The DISPATCH program for the dispatching of Canadair CL-215 and fire trucks in Greece

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Introduction

CANADAIR amphibian water bombers have been used in aerial firefighting in Greece since 1974. Currently the country owns a fleet of 14 CANADAIR CL-215 and 10 new CANADAIR CL-415 aircraft. This presentation is about a computer program that was developed in 1993, when the CL-415 was not available yet, with the purpose of providing decision support for the dispatching of CL-215s in the country. Although relatively old, this program and mainly its development effort are useful for illustrating some ideas that can be helpful for similar efforts in the future.

The CL-215 in Greece in 1993

The CL-215 does not need to return to its base to be reloaded with water which is a significant advantage given the proximity of most of the country's vulnerable low elevation pine forests to the sea. As a result, since the introduction of the first CL-215 in Greece in 1974, these planes were relied upon very heavily to fight fires all over the country. However, the concentration of the planes in one or two bases and erroneous delays in their dispatching resulted in an overall unsatisfactory performance of the aerial firefighting system.

For many years dispatching of the aerial firefighting forces was performed by a forester/dispatcher at the Firefighting Coordination Center in Athens who made decisions based only on a few general guidelines and on his own personal experience. Each dispatcher and his assistant served in this post only for a week every few months. As a result, there was a wide variation in dispatcher response, adding a very unstable element to the firefighting system. Better dispatching of aerial resources was obviously an area where immediate improvements could be achieved with minimal cost. In 1993, for the first time, it was attempted to provide dispatchers with a computer based decision support system (DSS) that would help them in their duties. Development of this system is described below.

Decision support system development

Development of the system was initiated in the beginning of 1993, its initial concept was presented in April 1993 (Xanthopoulos 1994) and the first version was completed in June 1993. At the time the author, who is wholly responsible for the development and programming of the system, worked for the "Institute of Mediterranean Forest Ecosystems and Wood Products Technology" of the Greek Ministry of Agriculture.

The system was named "DISPATCH" and its first version was specifically developed for the dispatching of the CL-215 water bombers. It relied heavily on computational models and rules of thumb, was based on real time inputs rather than using existing databases and developed quantified estimates projecting the impact of alternative solutions (Leigh and Doherty 1986). Its use as an advising aid to the dispatchers was initiated at the dispatching center in July 1993.

A number of constraints were obvious from the beginning of the development process. First, the system had to be operational by the onset of the high fire danger season in July. Second, the system had to be simple and extremely easy to use, given the poor computer skills of most dispatchers and their assistants. Third, the system had to have as simple data requirements as possible because complicated information coming from the location of the fire would not be available to the dispatcher. Additionally, there was no geographic information system (GIS) available or any other kind of a computerized database that would allow automatic information retrieval. Finally, the time required for data input, data processing and data output should be as short as possible to avoid dispatching delays.

The short time available for the development of the system precluded any in-depth research that would provide sophisticated models for fire behavior and fire suppression force effectiveness. Research on these subjects was scarce in Greece at the time. Due to this problem the models had to be derived using alternative techniques that included expert opinion, analysis of selected case studies and use of information from existing fire behavior prediction systems.

System output specification

The basic requirement specified for the system was to advise the dispatcher on the need to send or not water bombers to a reported fire and to suggest the appropriate number of aircraft. Analyzing formally this problem it was obvious that it has many of the attributes that characterize difficult real world decision-making problems (Kim 1991) such as imperfect information on the current state for the decision maker, non-obvious functional requirements, nebulous constraints and unknown impact of alternative actions. Automated allocation of limited resources between multiple nearly simultaneous fires through DISPATCH was clearly out of the question given the lack of a functional GIS to support it. Alternatively, it was determined to produce through DISPATCH an index called SERIOUSNESS that, as the name implies, represents an evaluation of the seriousness of the fire, and to provide the dispatcher with guidelines on how to interpret the index. It was determined that SERIOUSNESS should take values between 1 and 100 to facilitate interpretation.

In the middle of a particular day with high fire danger the probability of nearly simultaneous eruption of more than one fires, each with a very high SERIOUSNESS index that would justify immediate dispatch of water bombers, is quite high. Two more indexes, also in the range 0-100, were designed to provide guidance to the dispatcher in such a case.

One index is called NEED and refers to the need for water bombers in order to suppress the fire given the size of locally mobilized ground forces. The other index is called EFFECTIVENESS and indicates the probable effectiveness that the CL-215s will have if they are dispatched immediately to the fire under consideration.

Table 1. Input parameters for the DISPATCH Decision Support System

a.	Location of the fire
b.	Specification if the fire is in Attica
c.	Specification if the fire is in an area of special importance
d.	Specification if lives or homes are in immediate danger
e.	Date
f.	Time of the day
f.	Vegetation type being burned (forest fuel type)
g.	Wind speed (in Beaufort scale gradings, commonly used in Greece)
h.	Topography
i.	Size of reported fire at the time of announcement
j.	Accessibility of the fire to vehicles (existence of roads)
k.	Number of locally mobilized fire tracks
l.	Expected time of arrival of ground forces
m.	Time for take-off for the first CL-215
n.	Distance from the base of CL-215s to the location of the fire
o.	Distance between the location of the fire and the sea

The probability of limited availability or total lack of water bombers at a particular moment creates the need for quantitative guidance to the dispatcher for effective dispatching of the appropriate number of Forest Service fire trucks towards the fire from approximately 600 such vehicles distributed all over the country. Two more DISPATCH outputs were specified for this task: the number of ground TANKERS required to control the fire through extended attack if no planes are involved, and the probable MIX of water bombers and ground tankers in order to achieve fire suppression within a prespecified length of time.

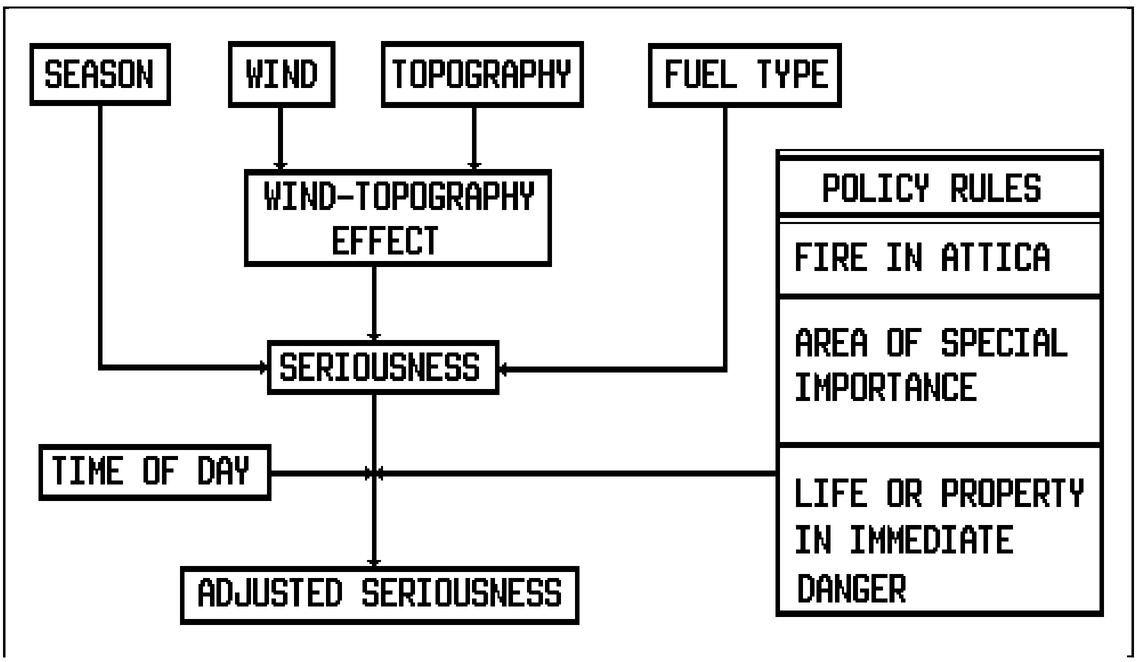

Figure 1. The procedure for the estimation of fire SERIOUSNESS

Required system inputs and development of models

Estimation of the system outputs specified above required development of a number of models. These models had to be simple and to have simple data requirements because complicated information would not be available to the dispatcher. As a result models from the international fire science bibliography could not be readily adopted. The alternative that was finally chosen was to combine some elements of such models with expert opinion and analysis of a few case studies, adding where needed policy rules of the Greek Forest Service. The minimum set of inputs that was finally judged as crucial while their timely collection was judged as possible is listed in Table 1.

Each one of these inputs is used for the calculation of at least one of the specified outputs as shown in figures 1 and 2. The actual algorithms for the calculation of these outputs are composed of simple mathematical relationships and adjustment rules in the form of "if..then" and "case of ..." statements in the computer program. They aim to match calculated index values to the results of an unofficial survey that collected the opinions of a few foresters with significant firefighting expertise. For example, SERIOUSNESS is calculated using the formula

$$\text{SERIOUSNESS} = \frac{100 \times \text{SEASON} \times \text{WIND\_SLOPE1,4} \times \text{FUEL\_TYPE}}{1398{,}83}$$

where

SEASON takes values between 1 and 5 based on the date with some additional adjustments for certain fuel type and wind combinations.

WIND_SLOPE is the value of wind (in Beaufort grades, limited to a maximum value of 9) multiplied by 1,2 for rough topography or by 1,1 for medium slopes. No adjustment is introduced for smooth topography.

FUEL_TYPE takes values between 1 (for fuels such as beech (Fagus silvatica forests) and 10 (for Aleppo and Calabrian pine (Pinus halepensis and Pinus brutia) forests).

The resulting SERIOUSNESS is adjusted positively or negatively for the time of day and is increased appropriately if the fire has characteristics that give it a special importance (parameters b, c, and d in Table 1). Trials with the system and expert opinion led to the development of simple guidelines for the dispatchers. If predicted SERIOUSNESS for a fire is between 0 and 30, then water bombers should not normally be dispatched if the necessary ground forces can be mobilized. For SERIOUSNESS values larger than 30 and less than 60 the dispatcher may decide to dispatch water bombers or not based on their availability, the existence of significant ground forces close to the fire location, the need to keep a minimum level of reserves and the need for dispatching the planes to other simultaneous fires in the area. The decision is based to a large extend on examination of the NEED and EFFECTIVENESS indexes and, in the case of simultaneous fires, on comparison of their SERIOUSNESS indexes. Finally, if SERIOUSNESS for a fire has a value larger than 60 then water bombers are immediately dispatched if they are available. The number of water bombers is determined by examining the planes-ground tankers MIX suggested by the system.

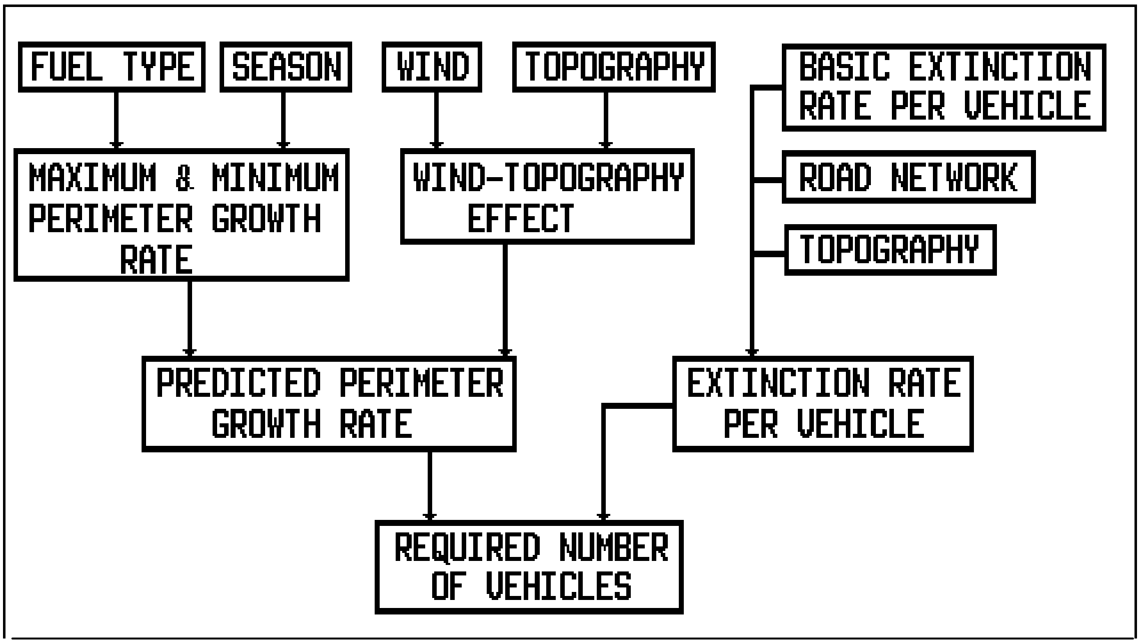

Figure 2. The procedure for the estimation of the required number of fire trucks.

Calculation of the required number of vehicles (TANKERS) was a challenging task. The basic philosophy was to predict a fire perimeter growth rate (PGR), obtain an estimate for the extinction rate of fire perimeter per vehicle and compare them (figure 2). Existing models such as the ones used in the U.S. BEHAVE fire behavior prediction system (Andrews 1986) could not be readily used for the prediction of PGR due to lack of appropriate data. Alternatively, information for fire spread rates under various conditions were collected from experienced foresters, published estimates and a few case studies. The model for PGR calculation that was developed is a linear interpolation between a maximum and a minimum possible perimeter growth rate for each fuel type, both adjusted for SEASON. The calculation is made for a 9 Beaufort grade wind and high slope and then it is reduced linearly for the actual conditions. Similarly, prediction of the extinction rate per vehicle is based on estimates from the same experts and is calculated by a linear formula that adjusts a basic extinction rate for density of the available road network and roughness of the topography. Forest type, which is another variable affecting the extinction rate, is not included in the calculation. Expert opinions were contradictory, probably due to different forest density causing varying difficulty of movement and flame extinction for the firefighters for the same forest type. Furthermore, information on the specific forest characteristics is not available to the dispatcher at the time of fire report. The resulting extinction rate per vehicle represents a conservative estimate. The minimum required number of vehicles, in case of extended attack, is calculated as the ratio "perimeter growth rate/extinction rate per vehicle".

The inputs obtained about the water bombers (time for take-off, distance from the base to the fire and distance between the fire and the sea) are used for an evaluation of the probable contribution of these planes if dispatched. First, an overall model was developed, offering a suggestion on the probable effectiveness of the planes for the particular fire. This effectiveness model is based on SERIOUSNESS, time required for the planes to get to the fire and productivity on the fire. The value obtained from this calculation is increased through rules of thumb for fires that are detected while they are still small and is reduced sharply when topography or wind conditions are unfavorable.

A fire perimeter extinction rate is calculated for the CL-215s based on the their theoretical fire front extinction rate per water drop and the number of drops per hour that they can achieve, given the distance between the fire and the sea. Then, given the estimated PGR, the perimeter extinction rates of planes and ground tankers and the time required for arrival of the planes, a complex model is used for the calculation of the required number of CL-215s, for a fixed number of tankers at the fire, in order to achieve control of the fire in a number of hours specified by the dispatcher.

System realization

The system was programmed in the TURBO PASCAL programming language, for DOS-based IBM compatible Personal Computers. System requirements were kept to a minimum (640 Kbytes of RAM, VGA card, 100 Kbytes hard disk space), which are insignificant by the standards today’s PCs.

The system's user interface is interactive and is extremely simple composed mostly of multiple-choice questions, each offering four to six options. Forest type is an exception since the user may choose between fourteen forest/fuel types. System output is presented on the computer screen but the user may also request a printed report for his records. An example of this report, from the version of the system in English, which was developed later, is presented in figure 3.

System performance

The system was introduced to the Firefighting Coordination Center in July 1993 and was used as an advising tool by most dispatchers through the 1993 fire season. All dispatchers who were introduced to the system were able to run through their first mock fire in less than 10 minutes. This includes dispatchers who were introduced to the use of computers for the first time. In normal use less than three minutes are required to run the program and obtain the printed output.

The simplicity of the program caused positive attitude from most dispatchers who worked with the system, due in part to the fact that it was not presented to them as a tool that would replace them but as a tool for their support. The decision was still theirs. Many dispatchers offered useful suggestions for further improvements.

The system was tested on more than thirty fires for which the author together with various dispatchers had the opportunity to examine the degree to which system predictions matched reality. The results for most fires were amazingly good, with the mix of dispatched planes and fire trucks controlling the spread of the fire in approximately the predicted length of time. When predictions differed significantly from reality, the deviations were always on the conservative side. In a number of cases, the deviations could be traced back to erroneous input information provided by the personnel reporting the fire. Although these results appear encouraging, there has been no official effort to evaluate system performance.

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*************************** F I R E   D A T A *******************************

LOCATION OF FIRE                                              : MILIES (N. EVIA)
MONTH : 7                DATE : 26                      TIME : 14
VEGETATION TYPE                 : PINUS HALEPENSIS FOREST
WIND SPEED                      : 6 BEAUFORT GRADES
TOPOGRAPHIC RELIEF      : HIGH (>50%) HOMOGENEOUS SLOPES
ESTIMATED FIRE SIZE AT REPORT TIME : 0,4 - 2 HECTARES
ROAD NETWORK DENSITY    : LOW
SIZE OF INITIAL ATTACK FORCES ALREADY ON THE WAY : 4 - 5 FIRE TRUCKS
EXPECTED ARRIVAL TIME OF THE FIRST GROUND FORCES : 0 - 10 MINUTES
TIME FOR TAKE-OFF OF THE FIRST CL-215         :  15 MINUTES
FLIGHT DISTANCE FROM THE BASE TO THE FIRE     : 100 KILOMETERS
DISTANCE BETWEEN THE FIRE AND THE SEA         :   8 KILOMETERS

*************** F I R E   A N A L Y S I S   R E S U L T S ******************

FIRE SERIOUSNESS (0-100)                                              : 62
----------------------- G R O U N D   F O R C E S -------------------------
PROBABLE EFFECTIVENESS OF GROUND FORCES (0-100)                       :  1
FIRE CONTROL WITH CURRENTLY DISPATCHED FORCES IS NOT PROBABLE EXCEPT IF CONDITIONS
CHANGE. IF THE FIRE ESCAPES INITIAL ATTACK, WITHOUT AERIAL SUPPORT, AT LEAST 19 FIRE
TRUCKS WILL BE REQUIRED.
----------------------- A E R I A L   F O R C E S -------------------------
ESTIMATED ARRIVAL TIME FOR THE FIRST CL-215                   :  47 MINUTES
MINIMUM CALCULATED TIME BETWEEN WATER DROPS                   :  10 MINUTES
NEED FOR DISPATCHING OF AERIAL SUPPORT (0-100)                : 100
IN CASE OF DISPATCH THE PLANES WILL REACH THE FIRE BEFORE IT IS CONTROLLED BY THE
MOBILIZED GROUND FORCES.
PROBABLE EFFECTIVENESS OF AERIAL FORCES (0-100)                       :  86

---------------- ESTIMATED REQUIRED NUMBER OF WATER BOMBERS -----------------
IF ONLY THE GROUND FORCES MOVING TOWARDS THE FIRE ARE USED,
FIRE CONTROL WITHIN 1 HOUR DOES NOT APPEAR POSSIBLE
FIRE CONTROL WITHIN 2 HOURS REQUIRES DISPATCH OF AT LEAST 12 PLANES

BASED ON THE ABOVE DATA FOR GROUND AND AERIAL FORCES ARRIVAL TIME, FIRE CONTROL WITHIN 2
HOURS CAN BE ACHIEVED BY THE FOLLOWING COMBINATIONS OF FIRE TRUCKS AND WATER BOMBERS:

TRUCKS  |   4   6   8  10  12  14  16  18
----------------------------------------------------------------------------
CL-215  |  12  10   9   8   7   5   4   3
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Figure 3. An example of the fire analysis printout produced by DISPATCH.

Some trends and significant benefits were obvious from the use of the system. First, a list provided to the dispatchers for collecting the required input data, made them work with better information that they would not necessarily have obtained otherwise. Second, the dispatchers appeared more careful with their decisions as, in the system's printout, they had a measure to compare them against. Third, and most important, the analysis offered by the system often indicated to the dispatcher, early in the development of a serious fire, that even when two or four planes were dispatched the overall resources would not be enough to suppress the fire. Having a quantitative estimate of the ground tankers required to complement these planes, most dispatchers started mobilizing ground forces from neighboring areas early on, rather than waiting for failure of the first wave and then start concentration of huge resources on an extensive fire perimeter.

Conclusions

The system was a useful addition in the Firefighting Coordination Center at the time and represented the first effort to introduce decision support systems there. Of course, it has certain obvious limitations such as:

- It only assesses CL-215 and fire truck dispatching
- It does not offer any parameterization that would allow adaptation to the dispatching of other means (e.g. CL-415 or other aircraft), or to different environment (e.g. different fire season).
- It cannot perform automated allocation of limited resources between multiple nearly simultaneous fires
- It offers no data recording capability other than by printing

In spite of these limitations though, DISPATCH provided some valuable quantitative support to the dispatchers, encouraging their active involvement for the timely mobilization of the necessary resources.

Although the comments for DISPATCH were positive, the plans for system improvement in 1994 did not materialize. The addition of helicopters carrying specially trained groups of firefighters for initial attack on forest fires in 1994, added a new element with unknown performance to the firefighting organization. The DISPATCH system is still available to the dispatchers as a “gaming” tool but the complexity they have to face in their decisions has increased significantly so it cannot offer operational support.

It should be noted that a few years later, in 1999, the DISPATCH program provided the basic ideas for the development of the firefighting/dispatching module for another much more sophisticated GIS based, DSS named FOMFIS (Caballero et al. 1999) that was developed within the framework of a European Commission, DG Environment funded research project with the same name.

Currently, DISPATCH is available for free to all interested members of the fire community who want to test it and get an idea of its features and the concepts behind it.

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