plan

The purpose of the forest fire alarm levels is to classify the firefighting actions when the forest fire scenario is simulated. There are three levels of alarm and each level has its own process.

Alarm level 1 (Controlled Situation): This is immediately activated when the fire is identified, if the burning area is lesser than 20 hectares.

Events: Sensor event, fire alarm event, fire area event.

Actions: Alarm level 1: send notifications to Ground Unit, Pump and Machinery Unit, Air Support. See Figure 3.

Alarm level 2 (Severe Situation)

If the burning area already exceeds 20 hectares, alarm level 2 is activated. Alternatively, if the fire starts to threaten settlements, this alarm level is also activated.

Events: Fire area event, fire distance to the settlement event.

Actions: Alarm level 2, evacuate settlement action, send notifications to Ground Unit, Pump and Machinery Unit, Air Support. See Figure 4.

Alarm level 3 (Disaster Situation)

If the Incident Commander decides that alarm level 2 has failed, alarm level 3 is activated. When this happens, the incident commander is empowered to mobilize all manpower and resources within the country to combat the fire.

Events: Fire controlled event (absence of this event within 2 hours of alarm level 2 action), fire area event (fire area continues to increase after 1 hour of alarm level 2).

Action: Alarm level 3, send notifications to Ground Unit, Pump and Machinery Unit, Air Support. See Figure 5.

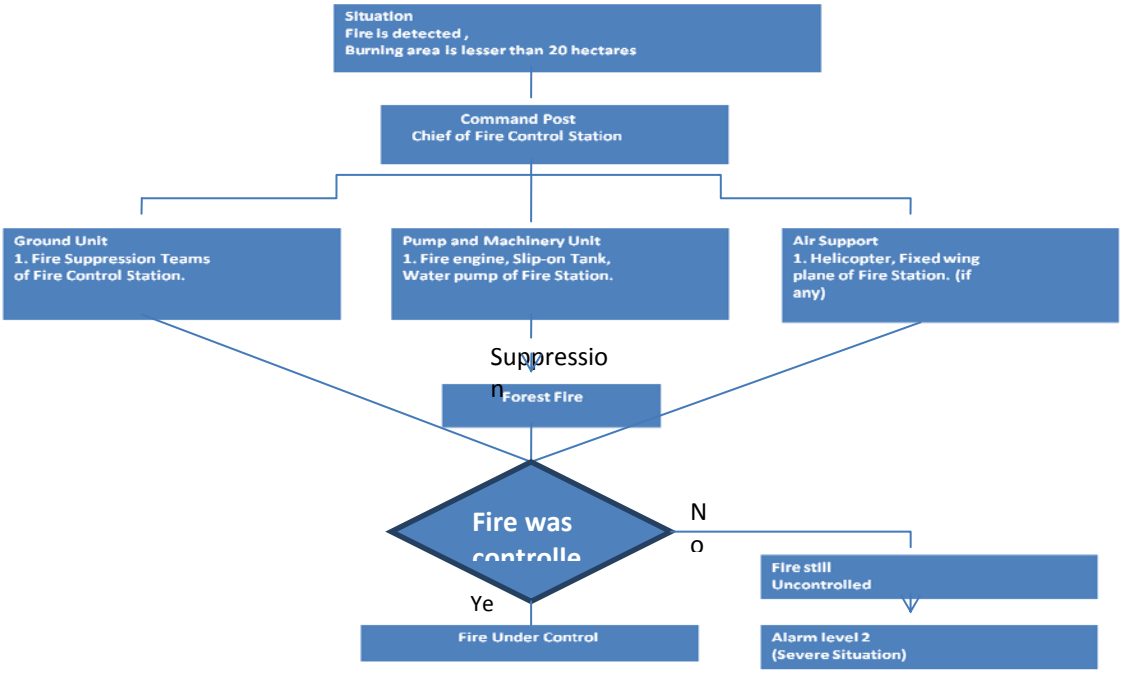


Figure 3: Alarm level 1 (Controlled Situation)

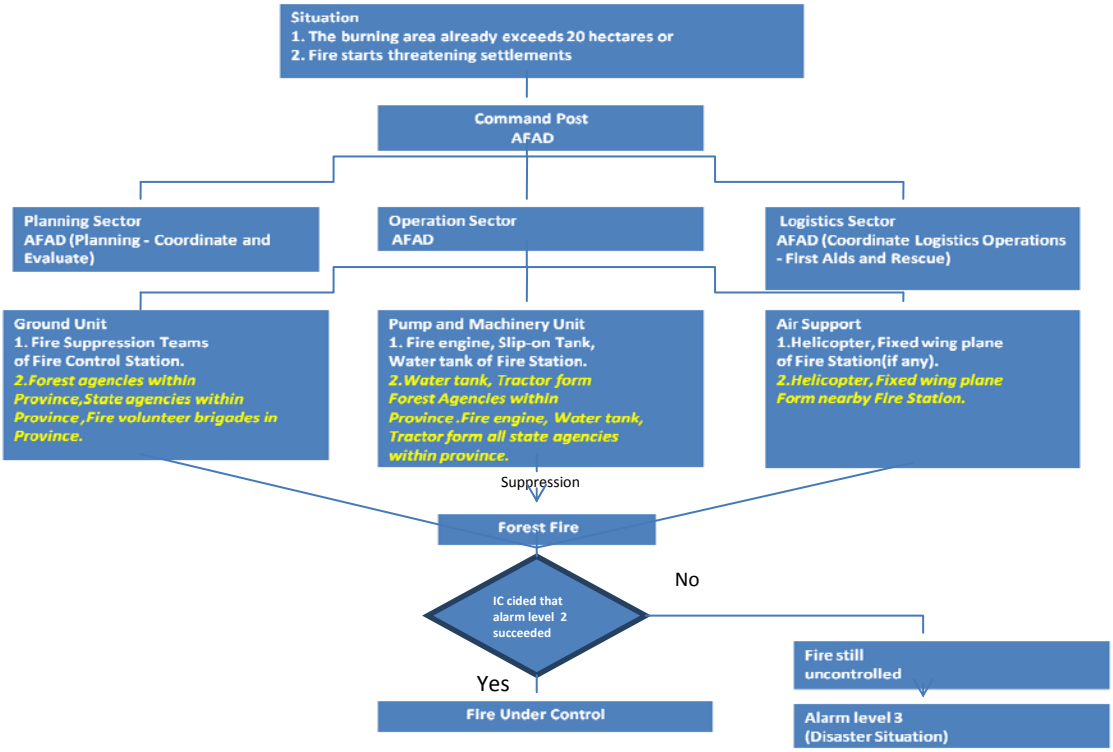


Figure 4: Alarm level 2 (Severe Situation)

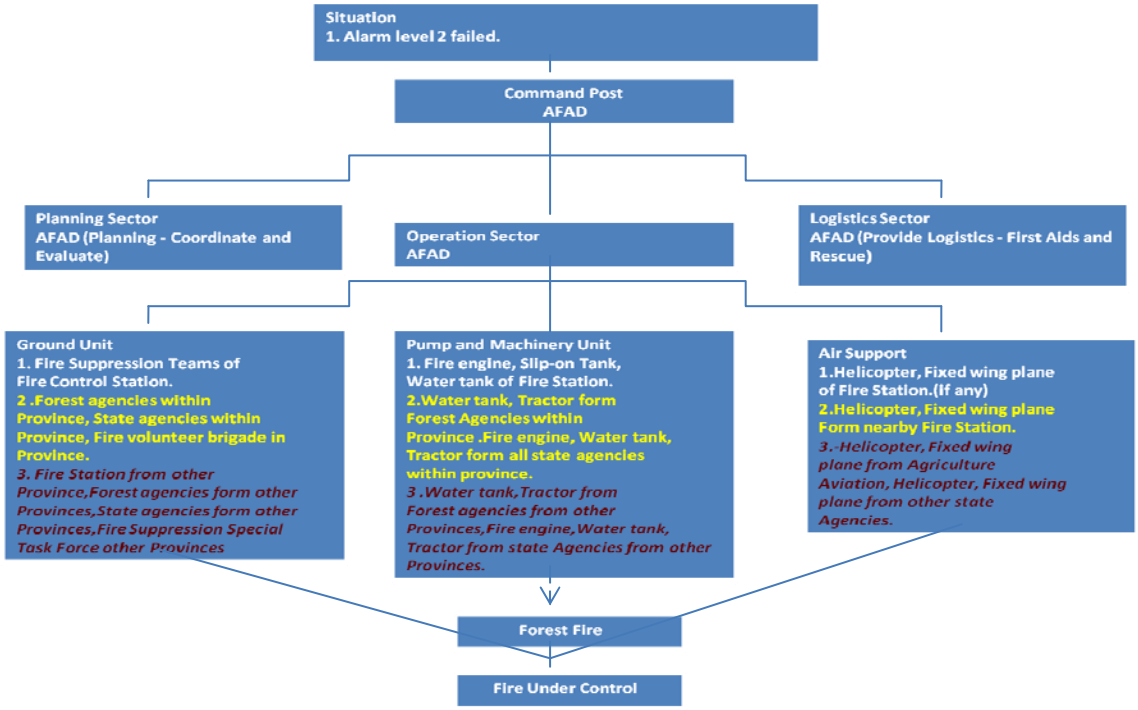


Figure 5: Alarm level 3 (Disaster Situation)

6. Conclusion

Istanbul is the most crowded and industrialized city of Turkey and has a high probability of forest fires. In this study, we have evaluated the disaster preparedness and response of Istanbul using as a case study a forest fire scenario. While developing the scenario, 'worst case' conditions were selected for the postulated actions to be dealt with by the Emergency Operations Centre. Before estimating the response of Turkish forest fire teams and disaster organization, their capabilities were considered. During whole progress of the scenario, some lack of capacity in response actions was also observed. The worst-case scenario process revealed new vulnerabilities for Istanbul. All these vulnerabilities increase the risks for Istanbul and, hence, a new systematic approach is needed.

The DiCoMa Framework is intended to ensure effective management of large disasters and complex emergencies by providing a set of tools that aim to improve the effectiveness of decision makers. If we simulate the worst-case forest fire scenario assuming that the DiCoMa system is functional, the system ensures more effective management in Consequences at Time 1, Consequences at Time 2, and Consequences at Time 3. In this way, we can reduce the vulnerabilities of Istanbul with the help of DiCoMa.

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References

[1]. Ay N., Ay Z. (2011), Aircraft and helicopter usages in forest fires in Turkey, **Proceedings, 34th International Symposium on Remote Sensing of Environment**, ISPR (International Society for Photogrammetry and Remote Sensing), Sydney, Australia, 10-15 April 2011 (2011).

[2]. Republic of Turkey General Directorate of Forestry, Forest Fires in Turkey, http://www.ogm.gov.tr/lang/en/Documents/Forest%20Fires.pdf (19.1.2015)

[3]. Turkey General Directorate of Forestry, "Forest Atlas", http://www.ogm.gov.tr/lang/en/Documents/Forest%20Atlas.pdf (19.1.2015)

[4]. Douglas P. (2003), Disaster preparedness: A social-cognitive perspective, **Disaster Prevention and Management**, 12, 210-216.

[5]. Rose, A. (2004) "Defining and measuring economic resilience to disasters." **Disaster Prevention and Management,** 13, 307-314.

[6]. O'Donnell, James; Corry, Edward; Hasan, Souleiman; et al. (2013), "Building performance optimization using cross-domain scenario modeling, linked data, and complex event processing", **Building and Environment,** 62, 102-111.

[7]. Cugola, Gianpaolo; Margara, Alessandro; Matteucci, Matteo; et al. (2015), "Introducing uncertainty in complex event processing: model, implementation, and validation", **Computing**, 97(2), 103-144.

[8]. Terroso-Saenz, Fernando; Valdes-Vela, Mercedes; Campuzano, Francisco; et al. (2015), "A complex event processing approach to perceive the vehicular context", **Information Fusion** 21(SI), 187-209.

[9]. Dunkel, Jürgen, et al. (2011), "Event-driven architecture for decision support in traffic management systems." **Expert Systems with Applications** 38, 6530-6539.