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Reshaping Engineering Management Practices for O&M Using Unmanned Aerial Vehicles

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RESHAPING ENGINEERING MANAGEMENT PRACTICES FOR O&M USING UNMANNED AERIAL VEHICLES

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ABSTRACT

Advances in technology are re-shaping and re-engineering prospective and practices, operation and maintenance is one field that is also changing to promptly adapt to such advances. Recently, drones have been introduced as an efficient alternative for traditional inspection practices. While, the state of practice for inspection is still adapting with terminologies such as laser scanning, the use of drones is starting to spread out and probably shall dominate within the coming decade. This paper presents a comparative effort performed to identify strengths and weaknesses of using drone in inspection with regards to state of practice traditional techniques. An initial swift over drone historical and technical aspects is portrayed together with further discussion on latest paradigm shifts with real world practices. A detailed comparison is additionally presented with a conclusion summarizing benefits of drones over traditional
Titles are not included. Authors from the same organization are grouped together.

Keywords: Unmanned Aerial Vehicles (UAV), Drone, Engineering Management, Operation & Maintenance.

INTRODUCTION

Integrating technologies from the field of robotics, sensing and process control is indeed a decisive step on digitalization of operation and maintenance industry. Drone technology, artificial intelligence, wearable technologies etc. are some of the emerging digital topics that can help companies to reduce the operation costs, improve the efficiency by making quick decisions and increasing workforce productivity. The Term Drone or in a more scientific wording unmanned aerial vehicles (UAV) is gaining more interest to be used in diverse fields one of which the operation and maintenance. In order to identify the power of using UAVs in operation and maintenance a historical overview should be presented clearly. In history, UAVs have been in use for military purposes long ago. The first unmanned aerial vehicle attempt is somehow debatable. One of the early actions is recorded in war fighting in July 1849 using a balloon carrier, which is recognized as a type of UAV. Austrian forces besieging Venice attempted to launch some 200 incendiary balloons at besieged city. The balloons were launched mainly from land. However, some were also launched from the Austrian ship. At least one bomb fell in the city, however due to the wind changing after launch, most of the balloons missed their target and some drifted back over Austrian lines and the launching ship [7].

Additional attempts were recorded specifically during World War I and World War II, when the Dayton-Wright Airplane Company invented a pilotless aerial torpedo that would explode at a preset time [5]. Moreover, in 1916 A.M. Low's "Aerial Target" was an early model for powered UAV, and the attempts by Hewitt-Sperry Automatic Airplane. In 1959, the U.S. Air Force began working intensively on using UAVs following an incident of losing pilots over hostile territory. Soon in 1964 (Ryan Model 147, Ryan AQM-91 Firefly, Lockheed D-21) were initiated into combat

missions in Vietnam War [12]. In the 1973 Israel used the UAVs to force the Egyptian troopson wasting expensive anti-aircraft missiles and provide real-time surveillance. The Israeli Tadiran Mastiff which first flew in 1973, is seen by many as the first modern battlefield UAV, due to its data-link system, endurance-loitering, and live video-streaming. Through the last decade further advancement for the use of UAVs in civil services were introduced, the interest was pioneered by the European Union, CAPECON (2002-2005) project was oriented towards developing UAVs. In 2013 at least 50 countries were evident to be using UAVs for military purposes. China, Iran, Israel and others designed and built their own varieties, recently including Pakistan with the latest and high-Tech Prestige Decision making UAVs Including NESCOM BURRAQ [6].

TRENDS AND INSIGHTS OF UAV USES

Nowadays, the uses of UAVs are covering wide spectrum ranging from military, commercial, and entertainment. While UAVs are increasingly being adopted for civilian uses, from research prospective, this raise is coupled by possible problems and tradeoff over economic benefits and social acceptance. The issues concerning social acceptance covers mainly fear of interference with privacy, safety of drone operation, use for criminal acts such as smuggling and targeted terrorist attacks, and trivial problems of property damage and personal injury due to collisions or crashes of civilian drones. Fig. 1 shows part of survey conducted by yougov.de in Germany for such dilemma as an assessment of the likelihood of potential problems [2]. On the other hand, adoption of UAVs in various applications has different trends according to each country regulatory intervention. For example, in Germany the first trending application for UAVs concerns natural disaster help, while the second and third involves monitoring and maintenance of facilities. Surprisingly, entertainment and filming is a least to come as trending applications. Fig. 2 illustrates results from survey mentioned above for acceptance of unmanned Aerial Vehicles in various applications. [2] Being trending technology, UAVs has been identified and studied for commercial use. One study by Gartner for emerging technologies named “Gartner Hype Cycle”, has illustrated a forecast that UAV will be approaching the ‘plateau of productivity’ in less than two years (Fig. 3) [8].

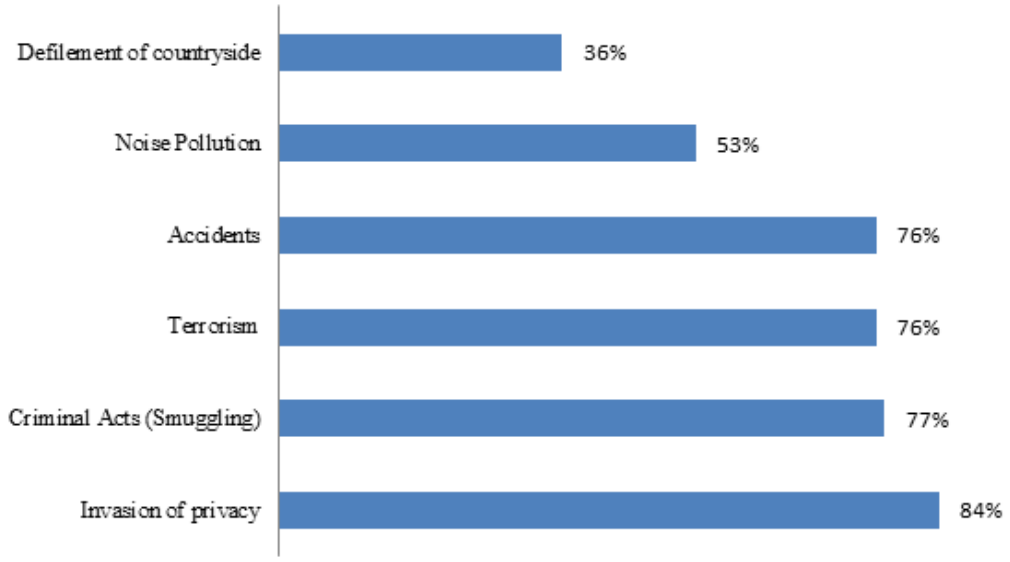

Fig. 1: Assessment of the likelihood of potential problems [13]

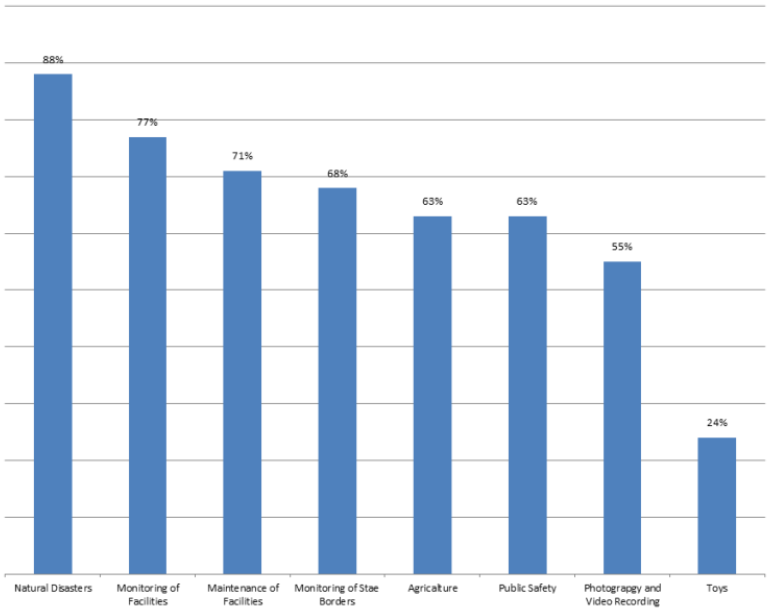

Fig. 2: Acceptance of unmanned Aerial Vehicles in various applications [13]

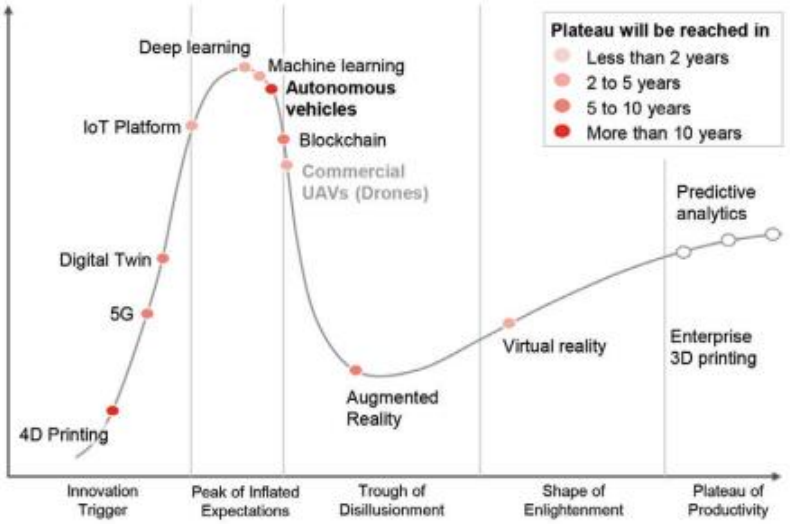

Fig. 3: Gartner Hype Cycle for Emerging Technologies, UAVs Plateau of Productivity [8]

ENGINEERING MANAGEMENT FOR OPERATION AND MAINTENANCE CONCEPTUAL VIEW

Operation and Maintenances of facilities as a concept has many inspiring definitions, one of which introduced by National Institute of Building Sciences (NIBS) “Facilities operations and maintenance encompasses a broad spectrum of services, competencies, processes, and tools required to assure the built environment will perform the functions for which a facility was designed and constructed. It is a rule of thumb that typically O&M includes daily activities that are necessary for the facility functional and structure capabilities preservation. [4] Generally, O&M tackles six professional areas as described by NIBS:

- **Real Property Inventory (RPI):** Provides an overview on the type of system needed to maintain an inventory of an organization's physical assets and manage those assets.

- **Computerized Maintenance Management Systems (CMMS):** Contains descriptions of procedures and practices used to track the maintenance of an organization's assets and associated costs, these projects are commonly repetitive, include preventive, planned/scheduled, and emergency activities, with projects under and established dollar threshold.
- **Computer Aided Facilities Management:** Originally referred to space planning technologies, however, is not used more generically to describe a variety of technologies addressing any or all aspects of Facilities Management. Examples include
- **Operation &Maintenance Manuals:** It is now widely recognized that O&M represents the greatest expense in owning and operating a facility over its life cycle. The accuracy, relevancy, and timeliness of well-developed, user-friendly O&M manuals cannot be overstated.
- **Historic Buildings Operations and Maintenance:** Balancing keeping old equipment running while contemplating the impact of installing new more efficient equipment
- **Project Delivery Methods:** The process established to efficiently define, cost, procure, execute, and manage operations and maintenance projects.

Within the professional areas listed above, integration of O&M activities is identified according to one of the functional ranges of Operation, Maintenance, Engineering, Training, and Administration. Fig. 4 illustrates these functional ranges with O&M integration as the core. Typically, O&M activities flow over three stages, the first stage is concerned with identification of work followed by the stage of planning/scheduling of work, the final stage covers executing/recoding of work. Additional overall actions are quality control and feedback for improvement.

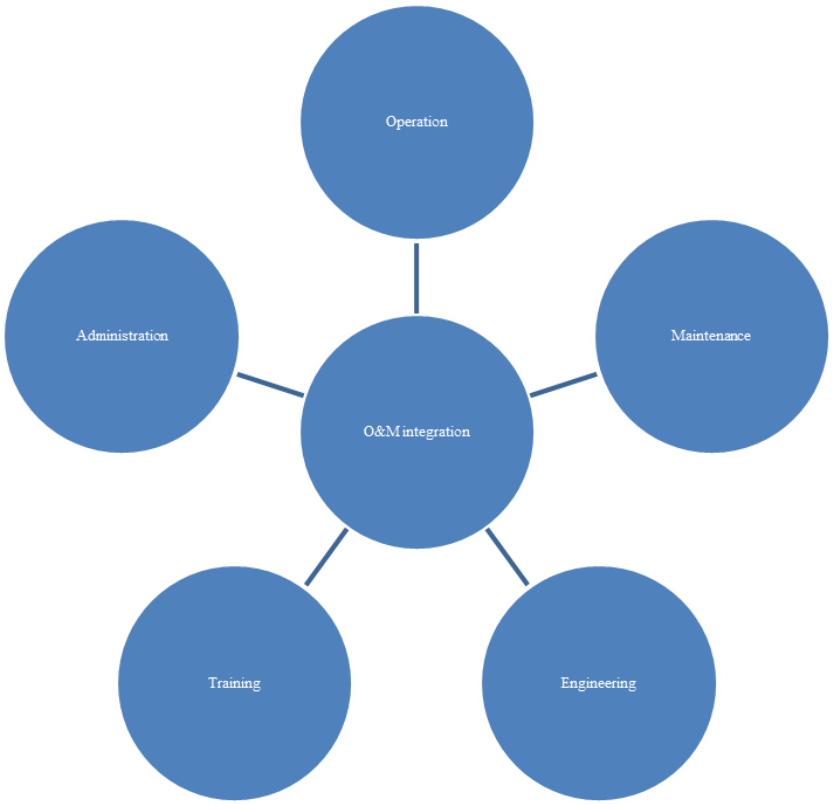

Fig. 4: Functional Ranges for O&M Integration

UAV IN ACTION FOR O&M

Throughout the last decade, UAVs were used as an alternative for traditional inspection within the first stage of identification of work. In this section definition of some famous applications of UAV in O&M is swiftly illustrated.

Bridges Inspection

Timely bridge inspection is a critical first step in keeping bridges safe and in good driving condition. A real-world example is the action by Minnesota Department of Transportation. Whereas the department inspects every bridge in its system at least once every 24 months, with fracture-critical bridges (where failure of a single component could cause collapse) receiving reviews every 12 months. Small bridges can be inspected in a day, but large bridges can take weeks to fully inspect. With more than 20,000 bridges and 600 bridge inspectors statewide, the task proves more than just a logistical challenge. Because the core of bridge inspection is visual review, inspectors are often put in physically challenging situations in order to access all the bridge components. They may need to utilize rope climbing gear or climb into the buckets of under-bridge inspection vehicles: articulated cranes that reach from the bridge deck surface over the edge of the bridge to the underside as shown in Fig.5. The “snooper” trucks cost about $750,000 and present expenses for fuel, training, maintenance and on-bridge traffic control. Fortunately, the new technology of unmanned aerial vehicles reduced some of this expense as well as the safety risk to inspectors. Camera-equipped drones flown beneath bridge decks to capture images and/or video footage of bridge elements quickly and efficiently with limited impact on traffic and at a significantly lower cost.

Recently, the Minnesota DOT has launched a project aimed to develop a field demonstration of UAVs for bridge inspection and to evaluate the technology’s effectiveness and safety implications for routine bridge inspections and interim or special inspections. The Project team identified four bridges in Minnesota that represented key configurations that inspectors encounter: an 80-foot local bridge in Chisago County; a medium-size concrete arch bridge in Oronoco; a large steel truss bridge in Morrison County; and a 2,682-foot-long railroad bridge near Stillwater that rises 185 feet above the St. Croix River. The Project team after acquiring necessary authorization for inspections and reviewing UAV options selected the Aeryon Sky Ranger UAV and contracted a drone pilot to help conduct inspections of each selected bridge. The Project team compared UAV results to recent bridge inspection records.

Fig. 5: Physically Challenging Situations for bridges inspection [10]

Conclusions from this effort identified that the UAV provided high-quality detail on the two large bridges, and its zoom lens was effective with the medium-size concrete arch bridge, allowing viewing and assessment of many bridge element conditions according to national standards. Smaller bridges with limited clearance underneath prove challenging for UAVs, particularly those which, like the SkyRanger, can lose GPS signals under concrete decks. At $140,000, the SkyRanger would be a cost-effective alternative to snooper trucks in many situations [10]. Finally, it was concluded that UAVs use provide the following:

- Minimizes risk to the public,
- Reduce safety risks for inspectors currently face.
- Efficient for routine inspection use and for situations not requiring hands-on inspection, testing, sounding or cleaning
- Suit pre-inspection surveys and can identify rope anchor points and other safety needs before hands-on inspection begins.
- Provide details without the traffic control requirements
- Significantly lower cost in equipment and traffic control needs.
- Provide both infrared and 3-D modeling detail of bridges
- Effectively identify concrete delamination
- Gather topographic mapping detail
- Efficiently map riverbank conditions upstream and downstream from the bridge site.
- Aviation rules are a time-consuming obstacle to using UAVs in bridge inspection.

Pavement Inspection

Another example of UAV strength is the pavement inspection project performed by Airsight Company for the Paris Charles De Gaulle Airport concerned with Runway pavement inspections. In August 2016, ADP selected Airsight to conduct the first large-scale inspection of Paris Charles De Gaulle Airport (CDG) using an untethered drone. This mission had for overall objective to determine if drone-based pavement inspections, as developed and already in used by Air sight at German Airports since 2015, could be used in the future in conjunction with conventional on-site visual inspections performed by Group ADP personnel driving the runway. Prior to the inspection, an operational concept and safety case were developed and validated by ADP, the local Air Navigation Service Provider “SNA-RP” and Airsight, to integrate safely the missions within airport operations. During the inspection, a surface of more than 200 thousands square meters was captured, almost 30 soccer fields. To minimize impacts on capacity, the overall net flight time of approximately 1 hour and 45 minutes was split into nine individual flight segments, to take advantage of periods of lower traffic. It is noteworthy saying that the maximum runway occupancy time for a flight segment was 18 minutes. This includes the time required to enter and exit the runway, obtain clearances as well as for conduction of final checks after each drone flight. All gathered data were post-processed at Airsight’s premises in Berlin to create a geo-referenced image of the runway with an extremely high resolution. This image served as a basis for a detailed assessment of the runway’s pavement conditions, which was documented in form of a report and associated interactive maps containing all identified distresses. This analysis and subsequent preventive maintenance actions enabled the Airport operator to extend the lifetime of the pavement, reduce cost, and increase safety for operating aircraft [1].

Oil and Gas

Moreover, in the field of oil and gas the inspection of vertical structures provided an efficient example for the use of UAV. It is well known that regular inspection of an oil and gas installations is vital for production, maintenance, safety and environmental impact assessment. The conventional methods for performing inspections of storage tanks, cooling tower, chimneys, flare stacks, boiler etc., are performed by using scaffolds, rope access inspection and helicopter. The challenges faced by conventional techniques are the construction of scaffolding, sending inspector into dangerous and fatal environments, shutdown of plant operations etc. that has financial burden on operating cost. The UAV technology provided a possible solution for these challenges by increasing the efficiency, reducing the risks and lowering the cost of tasks.

Renewable Energy

The next example covers the use of UAV in the vital fields of Acoustic Maintenance Management for Renewable Energy. Nowadays, wind energy is one of the most important renewable energy sources for covering the current electrical demand. The sophistication and the complexity of the wind energy systems are constantly growing. Therefore, new maintenance management techniques are required to ensure the efficiency and rentability of these systems. One of the famous activities that can be performed using UAV is the extraction of information from the noise generated by wind turbines. The noise information allows some types of failures to be detected incipiently and, consequently, preventive and corrective maintenance tasks can be improved. In this field, the use of unmanned aerial vehicles (UAV) can be very useful and facilitate the execution of the inspections. UAV can be examined using different methods for detecting failures through the processing of wind turbine noise.

Ports Facilities

Additionally, Port facilities are typically operated in a highly competitive environment and usually maintain several supply chains simultaneously. The performance and interaction of these supply chains are vital to the national logistics infrastructure as well as the hinterland with its connected services. Both aspects; competitiveness and dependency, make it vital for ports to maintain a structured and detailed inspection and maintenance schedule. Innovative approaches of using UAV for inspection works is widely adopted in the field, for example conducting Safety Inspections of Container Gantry Cranes. It is well agreed that such technology enables costs reductions and increased operative benefits via high definition image generation at the same time and providing a valuable support to maritime safety operations.

UAV INNOVATIONS FOR O&M

Innovation in the UAV industry is huge, and O&M is gaining a significant portion. The impact of UAV uses for inspection or data gathering is clear through the existing and developed applications. However, innovations for deploying UAV in other activities through the O&M chain is on the lead, for example a recent patent was issued for an innovative approach for deployment of lubricant with an unmanned aerial vehicle (see Fig. 6). The main objective of the approach is implementing a system for lubricating a machine. The system includes an unmanned aerial vehicle configured to fly to a lubrication location proximate the machine. A supply of lubricant is carried by the unmanned aerial vehicle. A controller is configured to deliver at least part of the supply of lubricant to the machine when the unmanned aerial vehicle is at the lubrication location [11].

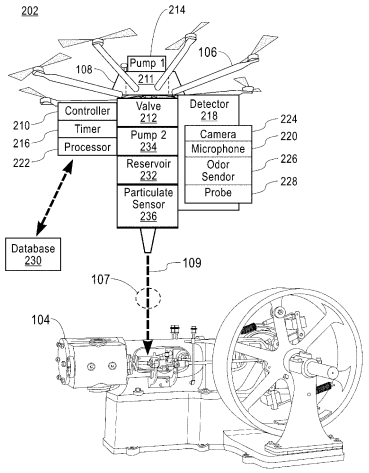

Fig. 6: System Components for Deployment of Lubricant with an Unmanned Aerial Vehicle [11]

Another example of innovations in chain is the system for spraying plant protection pesticides using UAV. In which seeds are treated with pesticides for plant protection with the use of UAV (UAV Plant Protection). The system includes UAV with chamber attached to a protective housing fixed plate with a uniformly water distributor and attached to pump pumping the drug. Fig. 7 presents a sketch of the system. [3]

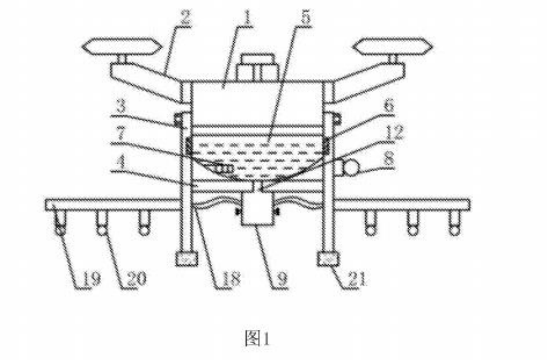

Fig. 7: Plant Protection System Sketch [3]

STRENGTHS, WEAKNESS AND CHALLENGES

The use of UAV in professional and commercial applications is somehow governed by degree of positive impact either functional, or financial. The following Table 1 summarizes part of an ongoing online survey to properly identify Strengths, Weakness and Challenges of using UAVs in professional and commercial applications [8].

Table 1: Summary of Strengths, Weakness and Challenges for using UAVs [8]

	Cases
Strengths	Low-Cost Technology Escalated Operational Durations Efficiency for real-time monitoring Mobility Safer in Operation Compatibility with wearable and electronic devices
Weaknesses	Potential for hijacking Privacy concerns Battery life limitation
Challenges	Legislation (Delays) Competition Shortage of Funding Security Tradeoff

REGIONAL PRACTICES

Likewise, regional interest for using UAVs in different applications is growing. A pioneering attempt towards imposing proper legislation, by the Kingdom of Saudi Arabia, was the establishment of the Saudi Federation for Cyber Security, Programming, and Drones (SAFCSP). Which is a national institution under the umbrella of the Saudi Arabian Olympic Committee, which seeks to build national and professional capabilities in the fields of cyber security and programming in line with the established and internationally recognized practices and standards, to expedite the ascent of the Kingdom of Saudi Arabia to the ranks of developed countries in the domain of technology innovation. Its mission is focused on building national and professional capabilities in the fields of cyber security and programming through awareness, education, and support based on best practices and international standards [9].

On the other hand, many institutions in the region are investigating UAV impact from the practicality prospective, one of the ongoing projects is the implementation of 3D mapping system for Pavement Distresses Using an Unmanned Aerial Vehicle (UAV). Project is part of an early effort for integrating UAVs within state of art practice. The aim of the project is to detect the distress on paved or unpaved road surfaces. Depending on the types of surface crack, required parameters are measured on-site to determine the severity level of damage. While it is already a running practice for automation of road surface using Multi-Purpose Vehicles, the use of UAVs result in great monetary savings and can lead to more frequent inspection cycles, for this reasons NAMAA Consult has initiated this effort. An additional benefit of using UAV system in pavement inspection is its ability to rapidly and autonomously acquire mobile three-dimensional (3D) mapping data to identify pavement distresses.

CONCLUSIONS

Unmanned Aerial Vehicles (UAVs), Drones, are gaining more and more attention every day. While implementing the technology is easy, safer, and cost effective, challenges are facing the mass adoption. These challenges can be fairly passed through solid but flexible legislations procedures. Drone use is allowed in most of the regional countries such as Saudi Arabia, United Arab Emirates, Egypt, and Kuwait. However according to practitioners in some countries it is very difficult to obtain permission. Additional conclusion for adopting Drones technology in the region is directed towards manufacturing, it was recorded that funding impose huge problem for escalating use, this problem may diminish for the region if one of the funding bodies in the region pioneers the act. From national security prospective manufacturing of a regional drone will provide a way to fulfill needs while preserving local privacies.

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