COMMERCIALIZATION OF TOPOGRAPHICAL SURVEY WITH USE OF DRONES

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This is to certify that the Lt Col Harmeek Singh a student of MBA (AVM), SAP ID 500035625 of UPES has successfully completed this dissertation report on "Commercialization of Topographical Survey with use of Drones" under my supervision.

Further, I certify that the work is based on the investigation made, data collected and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a dissertation towards partial fulfillment for the award of degree of MBA.

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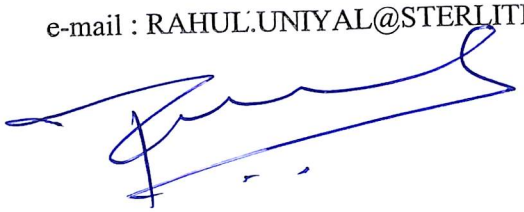

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Executive Summary / Abstract

Drone methods proved to be more accurate, take less time, and have better ground resolution and cost is in comparable limit with traditional survey methods being done today. Though a project survey using UAV Photogrammetry, results substantiated to the best method in terms of accuracy, reliability and cost aspect, but there are some inherent limitations which needs to be considered while scaling up the use of this technology. Also, this method is not effective when the terrain is having medium to high vegetation as the UAV won't be able to capture the ground profile and the processing software won't be able to reconstruct the terrain from the captured images.

The next limitation is in terms of UAV Regulations by Directorate General of Civil Aviation, India (DGCA). Though the regulations are in place from December 2018, it is still not in the matured state. There are a lot of confusions and lack of clarity in the type of aircraft which can be used, acquisition of UAV operators permits, Unique Identifications number (UIN) for every aircraft is still there. Once these things are clear, UAV photogrammetry survey can be scaled up and commercialized as a better replacement.

At the end, the two survey methods, when compared for the accuracy of data acquired through the use of drones, and the costs of acquiring that data using traditional land surveying and UAS were compared with favourable results.

1. Introduction

Commercial, government and private use of Unmanned Aerial Systems (UAV) are rapidly expanding. Use of these drones have grown in the industry in the last five years for various purposes,these areas of application includes topographical surveys, volumetric estimation,asset inspection etc. Nowadays UAVs are being used as a replacement for topographic mapping and volumetric surveying compared to traditional and accepted methods like Theodolite,Total Station and DGPS. The UAV companies in the field of mapping and surveying see a need for the technology, but must also weigh the capabilities and limitations of UAV to acquire and process survey data against those of more traditional methods.

In the profession of Land Surveying, new technologies, such as the Total Station, Light Detection and Ranging (LiDAR) devices, and Global Positioning Systems (GPS), are appropriately met with some level of skepticism. When first introduced, accuracy and precision are often compared to previously used and accepted technologies and practices to determine their scientific validity.

Likewise, the introduction of Unmanned Aerial Systems (UAV) has undergone serious scrutiny regarding precision, accuracy, and therefore validity in surveying by surveyors and their clients alike. This skepticism is often countered by the claims of versatility and capability of UAV by their manufacturers and proponents. Nevertheless, studies are emerging that show that UAV is a viable alternative to traditional more costly surveying methods.

The purpose of this study is to compare using UAV for surveying against traditionally accepted methods, so see if advantages exist in cost, time, and accuracy. One advantage of UAV that is universally acknowledged is the level of safety it can bring to the hazardous profession of aerial data acquisition.This study sought to answer the question of whether or not using UAV for topographic mapping and volumetric surveying can lower the cost and time to complete the same task using land surveying and manned aircraft systems while still achieving acceptable accurate results. This study compares the use of UAV within the surveying and mapping industry with traditional and accepted methods and provides a comparison of their use. Specifically, this thesis reports on tests comparing UAV data acquisition and processing for volumetric calculation and topographic mapping. Time, accuracy, and cost were compared between UAV and traditional survey methods. Establishing the ability of new surveying technology to provide accurate and precise data is just the first step in UAV technology's widespread use. The high cost of systems

such as LiDAR must be offset by the benefit of time and money saved from their utilization. UAV is no different in this respect.

The results of this study showed that using UAV for topographic mapping is more time and cost efficient than land surveying, with no loss in accuracy, but only when performed over bare earth terrain.

2. Literature review

There was a time when drone applications were confined to the military, but their uses as data capturing devices are on the rise and commercial uses of drones are growing fast. With the dawn of the 4th industrial revolution, drones will make an impact in biological, technological and physical fields.

A report from Business Insider[1] reveals that the drone applications continue to expand as cost goes down and the technology progresses. Among the industries and fields where drone technology uses are thriving include security, construction, agriculture, entertainment, land management... and the list keeps growing.

The report from Drone Analyst[2] suggests that the innovative uses of drones will expand most in the civilian and commercial sectors. However, its use is also going to increase in other industries such as mining, energy, utilities, infrastructure inspections and other growing fields. The report also estimates an annual growth of 20%, outpacing that of military use.

From recreational to professional uses,drone potential is expanding fast.Here is the list of areas of drone applications.

2.1 Aerial Photography and videography

Photo and aerial video are being used by marketing strategists, real estate agents and cinematographers. For real estate agents, UAV video presents them with a golden opportunity to provide a detailed look at the property they're selling. Check our Drone Photography Guide[3] where we go into much more details. By combining aerial drone photography and video, a real estate agent can provide a "fly through" of the property and showcase various features of the house that would be difficult to see in photos alone. The combination of photo and video makes it easy to highlight the landscape, the swimming pool, playground and other attractions in and around the area.

The same benefits are available to cinematographers. By using a drone, they can quickly scan the surrounding area and find the most attractive or suitable locations that can be used in a film. This is also

[1] http://www.businessinsider.com/uav-or-commercial-drone-market-forecast-2016-4-24
[2] http://droneanalyst.com
[3] http://dronenodes.com/drone-photography

true for advertising as the drone can be used to highlight areas and locations. Tour operators, travel agencies and airlines take full advantage of this technology..

2.2 Infrastructure Inspections

The growth of UAV industrial inspection can be seen in their use in various industries. An article published on Today's Energy Solutions shows how drones are now being used to inspect and maintain solar panels, ensuring their efficient operation.

This is not an isolated case, as UAVs are also used in inspections of aircraft parts, powerline installations, telecommunication towers and wide range of utility inspections. The oil industry also relies on drones to assess pipelines and other facilities. In many cities in the US, drones are now being deployed to ensure transmission lines operate smoothly, and power companies also use the same technology to alert them of problems.

UAV pipeline inspection and aircraft inspections are two of the most common uses for unmanned commercial drones. In the past, these tasks were performed manually, which is time-consuming. Today, trained personnel use drones to check pipelines and aircraft.

Airbus demonstrated the importance and benefits of using drones at the Farnborough Airshow[4], where the company showed how it works. The drone, controlled by a pilot, moved along a predetermined path, taking images of the craft. Once the images are retrieved, the pilot can easily look for signs of damage or dent.

The same technique is used for pipeline inspection as well as other industrial structures. Using these methods, companies stand to save time and money. In the Airbus drone demo, the done took just 15 minutes to complete the task, whereas other methods take 2 hours or longer. This is true for other industries as well.

2.3 Surveying and Mapping

The use of drones in GIS mapping, photogrammetry, cartography, geophysical mapping and surveying continue to increase as the technology grows. All of these fields can be generally categorized as geographical information system (GIS), or the gathering of data of the Earth's surface.

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[4] http://www.airbus.com/presscentre/pressreleases/press-release-detail/detail/airbus-demonstrates-aircraft-inspection-by-drone-at-farnborough-innovation-and-digitalisation-for-production-ramp-up

There are a lot of methods used for GIS, but there's no question that drone technology is at the top of the list. Experts in land surveying[5] agree that drones have become essential because it leads to quicker turnaround times and more accurate modeling. UAVs are also more cost effective and time savers.

UAV mapping is also efficient for LiDAR 3D Mapping. LiDAR 3D Mapping is dependent on GPS systems for accuracy, and that's where a drone comes in. By equipping the UAV with a GPS, there is no need to use an aircraft with expensive photogrammetry tools. A properly equipped UAV is accurate up to 1 to 2 cm, which makes it a reliable system.

Another reason why GIS UAV are gaining traction is being eco-friendly. Traditional geophysical mapping methods involve material sampling, drilling and other methods that could affect people in the area. Drones however, are non-invasive. As it flies through the area, the system takes videos or photos, collects and organizes data, all without disrupting the environment.

2.4 Swarm Intelligence

The term drone swarm used to refer to military moves, but not anymore. Nowadays they are also about light shows. Recently, a team of Intel Engineers[6] created a beautiful swarm consisting of 500 drones. These drones earned a place in the Guinness Book of Records Most Unmanned Aerial Vehicles (UAVs) airborne at the same time.

As cool as those swarms of UAVs are, their function is not limited to it as the same technology can be used for wireless communication[7]. The idea of using drones for WLAN is not as far-fetched as it sounds. In fact, Facebook[8] plans to use drones to provide Internet access in remote locations around the world.

A cluster of drones can also be used for large area monitoring. This can be for large public events, gatherings, rallies, protests etc. Any of these activities are ideal, and in many cases, essential. Other methods of large area monitoring are tedious, but drones simplify the process and make them more practical.

There are many benefits to using drones for monitoring. They are quiet and won't attract attention. During certain events, the noise generated by other monitoring equipment can be disruptive, which

[5] http://waypoint.sensefly.com/land-surveying-with-drones-1
[6] http://www.intel.com/content/www/us/en/technology-innovation/aerial-technology-overview.html
[7] https://arxiv.org/pdf/1602.03602.pdf
[8] https://futurism.com/facebooks-solar-powered-planes-will-beam-data-at-record-setting-rates

makes them impractical. In contrast, drones and UAVs are small and efficient. They can take photos and videos of the event and spot any problems that may be taking place.

2.5 Science and Research

Since drones are all about collecting data, it should not come as a surprise that drones in science are used extensively. Recently, scientists at Duke University's Nicholas School of the Environment have made the switch from using aircraft to drones for their coastal climate studies. According to David Johnston, assistant professor at Duke University[9], drones provide data in just hours whereas with aircraft it would take days.

The use of scientific research drones is applicable for archaeological research, analyzing volcanic eruptions, meteorological studies, plant species studies and more. Ecology, oceanography and marine science are other scientific fields which benefit from it.

- Archaeologists, for instance, use the images provided by drones to determine which areas are covered by vegetation and soil.
- For volcanologists, a UAV is the safest method of measuring a volcano's lava flow, which allows scientists to predict its path. Drone technology also makes it possible to study volcanic ash clouds and gas.
- These same drones are also useful for collecting data about glaciers. NASA recently gifted the University of Kansas and its students a UAV so they can create a radar system to study glaciers.
- Drones can also be used to collect data about wildlife[10], air pollution, map excavation sites around the planet, the possibilities are endless.

2.6 Search and Rescue

Drones used for search and rescue, post-disaster operations, emergency supplies delivery and first aid emergency response are increasing around the world. In South Korea there are plans to expand the use of drones for life-saving missions, and it's a trend that's taking occurring in the US as well.

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[9] https://today.duke.edu/2016/05/sharkdrones

[10] http://www.audubon.org/magazine/july-august-2014/drones-take-wildlife-conservation-tool

Drones can be used to make high resolutions maps of the site, which helps the response team navigate the site and take the proper approach. By making the drone surveillance part of the operation, rescue teams will be able to respond more quickly. A report from CNBC[11] explains how drones are now being used in various rescue missions, and it's a trend that will continue.

Drones are particularly useful for firefighters and various emergency response teams. These UAVs give firefighters a 360-degree view of the area and allow them to concentrate their response in the appropriate location. It is also possible to equip drones for large-scale rescue missions.

2.7 Security and surveillance

Many Police departments have began using drones for security and surveillance[12]. According to the police, the use of aerial surveillance drones is going to provide assistance in maintaining security. With today's UAVs, the benefits are obvious.

- Drones can be used to check traffic so authorities can quickly determine the location of an accident or traffic jam.
- Major sporting events and spectacles will benefit from having a drone overseeing the situation from above. This also provides law enforcers with a bird's eye view of what's going on.
- Drones are also effective for monitoring borders and civil security assistance.

The benefits of UAV security go further than that. With their ability to inspect areas at various angles and locations, drones can detect land mines, allowing for their safe removal. Researchers at the University of Bristol[13] are studying how drones can be used to inspect land areas and clear them of landmines.

This technology can also be used to detect radiation in the area. A properly equipped UAV gathers data about the location and the operator determines the level of radiation present. This method is not only quick but safer since people don't have to go anywhere near the site until it's declared safe.

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[11] http://www.cnbc.com/2015/11/20/how-drones-are-being-used-for-safety-and-rescue.html
[12] http://dronenodes.com/law-enforcement-drones
[13] http://phys.org/news/2016-04-scientists-drone-trafford-landmine-clearance.html

2.8 Precision Agriculture

There are many uses of drones in agriculture, and when properly used lead to bumper crops and higher yields. A report by Bank of America Merrill Lynch published in the Motley Fool[14] says the agriculture industry is going to make up the bulk of the commercial drone market in the US in the future.
Drones agriculture operates the same way as other UAVs but they're specially fitted to serve the industry's needs.

- Drones for farming for instance, can be used to scan the soil and locate potential problem areas. Farmers can also use drones to evaluate farm fields rapidly, and it's more efficient than manually scanning the fields.
- UAVs and agriculture are also cost effective. We have mentioned how much they save time. But aside from that they are also cost effective, and as this report shows[15], leads to the creation of jobs and produce a positive economic impact.

We have also mentioned how drones and GIS mapping integrate, and those same elements can be used by farmers to enhance their yields and crops. Thanks to the data the drone is able to collect, farmers can plan ahead, cut costs and move forward.

2.9 Cargo Systems

Google recently announced[16] their intention to use drone package delivery systems beginning in 2017. They're not the only ones as Amazon has stated they're going to do the same thing. Indeed, drones are considered the future of urban and rural deliveries, as they're cost-effective and practical.
Intralogistics is all about optimizing, managing and automating the flow of goods and cargo. This is the goal of all business enterprises and UAV is more efficient at this than other methods.
A report from Ark Invest[17] and also from Deutsche Bank illustrates the efficiency of delivery drones. A standard shoebox delivery costs from $6 to $6.50 for FedEx or UPS, while the rate for mid-tier carriers

[14] http://www.fool.com/investing/2016/11/25/drone-usage-in-agriculture-could-be-a-32-billion-m.aspx
[15] http://www.wuft.org/news/2015/06/06/drone-technology-helps-florida-farmers-cut-costs
[16] http://www.reuters.com/article/us-usa-drones-alphabet-idUSKCN0SR20520151103
[17] https://ark-invest.com/research/drone-delivery-amazon

is $5. The charge for USPS is $2 for the final mile, not including the rest of the journey. In contrast, a drone costs about $0.05 for each mile of delivery.

With cost so low, Amazon and other companies stand to gain from the reduced shipping, and this is passed on to consumers. Drones are fast too, capable of delivering packages in half an hour in most cases. The use of drones for delivering cargo, goods and merchandise are in its early phase, but the benefits are already evident.

2.10 Construction

The $8.5 trillion construction industry is increasing its use of drones[18]. In an article on Fortune[19], it's been pointed out that several tech companies are developing systems to meet the demand, and it's easy to see why construction firms want drones.

- Drones are less expensive than manned aircraft. They are easier to operate and collect more data.
- UAVs can be used to survey the construction site and send information back. This usually takes a long time and require use of various equipment and personnel. Drones are cheaper and they're more accurate in terms of data gathering.
- Your company can use drones to provide client updates. If they're unable to personally inspect the site, you can send images and videos and show details of the construction progress.
- Drones and unmanned aerial vehicles are also ideal for monitoring the site. Rather than invest in loads of expensive manpower and equipment, a construction company can purchase a few drones and have them scan the area and collect information.

UAVS are also useful for maintaining the safety standards in the construction site. An operator gets a first person view of the area and they'll get an idea of the progress and if they're meeting target goals, all the while being cost effective.

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[18] http://dronenodes.com/drones-in-construction-industry

[19] http://fortune.com/2016/09/13/commercial-drone-construction-industry

2.11 Mining and Aggregates

A report from Mining Weekly[20] reveals that the use of UAVs in mining industry continues to be on the rise. According to the report, remotely piloted aircraft systems (RPASes) companies in South Africa are fast tracking hiring and training of drone pilots to meet the increased demand from mining companies. While the report is about South Africa, the same thing is taking place around the world, including the United States. One of the reasons why is its cost efficiency. According to Mike Hutt of the U.S. Geological Survey[21], it usually costs $2,000 to rent a helicopter for an hour, while sending out a couple of drones and their operators is only $200.

The low cost of drones construction is the reason why mining companies prefer them. However, there are other reasons why they're now being used, such as improving safety, taking of soil samples, and raw mineral extraction, all of which is made easier by drones.

Out of the many applications of UAV's described above, we will be concentrating on surveying and Mapping part only. We have done the study in a sponsoring organization "Sterlite Power Transmission Ltd".

Sterlite Power is a leading global developer of power transmission infrastructure with 22 projects spanning 12,478 circuit kilometers in India and Brazil. Their innovative usage of global technologies such as helicranes to aid in project completion, and drones to survey and monitor transmission lines remotely has allowed us to reduce the need for human intervention, and minimize impact on the environment, while also increasing accuracy in project planning and execution.

In their Global Infrastructure Business, they bid, design, construct, own and operate power transmission assets across multiple geographies. Given our expertise in project execution and their experience in leveraging cutting-edge technology, they have built a track record of commissioning projects ahead of schedule, addressing the key constraint of time. They help meet the industry's need for capital by implementing projects on a BOOM (Build Own Operate Maintain) basis and being at the forefront of financial innovation via IndiGrid, India's first power sector Infrastructure Investment Trust (InvIT).

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[20] http://www.miningweekly.com/article/remotely-piloted-aircraft-possess-significant-benefits-for-mine-surveying-and-analysis-2016-08-26

[21] http://www.miningglobal.com/technology/1167/The-Mining-Sector-Puts-Drones-to-Work

Sterlite has an internal survey team which includes both traditional survey and modern survey using UAVs and DGPS devices. So this made it a great platform to conduct this study.

3. Research Design, Methodology and Plan

Acquiring survey grade data, either remotely through aerial LiDAR, or through traditional methods of land surveying, is a time consuming and financially burdensome endeavor. Utilizing UAV for data acquisition has three unique advantages: low initial investment cost, low mobilization cost, and decreased time required to complete acquisition. This study provides a comparison of using UAV to acquire land surface survey data. Study area selected for this work is a linear survey of around 3 km with a swath of 120 meters near Ajmer in Rajastan state of India.

In order compare the use of UAV to traditional land surveying methods the following hypotheses were tested in this study:

- Alternative Hypothesis 1: Using UAV for topographic mapping will take less time than traditional surveying methods.
- Null Hypothesis 1: Using UAV for topographic mapping will take more time than with traditional surveying methods.
- Alternative Hypothesis 2: Using UAV for topographic mapping will cost less money than with traditional survey methods.
- Null Hypothesis 2: Using UAV for topographic mapping will cost more money than with traditional survey methods.
- Alternative Hypothesis 3: Using UAV for topographic mapping will result in more accuracy than with traditional survey methods.
- Null Hypothesis 3: Using UAV for topographic mapping will result in less accuracy than with traditional survey methods.
- Alternative Hypothesis 4: Using UAV for topographic mapping will result in better ground resulution than with traditional survey methods.
- Null Hypothesis 4: Using UAV for topographic mapping will not result in better ground resulution than with traditional survey methods.

Another goal of this work is to advance the application of UAV in the profession of surveying. Additionally, this work will allow for dissemination of lessons learned regarding best practices for their implementation to the surveying community.

The base of knowledge for this study was achieved through the practical experience of the survey team (both traditional and modern) of Sterlite Power and by referring various journals and websites on UAV Technology, DGCA Regulations for RPAS in India,automated photogrammetric technology, project management and standard survey practices.

3.1 Methodology

This section describes the aircraft,sensors,softwares,Photogrammetry,and survey tools used in the testing conducted in the study.The UAV used for the topographical survey was DJI Phantom 4 Pro and DGPS device used was Trimble Spectra Precision SP80.

Fig 1: DJI Phantom 4 Pro aircraft

Fig 2: Trimble Spectra Precision SP80

3.1.1 Traditional Survey Methods and Systems

3.1.1.1 Topographic Mapping and Volume Calculation by Cross Section

Cross sections created through manual surveying in the field are one of several traditional survey methods used in this study. A cross section is a profile of the earth taken at right angles to the centerline of an area to be surveyed. Cross sections are established by noting latitude, longitude, and elevation of a series of points along a line perpendicular to the survey area. In modern surveying, those latitudes, longitudes, and elevations are established using Global Positioning Systems (GPS). Cross sections are

shot (measured) at regular intervals so as to cover the entire survey area. The size of the interval between cross sections differs depending on the goal of the particular project and is dependent on the ground measurement accuracy required. Topographic lines are then drawn by interpolation based on common points of elevation within the survey area.

3.1.1.2 Automated Photogrammetry using UAS

Modern software, such as Pix4D Mapper or Drone2Map, use a different approach to creating orthomosaics and generating topographic lines. When images are loaded into automated photogrammetric software, each image is divided into a set of pixels. The software then determines pixels from each photograph that match each other and creates automated tie points, generating an orthomosaic. This orthomosaic is based on the GPS position of the camera taking each photograph. Automated aerial triangulation and parallax measurements are calculated to generate an elevation for each point. To draw accurate topographic lines, ground control points must be used. Ground control points are set down within view of the planned coverage area, and each 3D location is measured using a GPS (Figure 3). The longitude, latitude, and elevation value for each ground control point are then manually assigned using the software to the corresponding pixel where the GPS shot was taken. The software can then assign the remaining pixels in the orthomosaic a 3D location based on their relative location to a known point. The results can include thousands of 3D D\data points, similar to LiDAR(Figure 4).

Figure 3: Example of Ground Control Points Viewed from a UAS

Figure 4: 3D Point Cloud from UAS Flight

3.2 Testing Systems

3.2.1 Topographic Mapping Testing Systems

The test conducted to compare the cross sectional method of topographic mapping with the use of UAS. The total area surveyed was approximately 89 acres. The land surveyor used a Trimble Spectra Precision SP80 to shoot 100-foot cross sections. AutoCAD software was used to interpolate topographic lines based on the GPS shots taken using the cross-sectional method. The UAS used was the Phantom 4 Pro, manufactured by DJI Inc. The DJI Phantom 4 Pro is a

1.5 kg rotory wing, remotely piloted aircraft. It uses a default camera of 20 MegaPixels. The Trimble Spectra Precision SP80 DGPS was used to record the horizontal and vertical position of ground control points. Mission Planner software DJI Ground Station Pro was used to plan the flight. Pix4D software was again used to process the photos, create an orthomosaic, and create 1-foot interval contour lines.

4.Analysis

This section describes the work testing methodology. This mainly discuss the comparison UAS Vs. Cross-Sectional Method for Topographic Mapping, . To conduct a comparison, of the two survey methods, the accuracy of data acquired through the use of UAS was determined, and the costs of acquiring that data using traditional land surveying and UAS were compared. As a control, the field collection and data processing completed for each method were conducted by the same researchers.

4.1 Comparison of Cross-sectional Method and UAS Method for Topographic Mapping

Both the cross-sectional method and the UAS method were conducted on the same day.

The accuracy of the topographic lines created using the UAS method was determined by comparing their location and elevation to the topographic lines created using the cross-sectional method. The total area mapped for this test was approximately 89 acres.

Elevation readings were noted on both sets of contour lines where they appeared to cross. The cost of each method was obtained by calculating the total time spent by each person involved in the test, and multiplying that time by their hourly charge rate, the amount of money billed for associated services. The labor rates were then added to hourly rates for the use of the equipment involved. The time to conduct each method of testing was determined as the sum of time spent planning in the office, mobilizing to the test site, collecting the data, mobilizing back to the office, processing the data and creating the topographic lines.

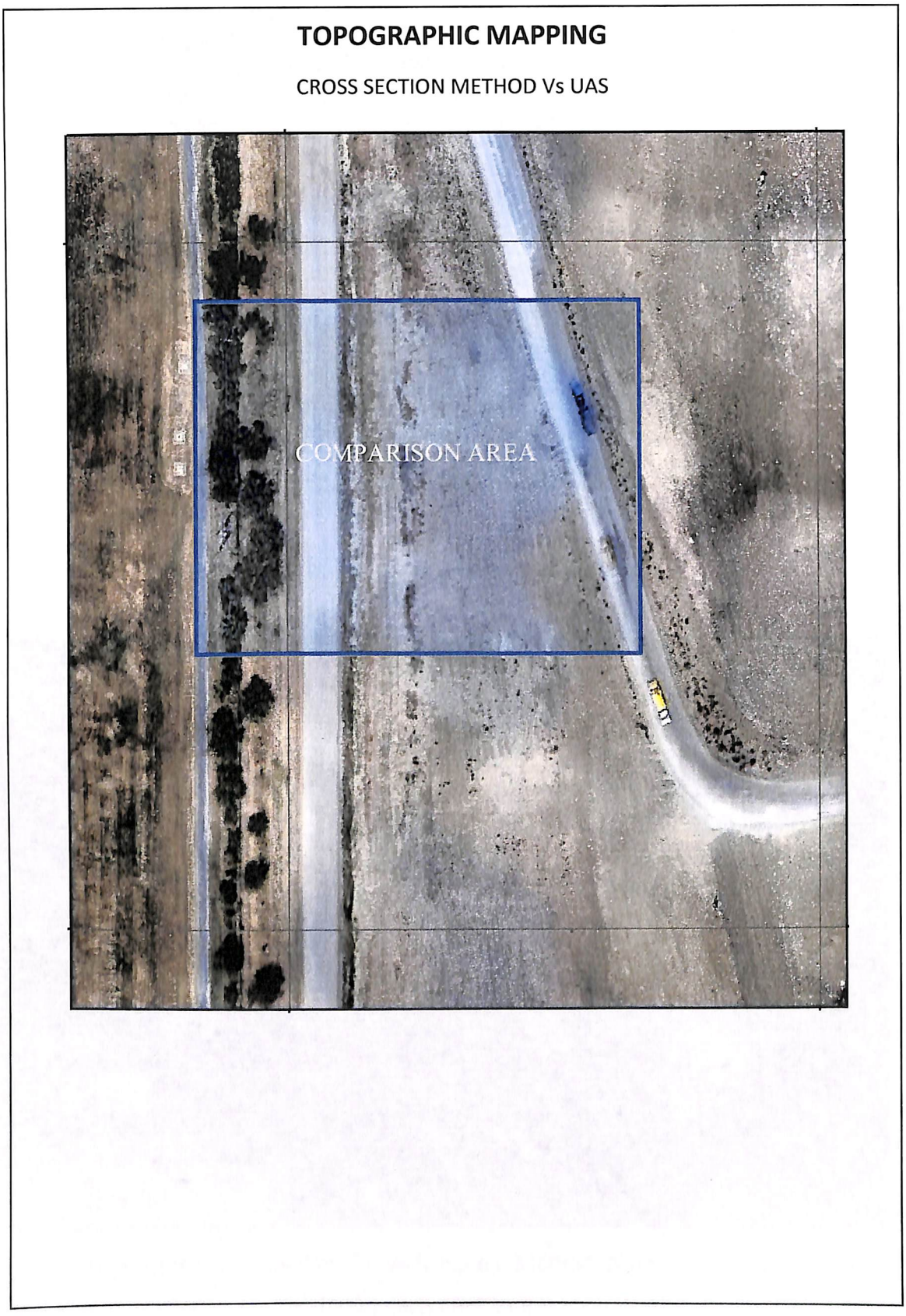

Figure 5: Cross Sectional Method Testing Site

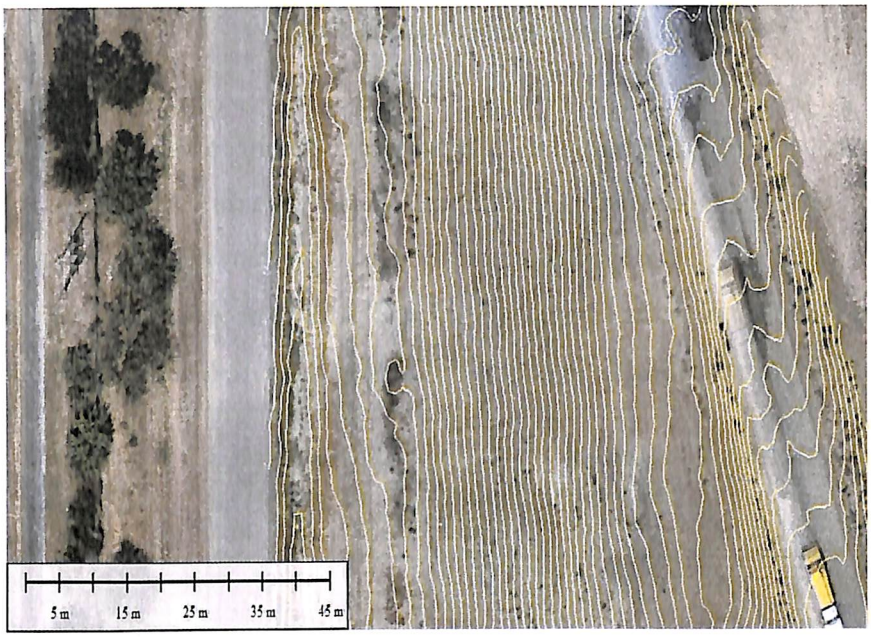

Figure 6: Topo Lines Generated by UAS

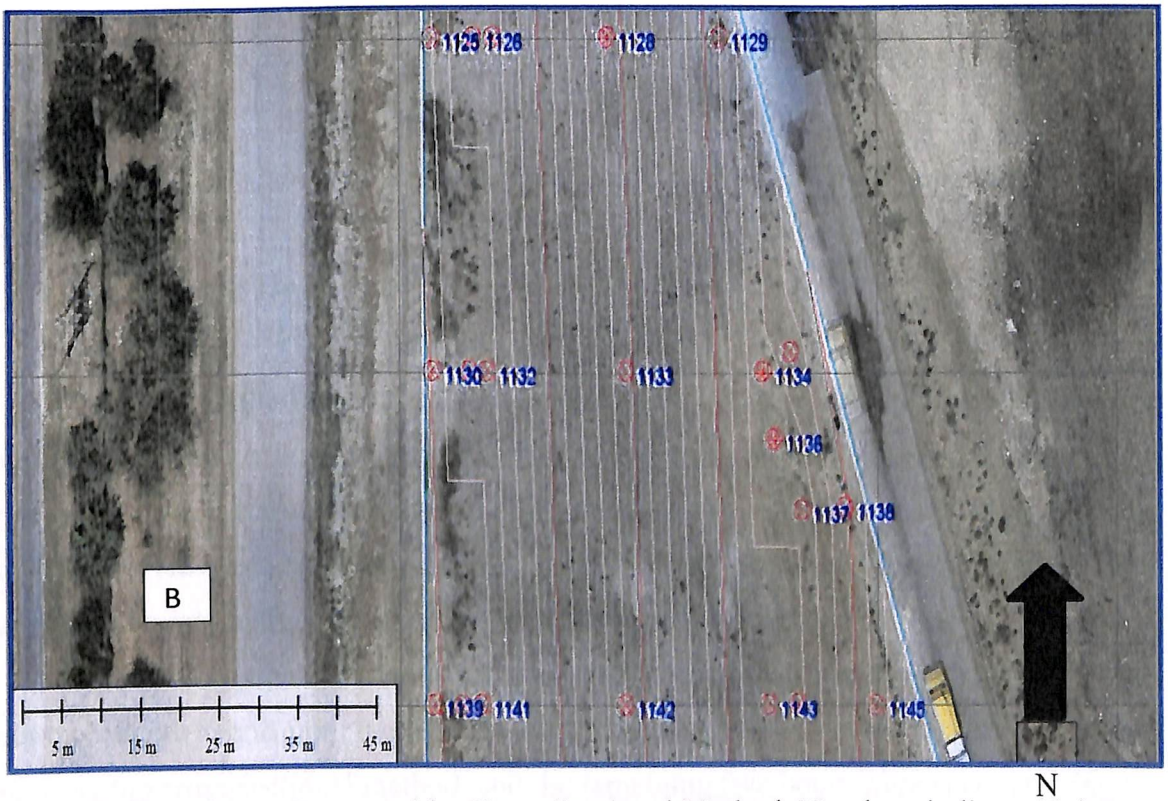

Figure 7: Topo Lines Generated by Cross-Sectional Method. Numbers indicate Unique ID for each GPS shot

5. Interpretation of results

This chapter details the results of the testing in regards to the time required to accomplish each task, the cost associated with each method, and the comparison of accuracy between methods used. Overall the UAS method proved to be more beneficial than using the cross-sectional method for topographic mapping. The UAS method took less time and cost almost same money with no loss in accuracy of the results. Table 1 summarizes the results.

Test	Traditional Method	Traditional Method Time	UAS Method Time	Traditional Method Cost	UAS Method Cost	Accuracy Comparison
Topographic Mapping	Cross Sectional Method	16 Hours	8 Hours	Rs 55000	Rs 60000	Less than 0.1' difference between contour lines
		↑	↓	↓	↑	↔
		Higher	Lesser	Lesser	Higher	Comparably Accurate

Table 1: Summary of results

5.1: Comparison of Cross-sectional Method and UAS Method for Topographic Mapping

5.1.1 Comparison of Time

The UAS method for topographic mapping in this test required a total of 8 hours to complete. Three hours were spent mobilizing to and from the test site, while planning the flight and preparing the aircraft took 15 minutes. The total flight time was 45 minutes long. Three hours were spent establishing ground control points, and the remaining time was spent processing the data in the office and creating the 1-foot interval contour lines.

The cross-sectional method took a total of 16 hours to complete. Three hours were spent mobilizing to and from the test site. Eight hours were spent collecting the topographic data using the cross-sectional method, and the remaining five hours were spent creating the topographic lines from the cross sections and conducting quality control of the data.

Using the UAS method required eight fewer hours to complete the data collection

and analysis than the traditional cross-sectional method. In this case, Alternative Hypothesis 1 proved to be true: Using UAV for topographic mapping will take less time than traditional surveying methods.

5.1.2 Comparison of Cost

To conduct the topographic mapping, the UAS method cost a total of Rs 60000 which is charged at a rate of Rs 20000 per km. We had a stretch of 3km with a swatch of 120m to be surveyed. This rate per km includes mob-demobilization, data collection charges and data processing charges. The total cost of using the cross-sectional method was Rs 55000,which also includes all the site works and office works. In this case, Null Hypothesis 2 proved to be true: Using UAV for topographic mapping will cost more money than with traditional survey methods. But the difference in cost is very marginal.

5.1.3 Comparison of Accuracy

Where the topographic lines from the UAS method and the cross-sectional method cross, there is less than a 0.1-foot difference in all three axes as measured using AutoCAD. In this test, Alternative Hypothesis 3 and 4 proved to be true. Alternative Hypothesis 3: Using UAV for topographic mapping will result in more accuracy than with traditional survey methods and Alternate Hypothesis 4:Using UAV for topographic mapping will result in better ground resolution than with traditional survey methods

6. Conclusion and future scope of work

In this thesis study, alternative hypothesis 1, 3, and 4 proved to be true and null hypothesis 2 are proved to be true. The UAS methods proved to be more accurate, take less time, and have better ground resolution and cost is in comparable limit with traditional survey methods.

Though this survey using UAV Photogrammetry is proved to the best method in terms of accuracy, reliability and cost aspect, it has some inherent limitations which needs to be considered while scaling up the use of this technology. This method is not effective when the terrain is having medium to high vegetation as the UAV wont be able to capture the ground profile and the processing software wont be able to reconstruct the terrain from the captured images. The next limitation is in terms of UAV Regulations by Directorate General of Civil Aviation,India (DGCA). Though the regulations are in place from December 2018, it is still not in the matured state. There are a lot of confusions and lack of clarity in the type of aircraft which can be used, acquisition of UAV operators permit, Unique Identifications number (UIN) for every aircraft is still there. Once these things are clear, UAV photogrammetry survey can be scaled up and commercialized as a better replacement for the traditional survey methods in terms of accuracy, cost and time but limited to less vegetated area only.

As a project management company in power transmission line business, Sterlite has already implemented this method of survey in areas wherever this is feasible and created a positive impact on results. They have done a linear survey of 300km in Rajastan and Gujrat in a record time of one month.

Bibliography

1. http://www.businessinsider.com/uav-or-commercial-drone-market-forecast-2016-4-24
2. http://droneanalyst.com
3. http://dronenodes.com/drone-photography
4. http://dronenodes.com/drones-in-construction-industry
5. http://dronenodes.com/law-enforcement-drones
6. http://www.airbus.com/presscentre/pressreleases/press-release-detail/detail/airbus-demonstrates-aircraft-inspection-by-drone-at-farnborough-innovation-and-digitalisation-for-production-ramp-up
7. http://waypoint.sensefly.com/land-surveying-with-drones-1
8. http://www.intel.com/content/www/us/en/technology-innovation/aerial-technology-overview.html
9. https://arxiv.org/pdf/1602.03602.pdf
10. https://futurism.com/facebooks-solar-powered-planes-will-beam-data-at-record-setting-rates
11. https://today.duke.edu/2016/05/sharkdrones
12. http://www.audubon.org/magazine/july-august-2014/drones-take-wildlife-conservation-tool
13. http://www.cnbc.com/2015/11/20/how-drones-are-being-used-for-safety-and-rescue.html
14. http://phys.org/news/2016-04-scientists-drone-trafford-landmine-clearance.html
15. http://www.fool.com/investing/2016/11/25/drone-usage-in-agriculture-could-be-a-32-billion-m.aspx
16. http://www.wuft.org/news/2015/06/06/drone-technology-helps-florida-farmers-cut-costs
17. http://www.reuters.com/article/us-usa-drones-alphabet-idUSKCN0SR20520151103
18. https://ark-invest.com/research/drone-delivery-amazon
19. http://fortune.com/2016/09/13/commercial-drone-construction-industry

20. http://www.miningweekly.com/article/remotely-piloted-aircraft-possess-significant-benefits-for-mine-surveying-and-analysis-2016-08-26
21. http://www.miningglobal.com/technology/1167/The-Mining-Sector-Puts-Drones-to-Work

References

1. http://www.businessinsider.com/uav-or-commercial-drone-market-forecast-2016-4-24
2. http://droneanalyst.com
3. http://dronenodes.com/drone-photography
4. http://dronenodes.com/drones-in-construction-industry
5. http://dronenodes.com/law-enforcement-drones
6. http://www.airbus.com/presscentre/pressreleases/press-release-detail/detail/airbus-demonstrates-aircraft-inspection-by-drone-at-farnborough-innovation-and-digitalisation-for-production-ramp-up
7. http://waypoint.sensefly.com/land-surveying-with-drones-1
8. http://www.intel.com/content/www/us/en/technology-innovation/aerial-technology-overview.html
9. https://arxiv.org/pdf/1602.03602.pdf
10. https://futurism.com/facebooks-solar-powered-planes-will-beam-data-at-record-setting-rates
11. https://today.duke.edu/2016/05/sharkdrones
12. http://www.audubon.org/magazine/july-august-2014/drones-take-wildlife-conservation-tool
13. http://www.cnbc.com/2015/11/20/how-drones-are-being-used-for-safety-and-rescue.html
14. http://phys.org/news/2016-04-scientists-drone-trafford-landmine-clearance.html
15. http://www.fool.com/investing/2016/11/25/drone-usage-in-agriculture-could-be-a-32-billion-m.aspx
16. http://www.wuft.org/news/2015/06/06/drone-technology-helps-florida-farmers-cut-costs
17. http://www.reuters.com/article/us-usa-drones-alphabet-idUSKCN0SR20520151103
18. https://ark-invest.com/research/drone-delivery-amazon
19. http://fortune.com/2016/09/13/commercial-drone-construction-industry
20. http://www.miningweekly.com/article/remotely-piloted-aircraft-possess-significant-benefits-for-mine-surveying-and-analysis-2016-08-26
21. http://www.miningglobal.com/technology/1167/The-Mining-Sector-Puts-Drones-to-Work