The contribution of forest roads to the forest fire protection

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Abstract:
In this work the contribution of forest roads in fire suppression is examined via the selection of two main forest roads of Thessaloniki's suburban forest road network, which became the reason for conflicts, concerning their environmental compatibility and efficiency on fire protection. The research includes the capability of improving the efficiency of fire suppression involving two aspects of fire protection, the area under protection and the time of early fire suppression. Specifically whether the available fire extinguishing vehicles moving along the two selected main forest roads are providing a fire protection for the total area of the forest or not and if the time required for them to reach a fire source is lower than 15 minutes, which is considered to be the crucial time interval for a successive fire suppression on the ground (early suppression). Additionally it is examined whether the two selected main forest roads are compatible environmentally and suggestions are made in both practical and theoretical manner for the improvement of the existing road network against fire incidents using technical and environmental criteria.

Keywords: forest roads, fire suppression, suburban forest

1 Introduction

Handling of forest fires combines both prevention and suppression. The first level of prevention is the most important, effective and less costly (Kailidis, Karanikola 2004). Prevention actions include forestry measures (cleaning the fuel of understory), observatories (patrols, aircraft and satellites), the construction of forest roads and water supply networks. It also includes actions for the immediate detection and early of fire as well as the immediate first intervention for suppression, not later than 15 minutes from the onset of fire (Kailidis, Karanikola 2004).

The action of suppression consists of several actions including the fire fighting, the implementation of equipment and available personnel and finally the monitoring of the burn area to avoid re-ignition. Aerial means are necessary in suppression only when ground means seem to fail. The most critical factor in fire suppression is the operational coordination. The aim is to achieve fire suppression during the first intervention by ground means avoiding the use of aerial ones. It is found that the overall average first intervention time for fire suppression in Greece is about 33.4 minutes. In prefectures with high risk of fire this time interval is estimated to be between 20-30 minutes while in mountain regions between 40-60 minutes. Only 21.9% of forest fire extinguishing vehicles arrive in less than 15 minutes at the fire source. The reduction of time needed for first intervention to less than 15-20 minutes, will result in a significant reduction of burned areas to about 70% (Dimitrakopoulos 2000).

From the above information it is derived that forest roads are necessary along with standby positions for fire extinguishing vehicles to specific locations to assist a successful first intervention. It is obvious that the objective of the initial response within 15-minute can only be achieved with well-distributed forest road network but not necessarily a high density one (Psilovikos T. 2010). In Greece, forests with high fire risk are usually those located near residential and tourist areas. The local communities impose a great pressure on land use and the state is not legally defended due to lack of national and forestry Cadastre. In these regions more than 50% of forest fire ignitions are intentional. (Kailidis, Karanikola., 2004 and Dimitrakopoulos A.P.,2008).

Usually these kinds of forests are not productive, but instead suburban or protected forests. Therefore the traditional methods of forest road network design are inadequate. Such a case is the suburban forest of Thessaloniki. The failure of early fire suppression by ground means during the summer of 1997 resulted in a disaster, with an estimated percentage of 64% of the total forest area burned (Stergiadoy et all, 2002). The fire of 1997 led to the creation of strong environmental organizations which demanded forest protection in an intense manner and oppose all forms of technical work (road construction, hydraulics). As a result there is always a conflict between environmentalists and forest authorities on the technical characteristics for any engineering work in the forest.

This study aims to examine the contribution of forest roads to fire protection against fire, concerning routing and geometrical characteristics causing the least impact on the natural environment.

2 Materials – methods

2.1 Study area

The suburban forest of Thessaloniki occupies a total area of 3000 ha located on the northeast side of Thessaloniki as a natural boundary of the city (Map 1). Today only 1200 ha of forest area remain intact and there is some natural reforestation in the burned area.

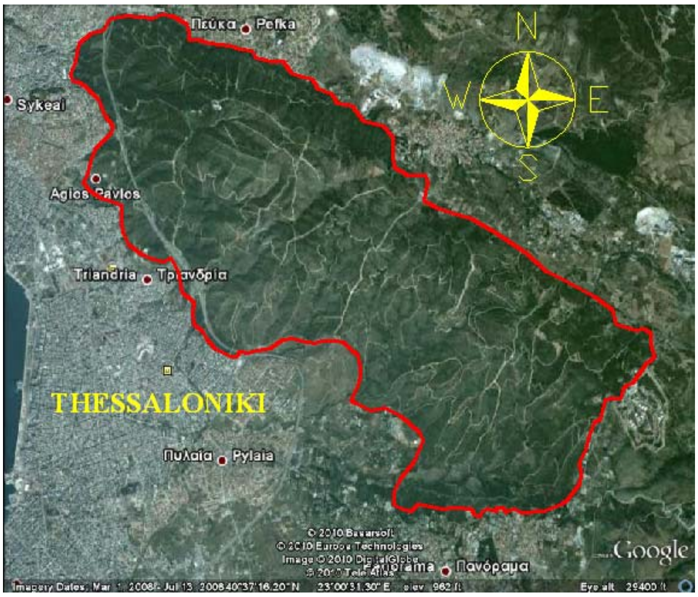

Figure 1: Orientation and limits of suburban forest of Thessaloniki. Source: Google earth

The Gazette 516/6-6-1994 defines that Thessaloniki's forest is under high protection (Gajogiannis and others, 1996). Also according to law (Presidential Decree 575, Gazette 157/9-7-1980) it has been declared as a high risk to fire zone. Beyond that it concentrates a list of characteristics according to those parameters taken into account (weather, vegetation type, topography, anthropogenic interference) (Xanthopoulos, Varela, 1999), in order to be categorized within the five categories of fire risk forests, published every summer across the country. Therefore the road network serves three purposes:

1. Access for visitors for pleasure

2. Access to services for forestry purposes

3. Access for fire prevention and suppression

According to the first two purposes the geometric characteristics of forest roads can be defined as the minimum to protect the environment but the third goal leads to the adoption of a lower limit of geometrical properties so that the fire extinguish vehicles will be able to move with safety and efficiency . At this point it is necessary to find the right balance between these two conflicting interests.

In 2005, under the supervision of Thessaloniki's forest service, a number of improvement projects (roads and related structures) were conducted to protect forest roads from erosion and improve access. The design was prepared by the relevant technical departments of Thessaloniki's Forest service. According to the design, the implementation of improvement works, concern specific routes based on their importance from the entire road network (Fassas and others 2007). The works were completed in late 2008.

In this paper we focus on the research area covering the eastern part of the suburban forest of Thessaloniki, with an estimated area of 1199.5 ha, representing 40% of the total area of the forest, as shown in map 2. From the various forest roads within the research area, two roads are selected to be examined, under the code names A1T1 "Chilia dendra-Eksochi" and A2T2 "Gefyra perebou-Monastery of Kimiseos Theotokou" (Map 1), for the following reasons:

1. They have the longest route and cover a significant part of the urban forest

2. They are the two main roads due to their geometrical characteristics most of the improvement works were conducted along their routes together with water supply networks and drainage, resulting in a controversy between environmentalists and services.

3. They provide excellent access to both the beginning and the end of national roads Panorama-Chortiatis and Eksochi-Chortiatis.

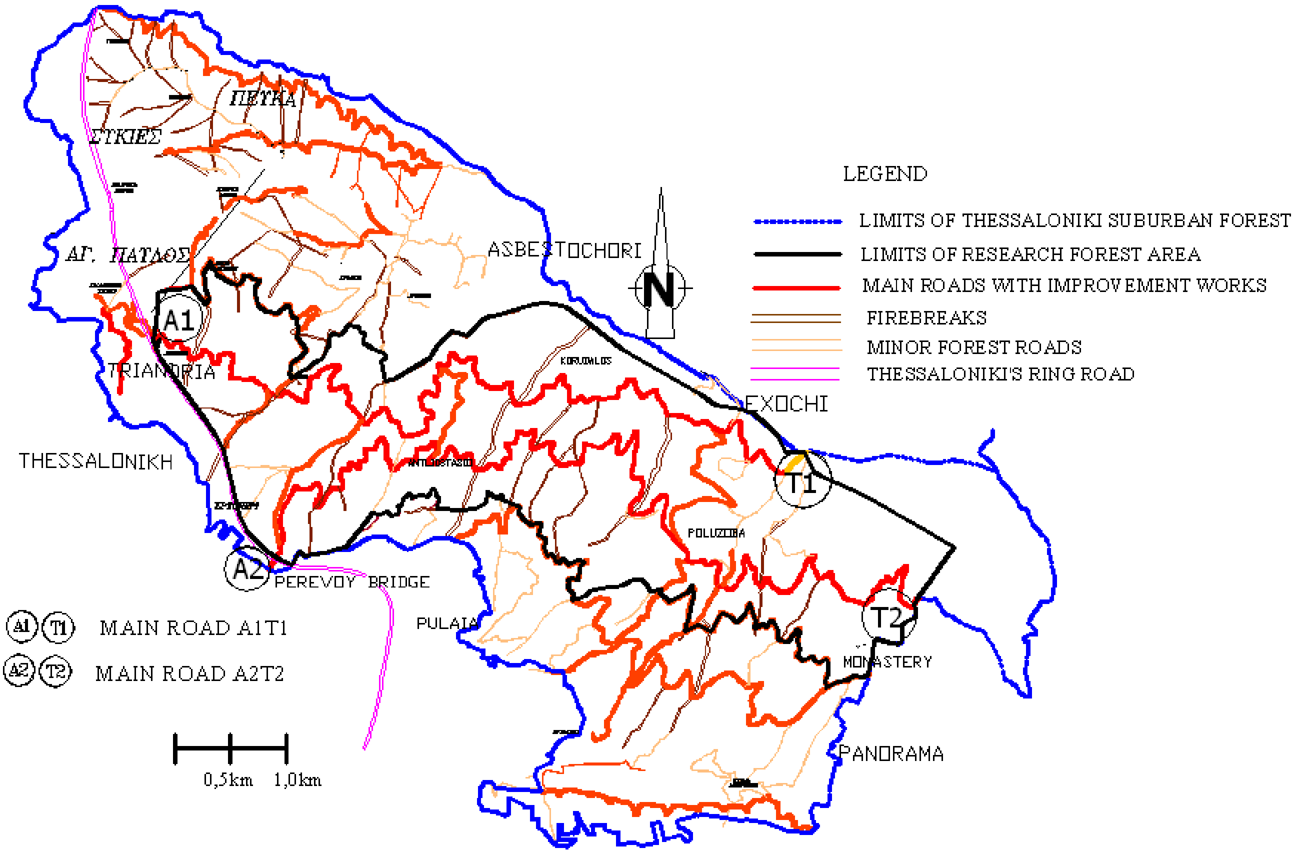

Figure 2: Limits of research area of suburban forest of Thessaloniki. (Psilovikos T., 2010)

2.2 Geometric properties of selected roads

The geometric characteristics of the two selected routes are:

A. Forest Road A1T1: Length 10.200 m. The width after the improvement projects ranging between 6.0 to 7.5 m. Road Construction Projects:38 concrete sewage pipes with a diameter of 100 cm and one concrete box sewage. Ditch rainwater collection with trapezoidal cross section.2 water tanks, water supply network covering 70% of the total length of road and 15 water supply hydrants.

B. Forest Road A2T2: length 12.690 m. The width after the improvement projects ranging between 5.0 and 6.0m longitudinal slope between 3-10%. Road Construction Projects:33 concrete sewage pipes with a diameter of 100 cm and 6 box sewages. Ditch rainwater collection with trapezoidal cross section. Network and hydrant locations: 2 water tanks, water supply network covering 10% of the total length and 5 water supply hydrants spaced along the road.

The environmental organizations strongly opposed against the improvement projects and created obstacles during construction. In their assessment they considered the road width as an excessive one together with all other structures (http://forestsos.wordpress.com/2009/03/).

Amongst the technical characteristics of forest roads the most important one is road width, in conjunction with the longitudinal slope, in order to provide efficiency and safe access for fire extinguish vehicles, provided that there is a limitation on the existence of sharp turns. In the case of the two selected roads decribed above, their widths allow the simultaneous passage of two fire extinguishing trucks in the opposite direction. The longitudinal slope is nowhere steeper than 12% and there are no sharp turns (Psilovikos T, 2010).

Therefore the fire extinguishing trucks and crews are not at risk during firefighting operations. On the other hand the increased occupation of forest land by forest roads is causing irreversible environmental impacts. In a forest protected by law and has the character of suburban forest, the excessive width is not acceptable.

Figure 3: A fire exstinguishing vehicle moving along main forest road A1T1 with large road surface width . Source: Psilovikos T. 2010

According to the relevant literature on productive forests the width of forest roads is calculated and specified only for the straight parts while for the curves widening rules are applied, according to the straight width in order to accommodate long trucks transporting logs with safety. Thus the minimum width of the road surface segments is derived from the width of a log truck multiplied by a factor of 1.5 or 1.6 on average speeds (Hafner, 1971, Kuonen, 1983, Stergiadis, 1986).

So if we apply this factor to the minimum width of a log truck being 2.50m the calculated road width is 2.50 x 1.6 m = 4.0 m. But the forest of Thessaloniki is not a productive but a suburban forest and the above calculation is unacceptable in our case.

The method of calculating the road width changes by taking into account the width of a large fire extinguishing vehicle among those used for fire suppression in Thessaloniki's suburban forest and a minimum clearance on both edges of the road . Therefore according to Table 1, the maximum truck width is 2.5 m plus 0.50 m clearance in both sides results in a total width of 3.50 meters for straight parts of the road. This is approximately the road width of 3.60m indicated by Demir, for the category of main roads in national parks with traffic volume of 200-400 vehicles / day. Concerning steep turns with small radius of curvature R, the formulae of widening for three-axle trucks passing vehicles is (17 / R) (Doukas et. Al. 1996). If for example the curve radius is 15m, using the formulae the widening becomes 1.13m, which is approximately equal to 1.20m according to Demir. Therefore the width of 3.50m calculated is acceptable for Thessaloniki's suburban forest providing widening where appropriate.

Table 1: Technical characteristics of fire extinguishing vehicles used in suburban forest of Thessaloniki

AVAILABLE FIRE EXTINGUISH TRUCKS IN THESSALONIKI'S SUBURBAN FOREST					
MODEL	**LENGTH**	**WIDTH**	**HEIGHT**	**Vol.capacity**	**Type**
UNIMOG 2,5	6,190m	2,350m	3,050m	2,5 ton	4x4
MAN 1,5	6,200m	2,300m	3,115m	1,5ton	4x4
IVECO 2,5	6,400m	2,500m	3,300m	2,5ton	4x4
MAN 5	7,590m	2,500m	3,950m	5ton	
MERCEDES 10	8,880m	2,500m	3,600m	10ton	
Hauling trucks for fire suppression					
CAT 908	6,012m	2,060m	4,506	1,00 m3	4x4
CAT D4G	4,04m	2,44m		1,92m3	4x4

Source: Fire brigade Vehicle management office

At the same time, the suburban forest of Thessaloniki has been officially categorized as a high fire risk forest. This means that facilitation of movement of fire suppression vehicles is of high priority and two-way passing should be possible for fire extinguishing vehicles. Following this necessity we consider the simultaneous existence of two large fire extinguishing vehicles moving towards each other. Therefore a total deck width of 0.50 +2.50 + 0.50 +2.50 +0.5 = 6.50 m. is required. Obviously, this width is large and is not acceptable for an environmentally protected forest, (Psilovikos, 2010).The best compromise is the adoption of a maximum width of 3.50 m, as reported previously, on the condition that widening will be applied not only along turns but also at the straight parts of the roads at a spacing of 250m between them (Figure 4) along with the existence of reversing positions every 500 meters spacing (K Doukas, 2004).

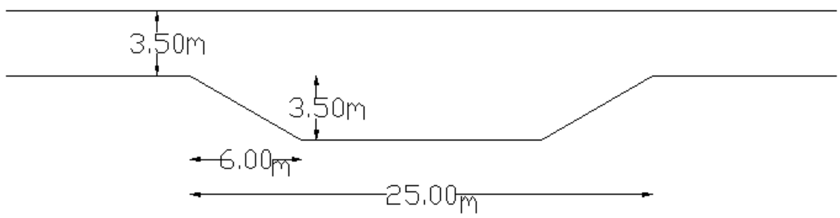

Figure 4: Proposed Widening along a straight part of a main road to accomodate two-way passing of fire trucks

2.3 Percentage of forest protection area

Every fire extinguishing truck carries multiple water hoses of different diameter each as shown in table 2. By connecting these hoses a total hose length is derived and it indicates the capacity of each truck to reach a fire source.

Table 2: Characteristics and total length of hoses on available fire brigade vehicles

Model Fire Trucks (1)	Water hose cross sections mm (2)	Number of hoses Per section (3)	Length of hose Per section in m (4)	Total Length of all hoses m (5) =(3)X(4)
UNIMOG 2,5	25 and 45	15 and 6	25 and 15	465
MAN 1,5	25 and 45	15 and 6	25 and 15	465
IVECO 2,5	25 and 45	15 and 6	25 and 15	465
MAN 5	25 and 45 and 62	15 and 6 and 6	25 and 15 and 15	555
MERCEDES 10	45 and 62	15 and 8	15	345
MERCEDES 11	45 and 62	15 and 8	15	345

In order to check whether the total hose length corresponds to the actual operational capacity to reach a fire source we consulted the fire brigade's personnel. The answer was that in most cases this is realistic but in some cases of very steep terrain the operational capacity is lower than the total pipe length. Therefore we decided to present a two case study concerning area of the forest being protected by fire extinguishing vehicles. The first one called "practical protection zone" corresponds to a fire suppression bandwidth (buffer zone) with a capacity radius of 150m uphill and 300m downhill from the origin point where the fire extinguishing vehicle stands.

The second one called "theoretical protection zone" corresponds to a fire suppression capacity of 300m uphill and 500m downhill and it is very close to the actual operational capacity except in rare cases of very steep slopes of terrain. The theoretical protection zone has been adopted as operational ones in practice by some fire brigade services in Greece (Doukas et al. 2008) like Kalamata's forest fire brigade in Pelloponese. Thus by adopting the theoretical protection zone we obtain more protected area even with fewer roads.

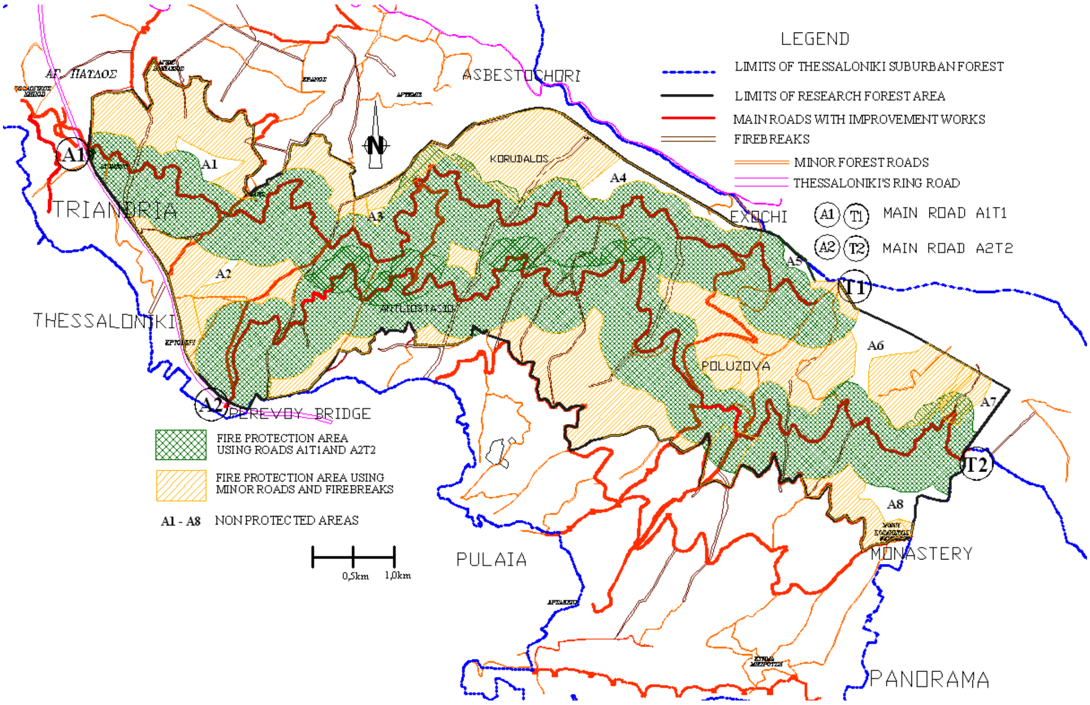

Figure 4: Area of fire protection using a range of 150-300m from forest roads within the research area. (Psilovikos T. 2010)

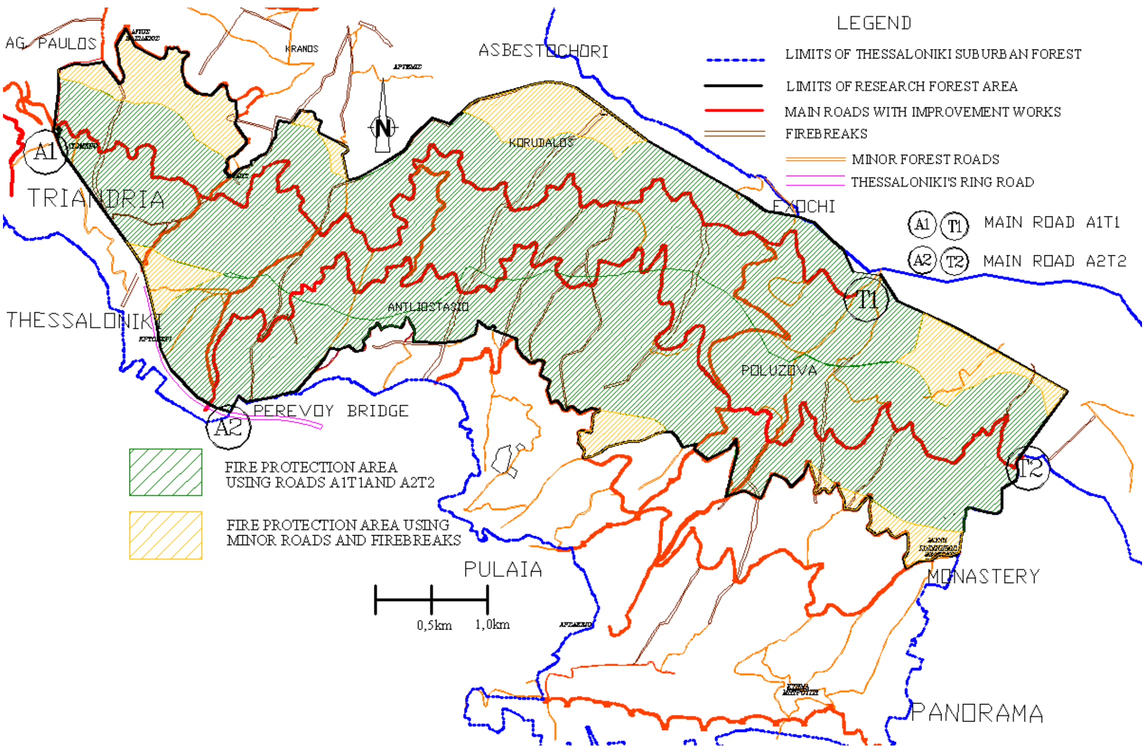

Figure 5: Area of fire protection using a hose range of 300-500m from forest roads within the research area

The above maps 4 and 5 show the percentage of the forest area being protected from fire corresponding to the two different zones discussed earlier. Using the routes of the two main roads presented in paragraph 2.2, in conjunction with local roads and firebreaks, the fire protected area was derived according to the contour lines indicating the uphill and downhill areas. For simplicity the overlapping areas of coverage are not shown. Map No 4 shows the practical protected area using operational hose lengths of 150m uphill and 300m downhill while map No 5 shows the theoretical protected area using lengths of 300m uphill and 500m downhill. In map No 4 it is observed that areas A1, A2 and A8 are out of reach and therefore not protected from fire, but their area percentage compared to the total research area of 1199.5 hectares is only 4.8% In map No 5, by adopting the theoretical protection zone, the total research area is covered by the hose lengths of the fire extinguishing vehicles.

2.4 Action of the fire trucks on forest roads within a 15 minutes time interval

The two selected main forest roads coded as A1T1 and A2T2 are the main arteries of the road network, used frequently by the fire service, including both on foot and vehicle patrols. During the dry season the fire extinguishing vehicles are located at the following stand-by positions of the forest:

A. Starting point A1 of main forest road A1T1 being a permanent fire brigade parking lot .

B. Close to the starting point of forest road A2T2, behind Perevou bridge.

C. At Polyzova hill situated uphill at 8.6kms from the starting point A2 of road A2T2

(Fire brigade's vehicle management office)

The time criterion is defined as the early first intervention within 15 minutes of firefighting forces to any spot along the routes of the two main roads since a fire incident is detected. Therefore the method followed is to calculate the time required, to move a fire extinguishing vehicle from the specific standby location to any fire incident within the operational protection zone along the two road routes. In order to calculate the time required, a minimum estimated operational speed of 30km/h is introduced, which is realistic due to the favorable geometrical characteristics of the two selected main forest roads (Psilovikos T, 2010 & Demir M, 2006)

3 Results

The starting point of road A1T1 consists of a parking lot serving the operational centre of fire brigade for forest fire suppression with at least two fire extinguishing vehicles permanently present. Also a fire extinguishing vehicle is located at a standby position 600m away from the research area at Kranos hill as shown in map No 6. The fire extinguishing vehicles starting from either of these two locations can reach any point of the first 7.5km of A1T1 road within 15min. The remaining 2.7km of A1T1 road can be reached by the fire extinguishing vehicle located at Polyzova hill in less than 15min. Concerning the second main forest road A2T2 the fire extinguishing vehicle near the starting point A2 is available during the dry season only. From this location it is capable to reach the first 7.5km within 15min. The remaining 5.19km of the A2T2 road are reached by the fire extinguishing vehicle located in Polyzova hill or in special cases from a fire vehicle situated on the regional road Thessaloniki-Hortiati outside the research forest area, at a place called German restaurant, 1.5km away from the finish point T2.

The findings concerning the current situation for the protection against fire of Thessaloniki's suburban forest is satisfactory. Specifically the percentage of the study forest area under fire protection is 95.2% when adopting the practical protection zone with a range of 150m uphill and 300m downhill and 100% if the theoretical range zone of 300m uphill and 500m downhill is adopted. Concerning the second criterion of early first intervention time it is shown that the available fire vehicles can reach a spotted ignition on both main roads within 15 minutes. The disadvantage is the lack of an independent available fire extinguishing vehicle at the east side of each road. The use of the fire extinguishing vehicle located at Polyzova hill for both roads create a limitation in availability especially during a simultaneous fire event. To improve the current forest protection against fires a number of measures should take place.

3.1 Proposals of measures to be taken

Due to the fact that the fire extinguishing vehicle located at Kranos hill has nothing more to offer than the vehicles located at the A1 allows for the possibility of a new standby location. The proposed location is 6.3km away from the starting point A1. The new location has the advantage of being on an intersection with a firebreak connecting the two roads A1T1 and A2T2. It is also located only 220m away from a water supply hydrant and 3.9km from the end point T1, so the time required for a fire extinguishing vehicle to reach T1is only 7.6 minutes. On the contrary there is no need for any additional measures on the forest road A2T2 although it is better to have the fire extinguishing vehicle located near A2 on a permanent basis throughout the year. Map No 6 shows both the existing standby locations of fire vehicles and the proposed ones described above. The mileage covered by fire trucks within 15 minutes on both roads appear in green color line as well as the vehicle routes and the corresponding response times on fire in a Table form. The above measures can lead to a successful fire suppression operation even against two simultaneous ignitions provided that the detection and notification of fire is done in short time.

In an effort to optimize the relationship between the conflicting interests of environmental protection and fire suppression operations a theoretical proposal is introduced. This is the replacement of the two existing main forest roads with one main road, coded as A0T0. This road should be placed between the existing roads having the same direction from south to north-east as shown on map No 5. The starting point of the proposed main road is located at the existing Triandria intersection on Thessaloniki's ring road and the end point will be located at the regional road of Eksoxi-Hortiati towns. Respectively the existing standby locations for fire extinguishing vehicles will be altered and moved to the starting point A0 instead of Perevou bridge. Respectively instead of Polyzova hill a standby position will be introduced at a distance of 5.75km away from A0 as shown on map No 5. The route of the proposed road was designed taking into account the terrain characteristics indicated by the ground contours to avoid steep slopes and sharp turns. The total length within the study area is 8.742km, far less than the two existing roads A1T1 and A2T2 and this alone reduces significantly the environmental impact on the research area.

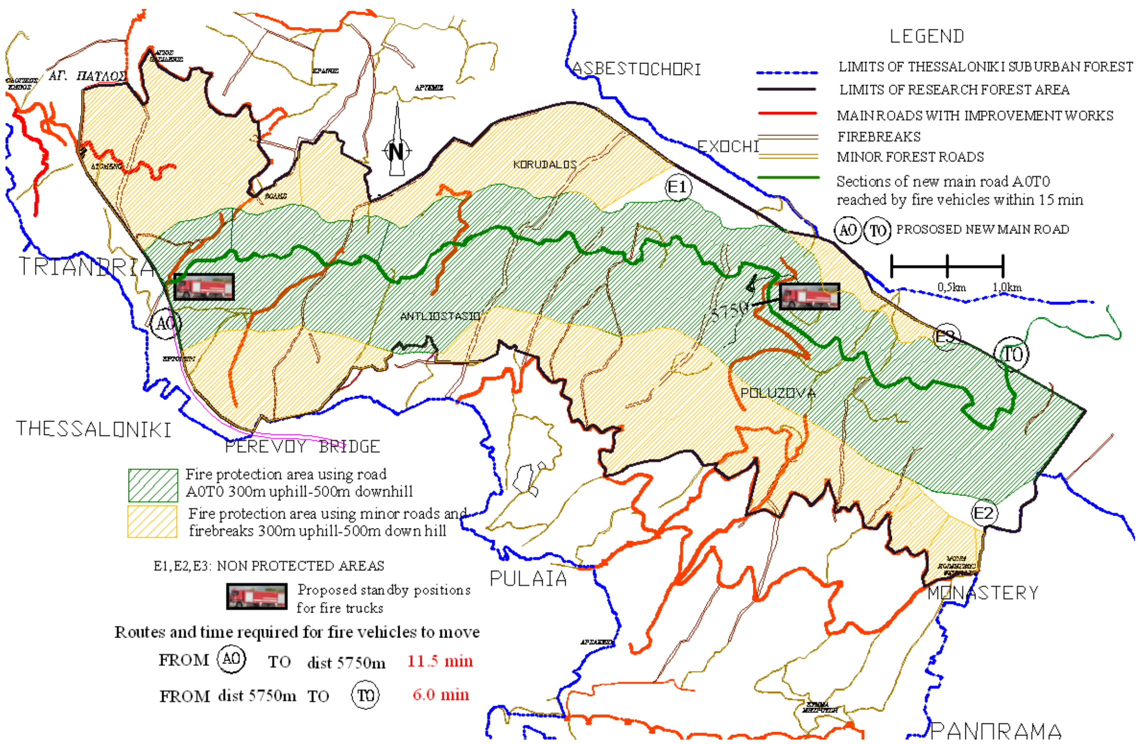

Figure 6: Area of fire protection and time needed for fire extinguish vehicles to reach a fire source using the proposed forest road A0T0)

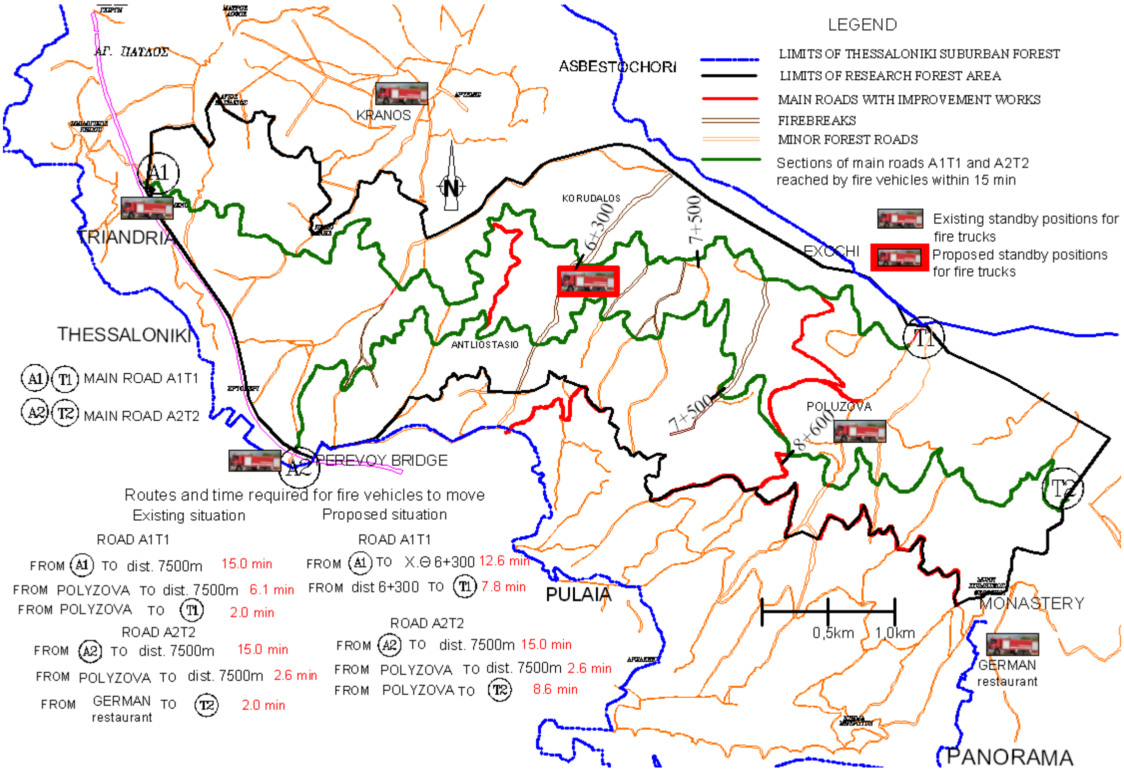

Figure 7: Routes and time needed for the fire extinguish vehicles to reach a fire source for existingsituation and proposed solution.

4 Conclusion

4.1. Construction of forest roads

Forest roads should be designed with a hierarchy according to the type of forest. The road networks in non productive forests should be dispersed and their geometrical characteristics should not follow the rules applied to productive forests, due to environmental issues. The width of 3.5 m corresponding to main roads in suburban forests like Thessaloniki's one is adequate provided the existence of special widenings every 250 m and of reversing positions every 500 m. Also the design of geometric features should ensure a maximum longitudinal slope of 12% and avoidance of sharp turns. The two main roads A1T1 and A2T2 examined in this work are wide enough to allow the two-way passing of large fire extinguishing vehicles throughout their routes and the longitudinal slope is limited to 12%. Therefore the fire services can operate in ideal road conditions but the environmental impact is hardly reversible. Therefore, in a theoretical approach, the proposed replacement of the two main roads A1T1 and A2T2 with a new main road A0T0 with similar route as shown in map No 5 is justified. The benefits are less construction and maintenance costs but mainly an optimum solution between the conflicting interests of environmental protection and fire suppression operations, provided, however, the accessibility of fire vehicles on firebreaks also.

4.2. Forest fire protection area

The selection of the "theoretical protection zone" corresponding to a fire suppression buffer zone of 300m uphill and 500m downhill has emerged according to the technical specifications of fire trucks and is realistic in most cases. The "practical protection zone" should be applied to very steep terrain or in case of smaller fire extinguishing vehicles. Map No 4 produced by the adoption of theoretical protection zone and results in a 100% fire protection of the research area of Thessaloniki's suburban forest.

The proposed forest Road A0T0 as shown on Map 5 replacing the existing main roads A1T1 and A2T2 offers an area protection coverage of 97.1%, leaving out only three small areas E1-E2-E3. This protection is possible on the condition of taking into account the accessibility of fire vehicles on firebreaks and secondary forest roads.

4.3 Action of the fire trucks on forest roads within a 15 minutes time interval

It is concluded that the existing fire service management provides full coverage on the two main roads A1T1 and A2T2 within 15 minutes from the detection of a fire source but not in the case of simultaneous fire incidents on both roads. The suggestion for an additional standby position for a fire extinguishing vehicle, located at a distance of 6.3km from the origin point A1, resolves the problem of independency. Therefore the fire forces could be able to fight simultaneous fire incidents moving along the two main roads as well as on secondary roads and firebreaks. Considering that more than 50% of forest fire ignitions are due to intention the new stand by location will enhance the fire protection considerably. In a theoretical basis the proposed main forest road A0T0 outlined in section 3.1 complies with the criteria of forest area protection and time limit of 15 minutes for first intervention at any point along its route as shown on Map No 5.

Finally at forests of high fire risk the prerequisite of an adequate traffic management should be established during the design of forest road networks in order to ensure traffic efficiency of fire service's vehicles but without imposing irreversible environmental impacts, focused on fast first intervention.

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