IMPROVING UAVs EFFICIENCY USED IN HIGHRISE BUILDING FIRES

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Abstract: *UAVs(Unmanned Aerial Vehicle) are deployed in large-scale applications for agriculture, logistics, firefighting and surveying in order to increase efficiency, safety and to reduce operation costs. Regarding firefighting in highrise buildings or remote areas, the UAVs are more often used because human intervention it's not always possible. As a result, the objective of this paper is to evaluate the existing drone capacity, to identify it's limits and to propose new techniques in order to increase UAVs efficiency when it's used in fires that occurs in tall buildings. The main disadvantages of using the UAVs in highrise buildings is compromise between the maximum water volume that drones can carry in a certain period of time and the range of the drone.*

Keywords*: building, height, fire, intervention, special vehicle, drone, artificial intelligence*

1. INTRODUCTION

People are aware that in high-rise buildings fires that break out on the lower floors put many individuals in danger because it is difficult to evacuate the upper floors. Large fires can damage the buildings irreversibly and the use of firefighting trucks in such cases is limited to certain intervention heights.

Recently, drones/ UAVs (Unmanned Aerial Vehicles) have started to be used for monitoring, automation of processes and data gathering across many areas such as: agriculture, construction, defence and emergency services [2].

As a result, drones can be extensively used in the detection and monitoring of fires in large forest and urban areas [1, 2, 14, 15, 16]. After a fire is detected, a specific number of drones or even a swarm of drones can be deployed to identify the nearest water sources and safely extinguish the fires in urban and forest areas [1, 2, 14, 15, 16].

The use of UAVs in high-rise building fires presents some problems that limit their potential. In order to use drones that can access narrow spaces between tall buildings, you need to limit the capacity of each drone. At the same time, the water volume that a drone can carry is often proportional to its time of flight and range [1, 2, 14, 16].

The focus of this paper is to present the actual capabilities of existing drones in terms of water capacity, range, and time of flight, and to present new techniques that can extend a drone's capabilities beyond traditional techniques that involve using just firefighting trucks.

2. USE OF AERIAL TRUCKS FOR HIGH-RISE INTERVENTION

According to Romanian legislation, buildings are classified according to height into 3 categories: normal buildings, tall buildings and very tall buildings. Normal buildings must have the last floor of the last usable level under 28 m height, measured from the groundfloor and the limit of 28 meters height should also be accesible on minimum 2 sides of the building [1].

A tall building has the last floor higher than 28 m. A very tall building has the last floor higher than 45 m [3].

This classification is interesting because the height criteria were chosen in correlation with the heights that can easily be reached by the most available fire trucks in Romania. In addition, using only fire trucks at fires that occur in tall and very tall buildings presents several challenges [1]. To be able to intervene, it is necessary to have a fleet of fore trucks and specialised personnel ready for work at height [1, 4].

Pavel et al. [1] described the complexity of firefighting operations using aerial apparatus at height.

The company MAGIRUS has designed the world's hightest turntable ladder which can reach a height of 68 m [5].

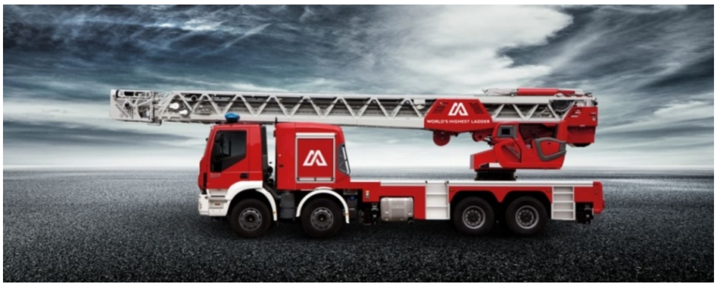

FIG. 1 MAGIUS M68L escalator [5]

Using a fire truck like the Magirus M68L implies many challenges. The maximum working height of the fire truck in Europe can reach 70 m. Due to the characteristics of fire trucks and the limitations of their working area , the lifting height of the fire truck cannot be significantly increased. Therefore, it is impossible to use the fire truck to extinguish a fire that occurs in buildings higher than 70 m. The working area of the fire truck is usually set up along one side of the building, so the remaining parts of the building cannot be protected by the fire truck. Secondly, the existing fire trucks in Romania work at a height of less than 50 m in most fire stations. Also, lifting fire trucks need a long time to deploy and are greatly affected by the weather. Taking the fire truck with a height of 70 m as an example, the actual deployment time is more than 3 minutes , and the platform of the fire truck rises to the top for more than 6 minutes . Furthermore, it can only operate in low wind speed conditions, usually below 10 m/s. Currently, there are no successful rescue cases of lifting fire trucks above 50 m with outdoor wind speeds exceeding 10 m/s in Romania. On the other hand, fires involving the exterior insulation material of high-rise buildings have no effective means to be extinguished. Once a fire occurs in these buildings, it will spread rapidly. Due to the fixed working position of the fire truck and the limitations of their working area , the fire cannot be put out in time, causing the whole building to be damaged by fire [1].

In most cases, more than one vehicle is needed in a typical fire intervention. The acquisition and maintance of such an equipment can be expensive and not many fire intitutions or low income regions can afford it.

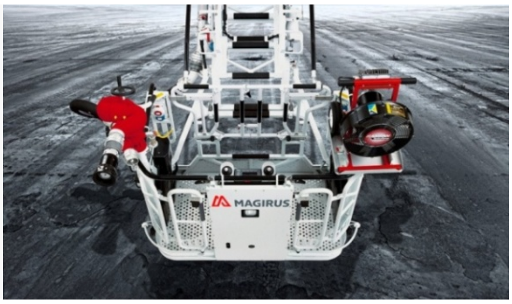

FIG. 2 MAGIRUS M68L6 turntable ladder [5]

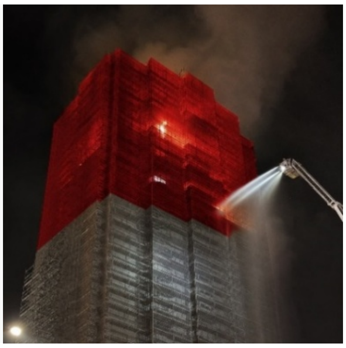

FIG. 3 Height from which it is no longer possible to intervene with the intervention escalator (red color)

Fires spread faster in high-rise buildings due to a combination of physics, architecture, and environmental factors—specifically the chimney effect—which creates a natural acceleration system. Consequently, numerous building zones rapidly become inaccessible via stairwells or elevators.

The tallest building in Romania is the Sky Tower, which stands at a height of 137 meters. Located in Bucharest, the building's height exceeds the maximum reach of standard fire truck ladders in the event of a fire emergency [1].

FIG. 4 Fire in a high-rise building [18]

FIG. 5 Bucharest Sky Tower Building [6]

To prevent fire spread and allow for personnel intervention, the building is equipped with its own firefighting systems, including interior hydrants, exterior hydrants, and a sprinkler system. While these fire systems make the building safer, there is still a chance that a fire could bypass them, requiring active firefighting crews to intervene. As a result, in similar cases, firefighting interventions can be carried out by employing drones.

3. USE OF DRONES FOR FIRE DETECTION AND EXTINGUISHING

Drones are often deployed in fire fighter interventions. Pavel et al. detailed the large types of drones that are built for various applications [1]. As a result, choosing the best drone for fire intervention in crowded urban areas can be very challenging. Practically you need to consider several constraints but the most important are: drone range, time of flight, size, autonomy and drone payload capacity.

3.1. Drone range and time of flight. Most drones can easily reach heights up to 500 m so they can easily monitor, detect and extinguish fires in most urban areas. The distance a drone can travel is linked to it’s time of flight and it’s payload. Thus, the time of flight limits the range of drones. Most drones can operate up to 60 minutes. There are a few models that can operate longer like the Wild Hopper with thermal engine but most of the drones equipped with electric propulsion can operate for a maximum 60 minutes (see section 3.4.).

In 60 minutes the drone must charge it's water tank, reach the fire area, drop the water and return to the starting point. Under these conditions there is no time to use the same drone more than once when a fire breaks out.

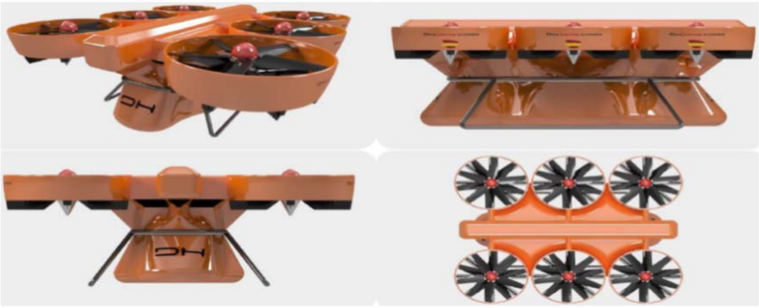

FIG. 6 Wild Hopper prototype [17]

3.2. Drone payload capacity. In general the payload capacity is linked to propulsion type. The drones that use electric motors and batteries are capable of carrying up to 150 kg meanwhile drones equipped with thermal engines can carry up to 600 kg [10].

3.3. Drone autonomy. In recent years, advances in AI (artificial intelligence) have made it possible to use autonomous drones. The main advantage of integrating AI in the drone manufacturing process is that it can be done on various types of drones with relatively few resources. As a result, drones can assist or entirely replace firefighter actions to enhance safety, efficiency , and reduce the financial cost of providing fire protection with firefighting trucks. Drones can also reduce the number of firefighters who risk their lives in fire interventions. Romania has a network of fire stations to protect urban areas from fires . Replacing existing networks with completely new ones is not a financially viable option. As a result, the optimal solution is to improve the efficiency of fire stations by using the existing equipment or adapting it.

3.4. Review on UAVs current capabilities. Drone technology has advanced in recent years so a wide range of drones is currently manufactured for different purposes.

No.	Drone name	Payload capacity	Time of flight	Type of propulsion	Reference
-	-	kg	min	Electric/fossil fuel	
1	JingHong FR300	150	63	electric	[7,8]
2	T-FC100X	180	360	electric	[9]
3	WILD HOPPER	600	30	Fossil fuel	[10]
4	EHang AAVs	100	120	electric	[12]
5	Griff Aviation (Griff 600)	350	30	electric	[13]

4. IMPROVING THE EFFICIENCY OF THE EXISTING FIRESTATIONS IN ROMANIA BY INTEGRATING UAV TECHNOLOGIES

4.1. Using autonomous drones for monitoring a specific area for fire prevention. This is a common practice employed in areas with a high risk of vegetation fires. Large areas can be monitored with several drones equipped with artificial intelligence and thermal vision capabilities.

This way, heat anomalies can be easily detected, reducing the need for on-site human presence and the probability of large fires. In this scenario, the existing fire stations, equipped with packs of drones, can monitor large areas without human intervention.

On the other hand, detecting a fire before it spreads can lower the resources needed to extinguish it. The main disadvantage of equipping the fire stations with drones is the initial investment. While entry-level professional packages can cost a few thousand dollars for basic equipment and training, most specialized firefighting systems require higher capital for high-end thermal sensors, specific software, and smoke and fire-resistant materials. Although the initial investment is higher, operating drones is significantly cheaper and faster than deploying full-sized crews and helicopters [11].

4.2. Crew firefighting interventions with UAV support. The next step in improving fire station efficiency is to extend drones' roles to actively assist in fire interventions. Firefighting personnel face life-threatening risks during interventions. The number of firefighting crews can be reduced by using UAVs as a force multiplier. Primary roles of UAVs in support operations are correlated with mapping the intervention area with real-time updates of hot areas, as stated in section 4.1, and active fire suppression , which is more complex. The complexity comes from the fact that each drone has a specific task; thus, the drones that are employed to monitor an area cannot be assigned to active fire suppression missions. In this case, each fire station must be equipped with several types of drones. As a result, the financial cost of adding UAV support will be higher. In conclusion, it is possible to reduce the number of firefighting crews to a minimum of one, but you still need specialized personnel to monitor and remotely control the drones in order to suppress an eventual fire. As a result , the initial cost of modernizing existing fire stations can range from $100,000 to $ 1,000,000.

4.3. Firefighting with autonomous drones and minimal human intervention. The disadvantage of the first two methods is that you cannot suppress fires without involving human crews. Therefore, there will always be a risk of human casualties. The recent technological advances in artificial intelligence can be used and integrated into firefighting crew interventions that employ drones for full support. Minimal human intervention is possible by integrating artificial intelligence on at least two layers. The first layer of integrated AI is applied to drones that act as "flying data centers," capable of navigating complex environments, avoiding obstacles, and processing data in real time, reducing the need for direct human piloting. The next level is to link these drones to a central artificial intelligence server through a wireless network. The server will collect information in real time from each drone that is employed to detect and monitor fires in a specific area. Furthermore, the AI will process the data, identify the best way to extinguish the fires, and deploy additional drones focused on removing one or more elements of the fire triangle-heat, fuel, or oxygen. The drones specialized in removing heat will carry water to the critical zones. Without a nearby water source, this method can be employed by using several drones like the ones described in section 3.4. Another possibility is to use drones that can carry a hose, which can be connected to a public water service or to a firetruck. In this case, the payload requirements are lower, so a medium drone can be employed to achieve this task instead of a large one. The main advantage is that it can reach remote indoor spaces that couldn't be accessed by high-capacity drones.

At the same time, smaller drones could carry self-activating balls filled with fire-retardant chemicals that explode on contact with heat. Practically, the method employs drones for specific purposes:

- Monitoring and mapping;
- Large drones in order to isolate and extinguish ;
- Medium drones that can lift hoses so smaller spaces can be reached;
- Medium and small drones carrying self-activating balls that can reach each indoor space;
- Tiny drones equipped with real-time transmission feeds and thermal cameras in order to verify the intervention's efficiency.

After the UAVs secure the area, making it safe, specialized human crews will verify the area without putting their lives in danger.

CONCLUSION

By taking over jobs with life threathening risks associated, drones can significantly reduce human exposure and save firefighters lives. Crew firefighting interventions with UAV support can easily be applied to every firestation in Romania with minimal financial cost.

Based on intervention experience, it has been found that the two high-rise firefighting methods - using intervention vehicles and drones - are highly complementary, yielding much better results [1].

Their combined use offers a comprehensive overview of the affected area, allowing the incident commander to efficiently allocate resources where they are needed most [1].

The next phase is to fight fires with autonomous drones and minimal human intervention. AI-driven drones will be able to navigate complex environments without GPS and perform real-time data analysis. The financial cost for integrating a fully autonomous national system is very high and further improvements are necessary in order to have a functional system. A good start can be a pilot project that identifies the main issues of the AI system and searches for new methods to lower the financial costs.

In the final phase, further research should focus on developing drones with improved propulsion in order to increase the payload capacity and decrease overall dimensions.

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