MONITORING OF TRAFFIC SITUATION ON HIGHWAY D1 BY UNMANNED AERIAL VEHICLES AND ITS FINANCIAL ANALYSIS

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The article gives a brief description of the specific civil role of UAV (Unmanned Aerial Vehicles) namely: monitoring of traffic situation on the highway D1 using two selected UAVs. To select these two specific UAVs, I decided in term of the availability of many technical details, fuel and oil prices and in term of differences of these unmanned vehicles. The aim of this article is also their financial analysis to use for this particular civil application. Result from this article is based on the conclusion which pilotless aircraft would be best to use when performing this civil application.

K e y w o r d s: unmanned aerial vehicle, civil application, analysis, monitoring of traffic situation

1 INTRODUCTION

Monitoring of traffic situation on the highway is always performing and performed by ground patrols. In today's modern time and fast-evolving technology market could be think over to introducing new systems of control for example by UAVs. This article suggests the possibility of using these unmanned systems on a highway in the Slovak Republic and the financial burden on this civilian application.

2 MONITORING OF TRAFFIC SITUATION ON HIGHWAY D1

Employment of civilian drones controlling compliance with traffic rules would improve the situation on the highways significantly. Even in case, that pilotless set would not be operated daily, drivers would be forced to follow the traffic rules, because there is a great likelihood that one's offences may be seen by the pilotless set. The main advantage would be mobility. When a police patrol stands at a certain place, drivers inform each other immediately (radio, light signals) and traffic controls loses their purpose. This problem would be removed by using unmanned aircraft. Drivers would not observe the sky and even if they would spot unmanned vehicle, it would not be at the same place all the time.

Unmanned aircraft will have to be equipped, in addition to the necessary navigation equipment, with an optical or infra camera. Civilian drones patrolling on highways in the automatic mode of operation could monitor compliance with traffic laws. Suitable software program would automatically alert the operator to the formation of traffic jams and other potential problems in the flow of road traffic. This automatic system could use data from optical and infrared camera. In the case of optical camera, software must be able to recognize individual cars and when in large concentration, alert the operator to this problem. In case of infrared cameras, the camera would monitor warmer points – the heated car engines. The system would alert the operator, if large concentration of vehicles appeared. Using the infrared camera would bring additional benefits. Traffic situation can be observed even under adverse weather conditions (heavy snow, rain), when the most road accidents happen. The system could be further supplemented by a system that would recognize license plates from acquired images. The system would secondarily compare whether a license plate matches a car's color and whether is the car registered under the given license plate and whether it is not stolen. The primary task would be to monitor the traffic situation. And because for the most of the time, there are no problems on highways, UAV would administer mostly secondary tasks, such as license plate control and control of the compliance of the traffic rules. Only in case of problems with the flow of traffic, secondary tasks would be stopped; the operator would manually turn on the system and would guide the drone over the area where the problem occurs. The aircraft would remain in the area until the problem is resolved and would provide real time images. Based on these data Guideline traffic control would then done as well as other steps to restore the flow of traffic.

To monitor the traffic situation unmanned aircraft will have to be operated outside the line of sight, otherwise by use of an aircraft would lose its purpose. Therefore, we assume that the use of aircraft of Category I is unlikely and most likely is the use of unmanned aircraft belonging to Category II. When employing the UAVs for monitoring compliance with traffic laws even small unmanned aircraft (up to 20 kg) operated in direct line of sight could be used. However, if the drones used to monitor traffic conditions will also perform secondary tasks, there would be only a small space for usage of small UAV's. In my opinion, for these purposes it is more suitable to use unmanned helicopter. Although the use of helicopters is more economically challenging, it also brings a number of benefits. When there are any problems on the motorway network, helicopter can immediately reduce its speed and flight over the area of interest, remain there and provide important data. Airplane would have to swirl over the area of interest. Conventional helicopters are difficult to manage. For unmanned helicopters, this is not the same. Yamaha company that manufactures pilotless helicopter R-max claims that their helicopter is equipped with such a system, which allows even unskilled users to operate the machine without problems. Personally, I think it would be more suitable to use APID MK3 for the police of Slovak Republic, R-max for smaller distances, which would control and monitor only a specific area within their range up to 100 km, and for larger distances (170 km) unmanned reconnaissance sets Sojka III would be used.

In Slovakia, the length of highway between Bratislava and Košice is approximately 515 km. The flight range of an aircraft would determine the number of fixed stations. The picture below (Fig. 1) shows solution for three fixed stations (range of about 150 km and 100 km). It would be appropriate to consider solutions using multiple fixed sites. Is not to say that every station must contain its own aircraft. Is it possible to be built up to 10 stations and the whole system would use only 3 aircraft. In the case of employing UAVs for these purposes, it will be necessary to choose a suitable compromise between useful aspect and financial costs. [2]

3 FINANCIAL ANALYSIS

3.1 Financial analysis of use unmanned system Sojka III

One of these circuits has a diameter of about 170 km. When using unmanned system Sojka III to this circuit, it would be needed to use at least two, but preferably at least 4 sets. The flight range of the aircraft system Sojka III is at least 200 km, but the fuel exhaustion would leave this circuit unattended and so at that time it would be necessary to release next plane for constant supervision of controlled area.

Calculation of the financial burden for a 24 hour period of operation of unmanned Sojka III based on the parameters listed in Table 1.

Tab. 1 Technical specification of Sojka III [3]

Type	one rotor engine type Wankel
Tank capacity	208 cm^3 (combustion chamber), (416 cm^3 4-tact equivalent)
Power	28 kW (maximum) by 7 800 ot/min
Gas consumption	0,34 kg/kW/h by maximum power (7 800 ot/min), 0,38 kg/kW/h by travel speed (5 000 ot/min)
Gas consumption per hour	cca 9,5 kg / cca 13 l
Carburetor	membrane with integrated fuel pump with high altitude adjustment
Ignition	electronic contactless magneto
Start	external starter to ramp ignition device
Fuel	Avgas 100LL
Greasing	multi-valve oil pump from a special tank
Oil consumption	268 cm^3 per hour by 6 000 ot/min
Weight	10,7 kg (without alternator)
Flight endurance	approx. 2 hours
Tactical flight range	min. 200 km at altitude 4 000 m (in half-automatic flight mode)
Altitude	50 - 4 000 m
Maximum speed	210 km/h
Take off weight	145 kg
Weight of user equipment	max. 20 kg/75 l
Engine power	28,4 kW/7 800 ot/min
Fuel prize	2,30 € per liter
Fuel density Avgas 100LL	720 kg/m^3
Oil prize	9,20 € per liter

Sojka III input data

Maximum speed of 210 km / h, the area of one circle 170 km, fuel consumption 13 l per hour, fuel price is 2,30 € per liter, oil consumption 0,27 liters per hour, the oil price is 9,20 € per liter.

Based on the input data, it is possible to calculate, that the cost of the fuel per flight hour is about 30 € and oil costs are approximately 2,5 €, consequently, the total cost of the fuel and oil are approximately 33 € per flight hour per one unmanned aircraft Sojka III. To monitor the traffic situation in each area with a diameter of up to 150 km, must be employed all reconnaissance aircrafts. One exploratory system Sojka III may include 4 aircrafts, so the final cost of fuel and oil in the operation of four aircraft in one reporting segment will be about 132 € per hour and 3,168 € for 24 hours.

The cost for the continuous monitoring across D1, i.e. all three areas, will be about 9504 € for 24 hours.

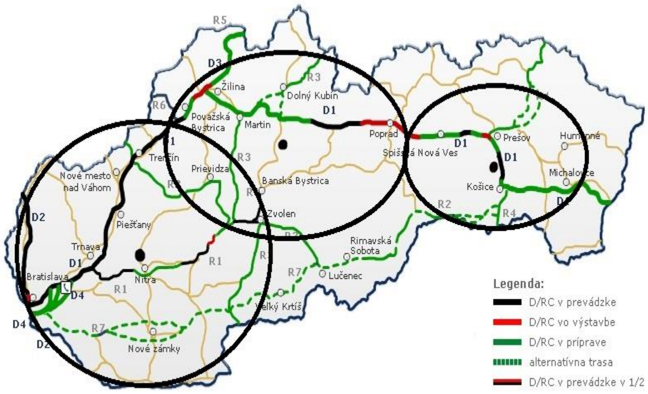

Fig. 1 Highway D1 with 3 fixed stations [1]

3.2 Financial analysis of use unmanned helicopter APID Mk 3

For controlling and monitoring D1 by unmanned helicopter APID Mk 3, the entire highway would be divided into 5 sections with a diameter of 100 km (Fig. 2), whereas the helicopter APID Mk 3 has range only 100 km.

Calculation of the financial burden for a 24 hour period of operation of unmanned APID Mk 3 based on the parameters listed in Table 2.

Tab. 2 Technical specification of APID Mk 3 [4]

Length	2,9 m
Body	carbon fiber composite, weight 5 kg
Main rotor	two bladed glass fiber rotor (diameter 2,9 m) with Hiller stabilisator, 900 rpm
Dry weight	35 kg
Maximum weight	55 kg
Engine	1 cylindric, 2-stroke, 125cc, 9500 rpm
Engine power	10 kW
Fuel	petrol 95 octane, lead free
Gas consumption	4 l/h
Fuel prize	1,50 € per liter
Speed	0-100 km/h
Flight range	100km (with 8 l gas and maximum 12kg payload)
Start	electric
Power supply	300W generator
Main voltage	24V (18-36V)
Backup	60Wh battery

APID Mk 3 input data

Maximum speed 100 km/h, range 100 km, one area within 100 km, fuel consumption of 4 liters per hour, fuel price per liter 1.50 €

Based on the input data it can be calculated that the total cost of fuel per flight hour per UAVs APID Mk 3 is about 6 €. To monitor the traffic situation in each area with a diameter of up to 100 km, must be employed all reconnaissance helicopters, using e.g. four helicopters to one area, the cost of fuel is about 24 € per hour and 576 € for 24 hours.

The cost for the continuous monitoring across D1, i.e. all 5 areas, the use of these unmanned helicopters will cost about 2880 € for 24 hours.

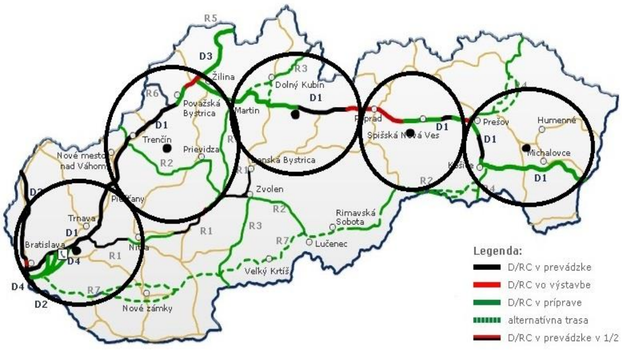

Fig. 2 Highway D1 with 5 fixed stations [1]

4 CONCLUSION

When comparing the two financial analyzes on this role of civil application I realized that it would be more cost-effective to use the second option, i.e. unmanned reconnaissance system APID Mk 3 due to lower fuel costs. The total financial advantage, however, can be evaluated only on the basis of the price performance of the acquisition of reconnaissance systems, but this was not possible due to the unavailability of real prices.

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