Advancement of Drones in Electrical Transmission and Distribution Construction[1, 2]

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ABSTRACT

The advancement of new equipment for construction of electrical transmission and distribution line is essential for safety, cost and time. The drone technology enhances the construction field with their enormous benefits as compared to their traditional method for the power lines construction. This article gives a prologue to drone technology innovation and give perspective result for technical specification, surveying and accurate measurement in construction and eliminate use of heavy air-craft. The primary viewpoints that have prompted the substantial spread of drone technology in construction of power lines are examined and here compared with their traditional methods with evolution with some technique like MADM, quantitative representation, relative weighing and additive weighing and then choose the best methods which provides strong position for attributes that consider for the subject. Although all methods are relatively important on its way of use but comparison between them made easy selection for most benefits for use. The iterative methods already show that the drone technology proven best practice for construction of power lines in terms of time, cost, risk, size, location, quality and environment sustainability.

Key words: Aircraft/ Transmission and distribution/ Construction/ Infrastructure/ Expensive/ Cost effective/Power sector

INTRODUCTION

Every year increasing demand in energy for domestic and industries create alarming situation for infrastructure of transmit and distribute it. Though construction of power line is not much easier as it looks. “Around 30 to 50 workers in every 1,00,000 are killed on the jobs every year and many others suffer from non-fatal loss of limbs from electrical burns and mechanical trauma

[1] Editor’s note: Student papers are authored by graduate or undergraduate students based on coursework at accredited universities or training programs. This paper was prepared for the course “International Contract Management” facilitated by Dr Paul D. Giammalvo of PT Mitratata Citragraha, Jakarta, Indonesia as an Adjunct Professor under contract to SKEMA Business School for the program Master of Science in Project and Programme Management and Business Development. http://www.skema.edu/programmes/masters-of-science. For more information on this global program (Lille and Paris in France; Belo Horizonte in Brazil), contact Dr Paul Gardiner, Global Programme Director, at paul.gardiner@skema.edu.

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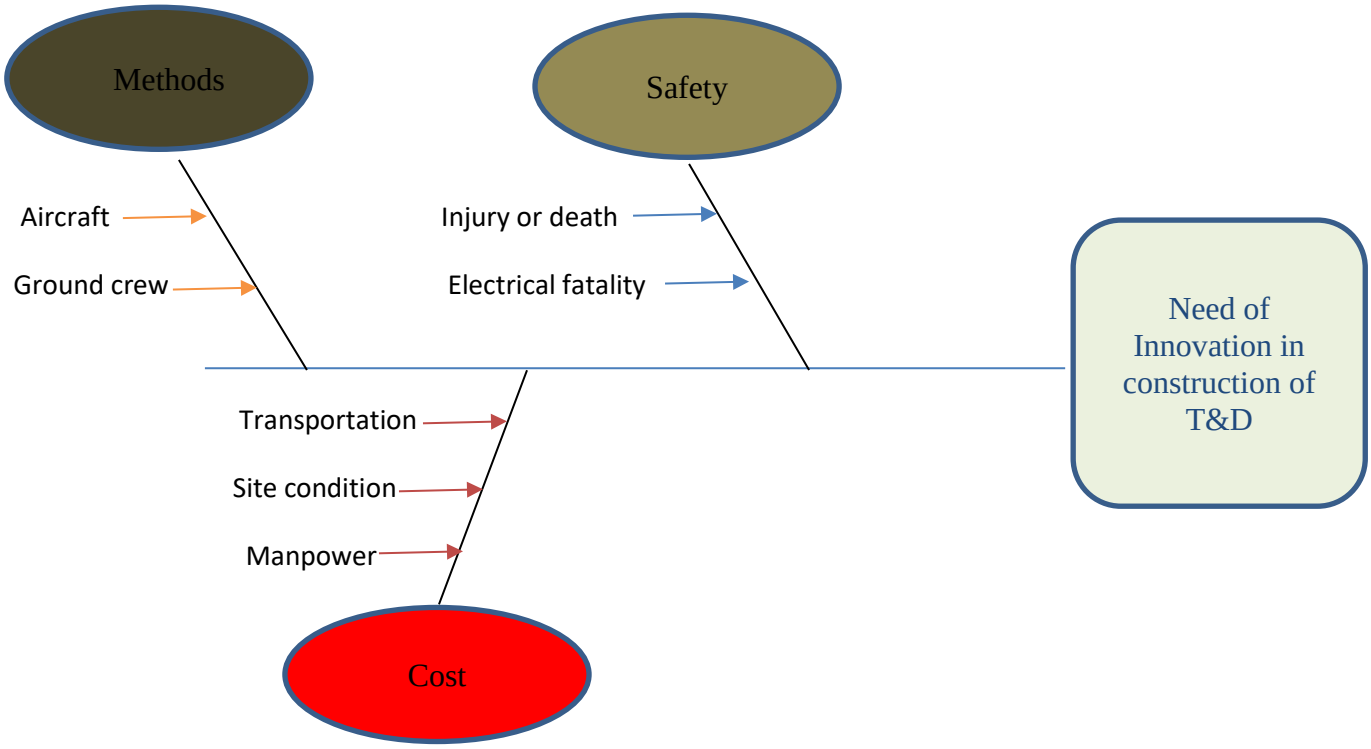
which is almost twice fatality rate than police officers and fireman"[3]. Moreover, the capital cost of construction is also expensive due to pre-construction inspection crew, transportation, helicopter and ground crew. Advancement in technology booming power sector also by using drones in construction, inspection and maintenance for energy lines and remarkable cost cutting in operations. This all reasons need some innovative alternative for construction of T&D lines.



Fish bone analysis for innovation in construction of T&D[4]

Using drones in construction of energy transmission line is not fairy tales now it is in infancy, but future of this technology is very enormous. In recent past, "Sharper shape and skyskopes, in cooperation with an investor-owned utility, have completed the project regarding string shock line installation of 765kv transmission power line successfully in USA"[5]. The main concern of this project is showing to world that drone technology have many applications than basic inspection with respect to safety, efficiency and cost-effective. Sock pulling, the act of strong and lightweight rope and connecting it to towers, is traditionally completed by helicopter and ground crew involve great risk to aircraft pilot and member of ground crews. Drone technology

[3] Ore, Timothy. (1996, June). Electrical Fatalities Among U.S. Construction Workers: Journal of Occupational and Environmental Medicine. Retrieved from https://journals.lww.com/joem/Abstract/1996/06000/Electrical_Fatalities_Among_U_S__Construction.9.aspx

[4] By author October 2018

[5] Sharpershape. (2017). Transmission line construction | Sharper Shape Inc. Retrieved from https://sharpershape.com/energy-industry-services/transmission-line-construction

eliminating typical complex process and divided into sub process of reattaching string and minimize the risk of injury for involved people. This is not small issue, approximately 1.5 deaths every year from helicopter crews trying to perform same task but using drones and expertise pilot, task done with maximum cost effectiveness and with no risk of injury to manned aircraft. According to Guild control of project Compendium and references for managing change "Identify what a change is and understand how to demonstrate the impact will have on our projects"[6] so, here impact of drone technology in construction of power lines is very clear and based on advantages decision making is also easy by facts and results in terms of safety, cost and operation as well.

Transmission line construction workflow[7]

Indeed, drones are useful in pre-construction survey and investment monitoring in T&D construction over only sock pulling of cables where they identify risks by aerial survey to ensure high level of safety and health. Using drones to monitor locations that may be crucial or hazardous for workers which can minimize safety risk this also decrease additional budget expenditure to ground based monitoring teams as aerial substitute. Drones also offer to monitories progress of construction for individual day and deliver data to administration or supervisor of construction site for delayed work in construction. Apart from only benefits, drones have challenges that increasing use of technology may be harm to environment, operational risk where more trafficking of aviation which leads to accidents or ground Collisions and loss of signal due to technical error can lead to incident which is really danger to public safety. Also, for data securities drones capture important information of power sector infrastructure which is growing risk of confidential data hacking. Furthermore, there are also some regulations, legal and contractual issues to use technology commercial and regulatory should be strict to perform operation.

In the end of this paper, we would be able to understand

- How drone technology project efficiently works in energy distribution line construction with safety and cost effective.

[6]Guild of project controls compendium and references. (2015, November 2). GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). Retrieved from http://www.planningplanet.com/guild/gpccar/introduction-to-managing-change

[7] Sharpershape. (2017). Transmission line construction workflow | Sharper Shape Inc. Retrieved from https://sharpershape.com/energy-industry-services/transmission-line-construction

- How drone technology overcome their key challenges against their potential future.

METHODOLOGY

Step 1: Summaries

As seen before, the main purpose of this paper is to overcome risk during construction project of power lines with more safety, within cost and advancement in technology for timely delivery. Thereby understanding the different procedures for construction and implementation in better way to complete a successful project. Line pulling as a job involves great danger. Transmission line workers, everywhere in the world put their lives at risk every time they go out for repairing old lines or laying out new ones. However, with a variety of new drones coming out, it is now changing very rapidly[8].

In cable stringing procedure which is complex part of power line construction where cable drums are placed next to each other and stringing done by both side by two opposite poles. This procedure is very complex and must perform as under:

1. Process planning and technical calculation
2. Analyze and correction of data
3. Prepare actionable report for process and perform operation

Step 2: Alternative solutions

The project manager must cover all the basic engineering to ascending the risk and confusions. Also, the work done by accuracy and without possibility to rework in further project phases. This process is performed by three methods in which drone technology is result of advancement of technology

UAV (unnamed Ariel vehicle) or Drones[9]:

"The unique A6 is used for pulling lines for installing conductors for one of the largest utilities in US and is believed to be first drone company to successfully installed 765-kv transmission line by sharper shape. As a complex starting to be installing high-tension cables for new transmission line construction this service safely installs conductor on line. The

[8] Drones are replacing helicopters in pulling transmission lines. (2018, June 29). Retrieved from https://www.geospatialworld.net/blogs/drones-pulling-transmission-lines-replacing-helicopters/
[9] Malcolm Malveiro; José Cordeiro. (n.d.). Overhead power line stringing with UAV - IEEE Conference Publication. Retrieved from https://ieeexplore.ieee.org/document/7964146?denied=

work done by drone technology is very safe whereas same work are approximately 1.5 deaths per year from helicopter crew trying to perform same operation"[10].

Manned Aircraft[11]:

"Helicopter is used for same operation, but it is quite expensive 1500 to 2000 USD/HR for operation and risk for injury or death is very high for cable stringing"[12]. "Moreover, for deep forest it is not possible to get inside easily also some countries the natural terrain and local laws make power line stringing by traditional means nearly impossible. In Bandung, Indonesia, a power line project had been delayed for seven years when the original contractor abandoned the job as impossible"[13].

Ground crew[14]:

"In the ground crew construction, a team of usually use road transportation and visual inspection is carried out with equipment. the construction of transmission line with personnel movement across roads are not easy given in hilly area and deep forest. Therefore, it is slow, monotonous and subjective, therefore larger defects sometimes can have overlooked"[15]. Sometimes crew member must climb tower and complete the cable pulling also in bad weather and rain work done would be slow for work.

[10] Sharpershape. (2017). Transmission line construction | Sharper Shape Inc. Retrieved from https://sharpershape.com/energy-industry-services/transmission-line-construction
[11] Wandi. (n.d.). Cable installation and stringing | Airtelis. Retrieved from http://www.airtelis.com/home/paper/item/cable_installation_and_stringing-6.sls
[12] https://www.theiet.org/factfiles/transmission-report.cfm?type=pdf. (n.d.). Retrieved from https://www.theiet.org/factfiles/transmission-report.cfm?type=pdf
[13] Alan Phillipe. (2017, May 31). Power to the People: Bringing Drones to Power Line Stringing Projects Everywhere - DRONELIFE. Retrieved from https://dronelife.com/2017/01/30/power-people-drones-to-power-line-stringing-everywhere/
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[15] (PDF) Power line inspection via an unmanned aerial system based on the quadrotor helicopter. (n.d.). Retrieved from https://www.researchgate.net/publication/271453876_Power_line_inspection_via_an_unmanned_aerial_system_based_on_the_quadrotor_helicopter

Machine tools[16]:

"The sock line is attached to a conductor pulling rope/cable, which is connected to a tensioning machine on a truck. The conductors are then pulled through by puller machine. The puller and tensioner work together during pulling operation to ensure that the conductor maintains the proper ground clearance always. Wire set-up sites or pulling stations, where the associated pulling machinery and equipment are staged, are located at intervals along the span"[17].

The attributes that are compared to above mentioned alternatives are[18]:

1. Project size
2. Project location
3. Safety
4. Deliverables (In time)
5. Quality
6. Environment
7. Cost

Step 3: Selection criteria

In this paper we are using Multi attribute Decision making analysis for the best alternative solution method accordingly with respected to selected attributes for achieving successful execution for projects. Here the alternative solution is ranked based on the attributes with High, Neutral and Low. Therefore, the color difference varies from green, yellow and red whereas red indicates low, while yellow indicates neutral and the green indicates high.

[16] EEP - Electrical Engineering Portal. (2017, August 7). Guidelines For The Construction And Maintenance Of Transmission Lines. Retrieved from https://electrical-engineering-portal.com/guidelines-for-the-construction-and-maintenance-of-transmission-lines
[17] transmission line construction - Google Search. (n.d.). Retrieved from https://www.google.fr/search?q=transmission+line+construction&oq=transmission+line+construction&aqs=chrome..69i57j69i60l3j0l2.11706j0j8&sourceid=chrome&ie=UTF
[18] Powerline Inspection - xyHt. (2018, April 4). Retrieved from https://www.xyht.com/aerialuas/powerline-inspection/

Table 1. Multi Attribute Decision Matrix

Alternative solution /Attributes	UAVs or Drones	Manned Aircraft	Ground crew or People	Machine tool
Project size	High	High	Low	Neutral
Project location	Very High	Low	Neutral	Neutral
Safety	Neutral	Very Low	Very Low	Neutral
Deliverable	High	Very High	Low	Low
Quality	High	High	Neutral	Very Low
Environment	Very High	Low	High	Neutral
Cost	Very High	Low	Neutral	Low

Figure 1: MADM[19]

Step 4: Analysis and selection of best alternative solutions

To utilize the approach which we shown in the table 1, we need to represent the alternatives quantitively for the analysis. So, we need to start converting the relative scoring (High, Neutral and low) as a dimensionless value.

Table 2 – Quantitative representation of attributes

Attributes/relative scoring option	Project Size	Project Location	Safety	Deliverables	Quality	Environment	Cost
Very High	**1**	**1**	**1**	**1**	**1**	**1**	**1**
High	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**	**0.75**
Neutral	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**
Low	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.25**
Very low	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Figure 2: Attributes scoring[20]

Now, we shall use the above-mentioned dimensionless values relative rank or weight for each of the alternatives.

Table 3- Relative weighting

Alternative solution/Attributes	UAVs or Drones	Manned Aircraft	Ground crew or people	Machine tool
Project size	**0.75**	**0.75**	**0.25**	**0.50**
Project location	**1**	**0.25**	**0.50**	**0.50**
Safety	**0.75**	**0**	**0**	**0.50**

[19] By Author November 2018
[20] By Author November 2018

Deliverables	**0.75**	**1**	**0.25**	**0.25**
Quality	**0.75**	**0.75**	**0.50**	**0**
environment	**0.75**	**0.25**	**0.75**	**0.50**
Cost	**1**	**0.25**	**0.50**	**0.25**
total	**5.75**	**3.25**	**2.75**	**2.50**

Figure 3: Relative weighting[21]

FINDINGS

Step 5- Selecting and Re-arranging the best alternative solutions

Now, we will use the additive weighting technique by ranking each of attributes by their importance. The sum of each solution can be compared to the normalized weight of 2.80, which is the score to be reached out. So, the attributes are ranked from most important to the least important (Environment> Safety>quality >Project location>cost >project size>Deliverable) according to this arrangement we can now use this technique.

Table 4- Additive weighting technique

Alternative solutions/Attributes	Relative rank/Weight	Normalized weight	UAVs or Drones		Manned aircraft		Ground crew or people		Machine tool	
Project size	6	0.60	0.75	0.45	0.70	0.42	0.25	0.15	0.50	0.30
Project location	4	0.40	1	0.40	0.25	0.10	0.50	0.20	0.50	0.20
Safety	2	0.20	0.75	0.15	0	0	0	0	0.50	0.10
Deliverables	7	0.70	0.75	0.525	1	0.7	0.25	0.175	0.25	0.175
quality	3	0.30	0.75	0.225	0.75	0.225	0.50	0.15	0	0
environment	1	0.10	0.75	0.075	0.25	0.025	0.75	0.075	0.50	0.05
cost	5	0.50	1	0.5	0.25	0.125	0.50	0.25	0.25	0.125
total	28	2.80	Total	2.325	Total	1.595	Total	1.0	Total	0.95

Figure 4: additive weighting technique[22]

After ranking the attributes according to their importance for the project deliverables by different various methods. We can now see the difference between all alternatives has been decreased precisely and now we can say that the most important factor to be considered will be the" Drone technology "then we should consider with the "manned aircraft" as it works with very fast and taking intermittent ranking for alternative method and lastly, we should also take into consideration with the "Ground crew" and " Machine tools". So according to these factors that every project must in execute this success factors to avoid project delays to avoid over budget and risk as well.

[21] By Author November 2018
[22] By Author November 2018

Step 6: Selection of preferred alternative:

Now we are going to arrange our alternatives as per popularities as per best to worst.

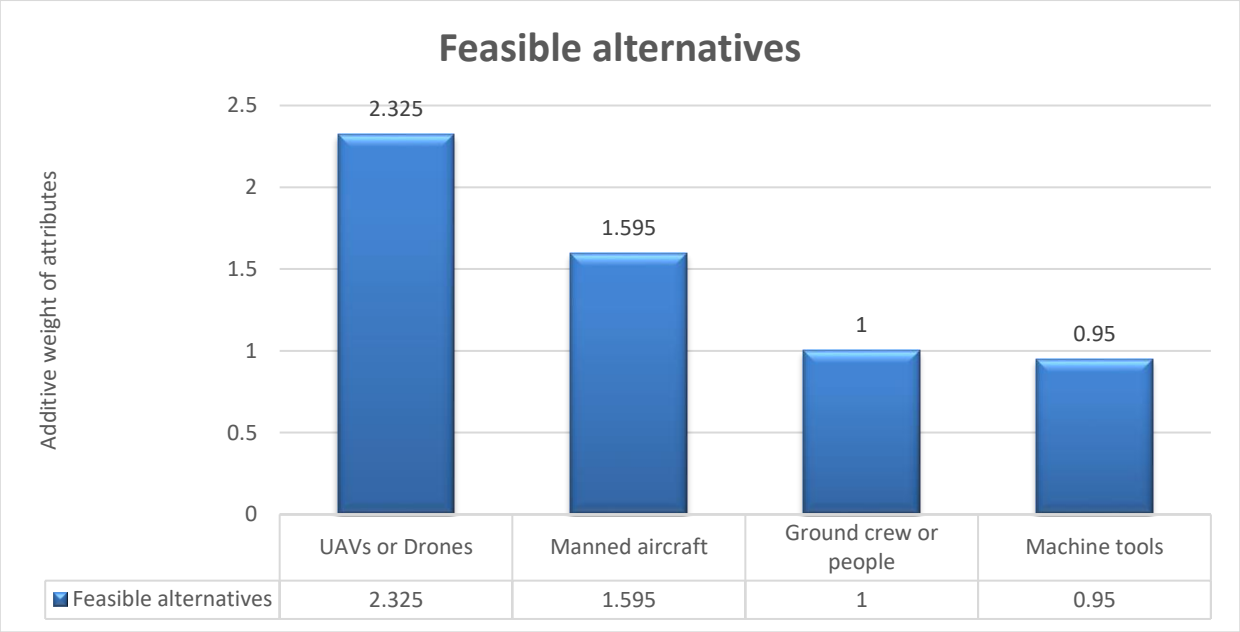

Figure 5: feasible alternatives with additive weighting technique of attributes[23]

As discussed previously, the most advantageous method for construction of power line project is with drones to execute project on time no matter what project size or location with safety and environmental impact is low also where as other alternatives are very costly and threaten to environment and as well human being. Project integration should be sustainable in terms of environment which is very most important factor. Manned aircraft is very rapid responsive and high level of accuracy there for project, but safety and environmental hazard put behind after drones. Moreover, ground crew is good alternative and used to execute project on time in worst circumstances and environment where aerial equipment not able to work. Least one is machine tools which response and accuracy level are low with less quality work.

Step 7: performance monitoring and post evaluation of results

This analysis is performed for finding the best alternative solution for our projects for real time execution with maximum efficiency. For best performance of project, we need to use and utilize best method and techniques & tools as respectively." Measuring performance is a critical factor in optimizing performance. Optimal performance is sustainably achieving multiple, often

[23] By author November 2018

conflicting, objectives under changing condition."[24] The change is indeed to improve performance of any projects. Thus, the best alternative is drone technology, manned aircraft followed by machine tool and ground crew.

To review the performance of individual alternative can be monitored by using drone technology for project must be 82%(5.25/7*100) for construction of power lines project which is followed by manned aircraft is 46%(3.25/7*100) and afterward ground crew have potential to 42%(3/7*100) and least one on list is machine tools which is 39% (2.75/7*100).

CONCLUSION

The main aim of this paper is to make understanding how drone technology up brings with future technology in construction of electrical transmission and distribution line project as well minimize risk factors for project success and deliverable with sustainability. And it is the best alternative for solution that should be implementing to overcome project failure.

Through this paper we have research the most considerable alternative solution to the least considered alternative solution to resolve the problems on execution phase such as: Drone technology, Manned aircraft, ground crew and machine tools. We have explained each alternative solution and selected the best solutions accordingly with respect to our project. The drone technology is highly recommended for future use because of its enormous benefits like cost saving, safety, environment impact and quality with accuracy after that manned aircraft which is highly recommend for project deliverables due to its high speed and accuracy." Delay and cost overrun in project could be because of **scope change**. Scope is the term that defines the entire deliverables that is expected at the end of a project"[25]. Whereas ground crew and machine tools are used as alternatives where aerial instrument is prohibited or not able to work but these alternatives are also important on their places for project execution." Executing consists of the processes used to complete the work defined in the project plan to accomplish the project's requirements. Execution process involves coordinating people and resources, as well as integrating and performing the activities of the project in accordance with the project plan**"[26].**

[24] Project Management | Measuring In-progress Project Performance. (n.d.). Retrieved from https://www.projecttimes.com/george-pitagorsky/measuring-in-progress-project-performance.html
[25] FIVE CAUSES OF PROJECT DELAY AND COST OVERRUN, AND THEIR MITIGATION MEASURES. (n.d.). Retrieved from https://www.linkedin.com/pulse/five-causes-project-delay-cost-overrun-mitigation-measures-buys/
[26] Free Management Research Library of White Papers, Magazines, Reports, and eBooks. (n.d.). Retrieved from http://www.free-management-ebooks.com/faqpm/processes-04.htm

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