A

Dissertation Report on

Feasibility Study of LiDAR Survey over Total Station Survey of Roads

Submitted

in partial fulfilment of the requirements for the degree of

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in

Civil-Construction Management

by

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CERTIFICATE

This is to certify that, Mr. Jetti Anilkumar Ramesh Student Name (Roll No-1727002) has successfully completed the dissertation work and submitted dissertation report on "Feasibility Study of LiDAR Survey over Total Station Survey of Roads" for the partial fulfillment of the requirement for the degree of Master of Technology in Construction Management from the Department of Civil Engineering., as per the rules and regulations of Rajarambapu Institute of Technology, Rajaramnagar, Dist: Sangli.

Date:

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DECLARATION

I declare that this report reflects my thoughts about the subject in my own words. I have sufficiently cited and referenced the original sources, referred or considered in this work. I have not misrepresented or fabricated or falsified any idea/data/fact/source in this my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute.

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ABSTRACT

The research work entitled "Feasibility Study of LiDAR Survey over Total Station Survey of Roads", deals with the comparative analysis by considering different factors like Accuracy, Cost and Time. Among all types of LiDAR(Light Detection and Ranging) reseach focuses on Vehicle mounted LiDAR. In this research Accuracy is considered as very important factor because it indicates the quality of survey. For accuracy two studies have been performed, firstly on the same span of 2 kms survey is carried out and another study performed by studying plan and profiles of different projects made after both LiDAR and Total station survey and checked OGL(Original Ground Level) at each chainage. The data of cost and time is also taken from the respective organisations and concerned persons involved in road survey projects. In this research it is observed that LiDAR is economically feasible if we considers Return on Investment. LiDAR is comparatively operationally, technically more feasible and completes the task in time than that of Total Station. LiDAR gives very close readings with the readings of Total Station at constant speed for longer spen and at plain terrain.

Keywords: Feasibility Study, LiDAR, Total Station, Return on investment, Original ground level.

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ABBREVIATIONS

LiDAR	Light Detection and Ranging
TS	Total Station
OGL	Original Ground Level
NHAI	National Highway Authority of India
ROI	Return on Investment
AU	Aurangabad
NSK	Nashik
GPS	Global Positioning System

Chapter 1

INTRODUCTION

1.1 General

Highway surveying is a specialized type of land surveying generally conducted for government or private agencies during the planning stages of a highway development project. After the highway is constructed, a highway survey can be carried out to provide an accurate layout of roadways, utilities, storm drainage systems, overhead wires, nearby buildings, and other features of the landscape.

A Topographic Survey is a survey that gathers data about the elevation of points on a piece of land and presents them as contour lines on a plot. The purpose of a topographic survey is to collect topographic information about the natural and man-made features of the land, as well as its elevations. Topographic maps are used to show elevations and grading features for architects, engineers, and building and road contractors.

Usually topographic survey is carried out by conventional method i.e Total Station. The instrument gives its output data with great accuracy. In which a lot of human efforts and skills are involved. Total stations are mainly used by land surveyors and civil engineers, either to record features as in topographic surveying or to set out features (such as roads, houses or boundaries). They are also used by archaeologists to record excavations and by police in crime scene investigations, private accident reconstructions and insurance companies to take measurements of scenes.

Nowadays, LiDAR (Light Detecting and Ranging) is more and more frequently used in all kinds of fields, such as forest measurement, transportation and power

transmission fields[1]. LiDAR may prove to be an alternative technology to obtain terrain information in a more expedient manner since it does not face the same limitations as traditional data collection methods. LiDAR data can be collected under variety of environmental conditions, including low sun angle, cloudy conditions, and even darkness, resulting in expanded windows for data collection[2].
Many of the nations are currently using LiDAR technology for different types of surveys. Nowadays, this technology is also emerging in India rapidly. The NHAI made it mandatory to use LiDAR for feasibility study of all highway projects as it takes a day to complete survey of 100-200 kms. On the other hand, survey of only 2 kms can be carried out by total station per day.

1.2 Total Station

A total station is an electronic/optical instrument used in modern surveying and building construction that uses electronic transit theodolite in conjunction with electronic distance meter (EDM). It is also integrated with microprocessor, electronic data collector and storage system.
Total stations were first developed in the 1980s by Hewlett-Packard (Brinker and Minnick 1995). The instrument is used to measure sloping distance of object to the instrument, horizontal angles and vertical angles. This Microprocessor unit enables for computation of data collected to further calculate the horizontal distance, coordinates of a point and reduced level of point. Data collected from total station can be downloaded into computer/laptops for further processing of information.
Total stations are mainly used by land surveyors and civil engineers, either to record features as in topographic surveying or to set out features (such as roads, houses or boundaries). They are also used by archaeologists to record excavations and by police, crime scene investigators, private accident Reconstructions and insurance companies to take measurements of scenes.
Total stations combine electronic theodolites and EDM into a single unit. They digitally observe and record horizontal directions, vertical directions, and slope distances. These digital data observations can be adjusted and transformed to local X-Y-Z coordinates using an internal or external microprocessor. Various

atmospheric corrections, grid and geodetic corrections, and elevation factors can also be input and applied. The total station may internally perform and save the observations or (more commonly) these data may be downloaded to an external data collector. With the addition of a data collector, the total station interfaces directly with onboard microprocessors, external PCs, and software.

1.2.1 Output data of Total Station

For highway design after GPS observation, TBM fixing, traversing, TBM shifting, topographic survey is done. In topographic survey of any road project total station is mostly used. Total station directly gives output as a CAD drawing(.dwg). Output data of TS is shown in figure 1.1

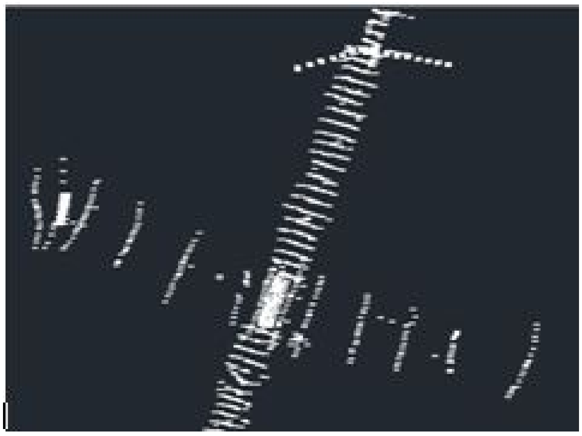


Figure 1.1: Total station output data

In above figure, we are having levels of roads and structures coming across it. That white spots are nothing but the elevations of those particular points. In the figure 1.1, we can see the detailing of data in which we can see road levels and level of minor bridge and pipe culvert. Northing and Easting of each and every point can be determined by using commands like ID and LI. This data needs to be join to get final plan of road.

After joining this data we get actual plan of road after which ROW details, inventory details needs to be fill. Then geometric design starts. Sometimes, during drafting and designing errors in survey occurs so it causes for time and cost overrun because of re mobilization.

1.3 LiDAR(Light Detection and Ranging)

LiDAR(Light Detection and Ranging), or 3D laser scanning, was conceived in the 1960s for submarine detection from aircraft and early models were used successfully in the early 1970's in the US, Canada and Australia. Over the past ten years there has been a proliferation in the use of LiDAR sensors in the United Kingdom, with several regularly used in both airborne and ground surveying. This has been accompanied by an increase in the awareness and understanding of LiDAR in previously unrelated industries as the application of LiDAR has been adopted.

1.3.1 Components of LiDAR

Figure 1.2: Components of LiDAR

The most important components of LiDAR are as follows:-

1. Scanner - mirror spins or scans to project laser pulses to the surface - scanning angles up to 75 degrees; scanner measures the angle at which each pulse was fired - receives reflected pulse from surface ("return").

2. Global Positioning System (GPS) - records the x,y,z location of the scanner - surveyed ground base stations in the flight area.

3. Inertial Measurement Unit (IMU) - measures the angular orientation of the scanner relative to the ground (pitch, roll, yaw).

4. CCD cameras- CCD(Charged Coupled Device) cameras to enhance accuracy. CCDs are sensors used in digital cameras and video cameras to record still and moving images. The CCD captures light and converts it to digital data that is recorded by the camera.

1.3.2 Types of LiDAR

There are three types of LiDAR, classified as per the platform on which it is mouted are described as follows,

1) Airborne LiDAR- It is mounted at the bottom of Aircraft and Helicoptor. It is used for town mapping, Large scale survey, feasibility studies. Achives target of 100-200kms/day. It gives very less accuracy. Survey gets affected by the turbulence. It is not commonly used in India. It is used in USA, Canada, Australia for mapping of towns and villages. In figure 1.3, overall process of Airborne LiDAR is explained.

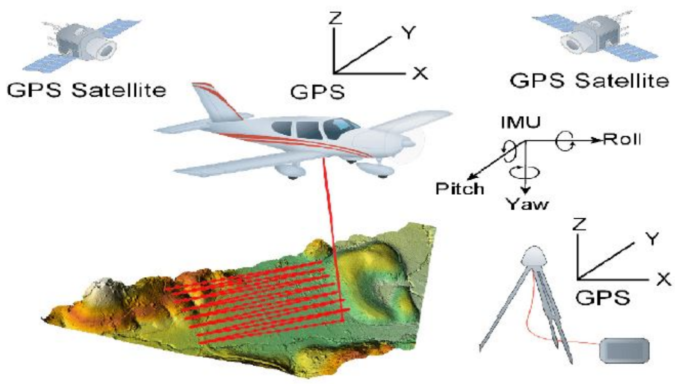


Figure 1.3: Airborne LiDAR

2) Terrestrial LiDAR:- For highway topographic survey this method is adopted. It gives more accuracy as compared to airborne LiDAR. In India this method is used for road topographic survey. In figure 1.4 there is a vehicle mounted LiDAR.

Figure 1.4: Vehicle mounted LiDAR

3) Bag pack:- It is used for small scale mapping. In this type, surveyor carries a bag with the LiDAR system weighs 15 kg and by just walking across the area of operation. An area or locations where vehicle or aircraft can not be reached or can not be captured in that situations Bagpack LiDAR is used. Figure 1.5 is the picture of surveyor surveying at Dharavi slum, Mumbai. In this slum it is impossible to drive car, so bagpack LiDAR is used.

Figure 1.5: Bagpack LiDAR

1.4 Closure

In this chapter, both the technologies were introduced in detail. The overview of both the technologies was given here. Components of LiDAR, applications of each component, types of LiDAR etc.was discussed in this chapter.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the studies and practices adopted by many researchers are reviewed. Also, research gaps in these studies are summarized, which are led to decide methodology of the dissertation work.There are various analytical researches made to study the effect of seismic action and the various damage states are studied. Following are some of the literatures that are used as a reference to carry out the project work.

2.2 Review of previous studies:

- **Wanquan, H. (2017), "Research on Analyze Accuracy of LiDAR Data in Surveying Projects"**

In this paper, the author make the analyze accuracy of LiDAR data base study site in Nanjing, China. It involved various operations done by LiDAR as DEM/DSM (Digital elevation Model or Digital Surface Model), DOM (Digital Orthoimages Mapping), DLG (Digital Line Mapping) and three-Dimensional Models (3DM). In conclusion they found quite errors with all the opration. Author mentioned that, LiDAR is best for 3DM and it can be used for other operations also without any considerable error.

- **Veneziano, D. "Accuracy Evaluation Of Lidar-Derived Terrain Data For Highway Location"**

In this paper, the author tried to find elevation accuracy of LIDAR as it compares to a set of GPS control points on varying surfaces. This allowed for a determination of which surfaces LIDAR performed well on, as well as surfaces it did not. The focus of this research was to determine how accurately LIDAR performed in comparison to GPS data on different surface types like hard, ditch, slope, rolling terrain, harvested, unharvested etc.

- **Yi, H. et al. (2017), "Updating highway asset inventory using airborne LiDAR"**

In this paper, the author analyzed the capability and strengths of airborne LiDAR in highway inventory data collection. A field experiment was conducted to collect airborne LiDAR data, and an ArcGIS-based workflow was proposed to process the data. The results demonstrated the effectiveness of the proposed workflow as well as the feasibility and high efficiency of airborne LiDAR for highway inventory data collection.

- **Duffell, CG. et.al. (2006), "Detection of Slope Instability using 3D LiDAR Modelling"**

This paper describes that, whether 3D modelling by LiDAR can be used for the detection of slope instability. Here author identified that the LiDAR can be used for the 3D modelling without any considerable error. One of the key advantages of LiDAR is that with sufficient density of laser scan points, LiDAR returns from beneath a vegetation canopy will be recorded. This allows the ground profile beneath wooded slopes to be identified.

- **Gabriel, P. and Daniela, I.(2016), "The Geolocation Accuracy of LiDAR Footprint"**

This paper describes the geometric geolocation accuracy of LiDAR footprint, by examining efficiency of the IMU(Inertial Monitoring Unit) which reduces the vibaration and turbulence effects of aircraft on the output results. Using the derived error formulas, based on the accuracy of the navigation solution, the boresight misalignment angles, the ranging and scan angle accuracy, and laser beam divergence, the achievable point positioning accuracy can be computed for any given

LiDAR system which operates at different flying heights between 70 m – 6,000 m.

• **Keawaram, B. and Dumrongchai, P.(2017), "Comparison of Surveying with Terrestrial Laser Scanner and Total Station for Volume Determination of Overburden and Coal Excavation in Large Open-Pit Mine"**

This study aimed to evaluate the accuracy of terrestrial laser scanner (TLS) used to measure overburden and coal excavations and to compare TLS survey data sets with the data of the total station. Here, Total station and Laser scanner survey were conducted in large coal mine. In this article, authors concluded that Total Station is more accurate than Laser scanner. In this way this article was useful for the thesis work.

• **Lohani B. and Ghosh, S. (2017), "Airborne LiDAR Technology: A Review of Data Collection and Processing System"**

This paper presents areview of the current state- of the-art of LiDAR technology. The paper covers both data capture and data processing issues of the technology. This is very informative article on LiDAR technology. The main aim of this paper is to review the status of LiDAR technology, highlight the research issues associated with the technology and identify the direction where the technology is heading to. The detailed information about different LiDAR sensors, processing etc. were provided.

• **Mukherjee, M. and Roy, S. (2017), "Feasibility Studies and Important Aspect of Project Management"**

In this paper authors want to describe stepwise, different studies are essential for design and layout of plants. In this paper author also described different benefit conducting the feasibility studies. The survey is also extended more detailed regarding different considerations. Here its also discussed different test parameters. We also try to measures different impact on the organizational characteristics; fulfill user requirements. Five essential areas of project feasibility are also discussed here. Benefits of conducting feasibility study and different aspects consider here for discussion.

2.3 Gap Analysis

Most of the literature was focused on airborne LiDAR but, in India specially for highway topographic survey terrestrial (vehicle mounted) LiDAR is generally being used. All the accuracy tests taken at ideal condition. Important issues involved in highway topographic surveys are not previously considered. Accuracy considered with respect to the speed of vehicle has its own importance due to various effects like beam divergence, Pulse repetition frequency. On which ground condition terrestrial LiDAR gives best it is also to be evaluated.
With accuracy there are other factors like cost and time. This factors are to be considered for feasibility of LiDAR over total station survey which are considered earlier.

2.4 Problem Statement

Feasibility of LiDAR in terms of Accuracy, cost and time over Total station is to be checked.

2.5 Closure

In this chapter, previous relevant researches were studied. Relevance of every literature was explained. Gap between earlier researches evaluated. Problem statement was proposed.

Chapter 3

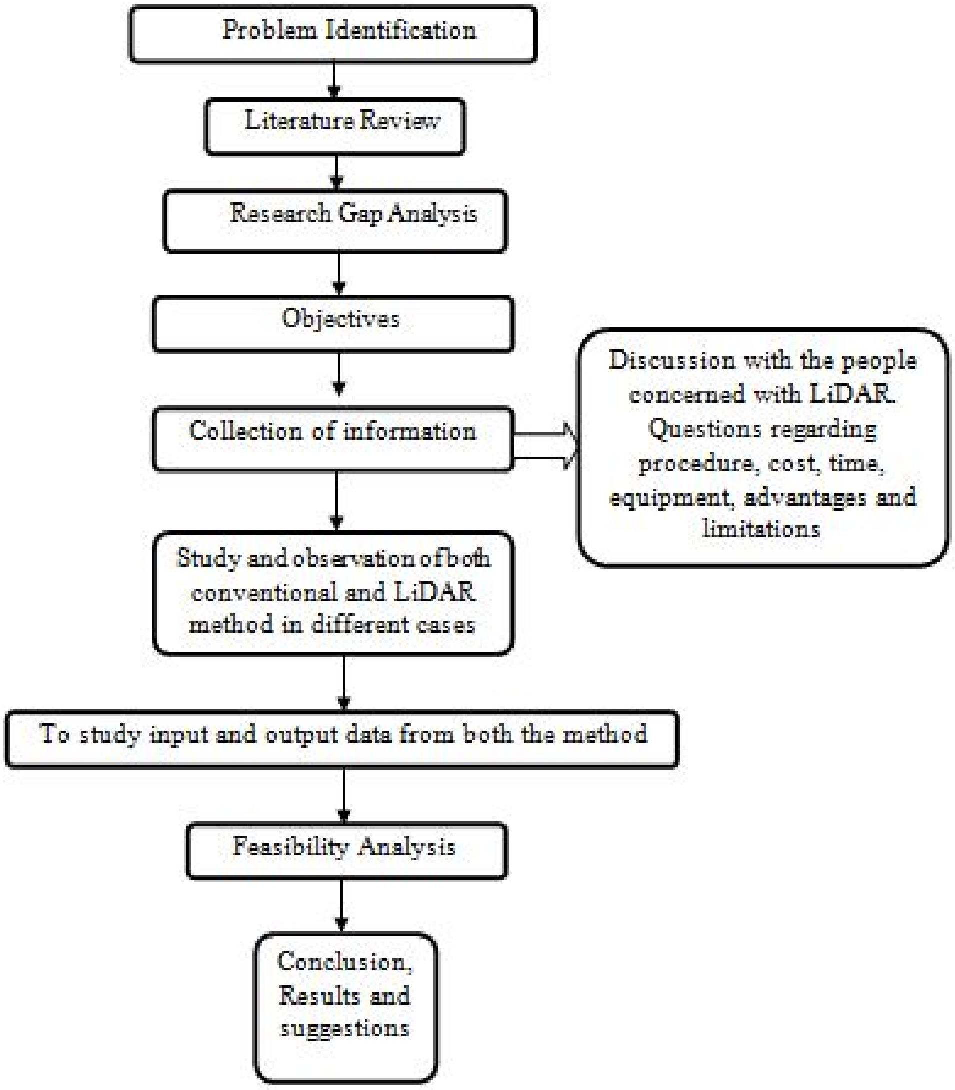
RESEARCH APPROACH METHODOLOGY

3.1 Objectives

1) To collect the information from concerned persons i.e. initiator, operator, surveyor, designer.
2) To perform comparative analysis of LiDAR for topographic survey over Total Station considering different factors(i.e time, cost, accuracy).
3) To study output data of LiDAR survey and TS survey for the same projects in different conditions.
4) To analyze output data by both the methods of survey, for feasibility study and to give final results and conclusions.

3.2 Methodology

For feasibility study of LiDAR over total station three factors considered. First and most important factor considered is Accuracy. Then the factors considered are Time and cost. With this three factors Feasibility study is carried out.for feasibility study of LiDAR over total station three factors considered. First and most important factor considered is Accuracy. Then the factors considered are Time and cost. With this three factors Feasibility study is carried out.Following methodology is adopted for dissertation work.



For this feasibility study The road projects taken into consideration are Ghoti-Trimbak(Nashik District), NSK 70A(Karjat- Bhigwan road upto Ahmadnagar district border), AU 115(Patonda-Basamba in Hingoli District).At Ghoti-Trimbak 2 kms span was choosen to carry out topographic survey by LiDAR and Total Station methods.

Figure 3.1: Vehicle mounted LiDAR at the site of Ghoti-Trimbak road

LiDAR survey was carried out at the project of Ghoti-Trimbak in Nashik district with the vehicle shown in Figure 3.1. Then further Total station survey carried out for the same. Output result in AutoCAD was compared for the accuracy, time and cost for same also studied.

3.3 Closure

This chapter introduces with the objectivesof project. The methodology for project was introduced in this chapter by flow diagram. Overview is taken of all the work which is carried out for this project.

Chapter 4

ACCURACY

4.1 Introduction

Accuracy is a vital part in each and every type of survey which indicates quality of the survey. Currently, LiDAR is used for topographic survey in so many highway projects because it is very less time consuming than conventional method. But, there are some issue regarding its accuracy. In India vehicle mounted LiDAR is mostly used. As LiDAR is operated with moving platform so it is unable to give that much accuracy as that of traditional method. In case of Topographic survey there are three applications of LiDAR must be considered i.e. DEM (Digital Elevation Model), Line Mapping and DTM (Digital Terrain Model). In DEM there is elevation of ground is measured by making use of reflection of LASER point clouds. Formulas used to measure ground elevation are as follows,

$$\text{Distance between machine and ground} = [(\text{Travel Time}) * (\text{Speed of Light})]/2$$

To find ground elevation we have to subtract this occurred distance from the altitude of machine as follows,

$$\textbf{Ground Elevation} = \text{Altitude of machine} - \text{Distance between machine and ground}$$

By using these formulas, we can actually calculate ground elevations and this we get very rapidly by using simple computer programming. Here in these formulas

we can factors which can affect the accuracy of LiDAR. Another factor is GPS observations of particular control points. It is very important to match GPS data with the topographic survey. So, on site what adjustment can be done that is needed to be studied.
Final and main factor which affects the accuracy is processing of data taken by LiDAR. In this process Line mapping and DEM needs to be join if we achieve more perfection in this process more accuracy we can give in output data.

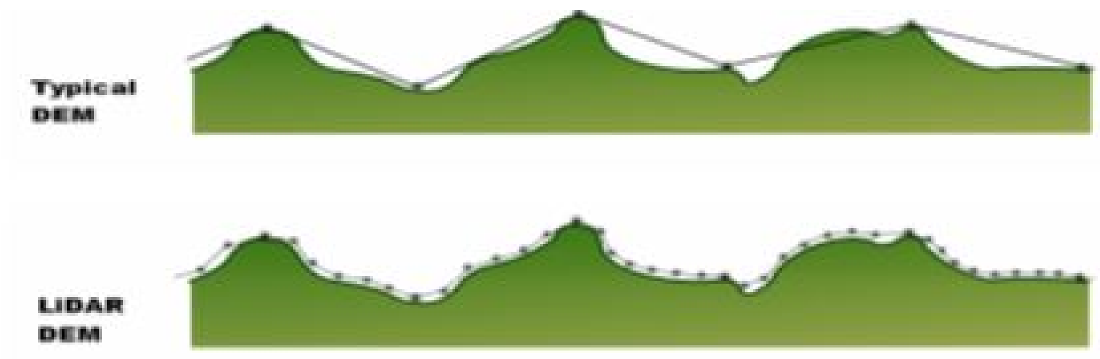


Figure 4.1: Comparitive representation of LiDAR survey and Total Station

In Figure 4.1, the frequency of points taken while survey is shown. By typical DEM means total station points at several distances are taken as per the convenience, But LiDAR takes throughout survey at each and every interval in between start to end. It is the reason behind the good relative accuracy of LiDAR. Due to different reasons accuracy of LiDAR varies that reasons are described as follows:

a) Pulse Repetition Frequency
In cost consideration high pulse repetition frequency gives advantages over low pulse repetition frequency for the same cost and time . A high PRF causes for the reduction in time the laser diode can recharge since pulses are being generated in rapid succession. With less time to recharge each individual pulse will contain less energy. The power loss has its greatest consequence upon pulse reception. With all other settings being equal. Figure 4.2. displays how changing the PRF affects point spacing and pulse energy. Notice that the pulses follow similar paths, however when a low PRF is implemented there is significantly more spacing between the points; however, the dots are much larger representing the increase in transmitted energy.

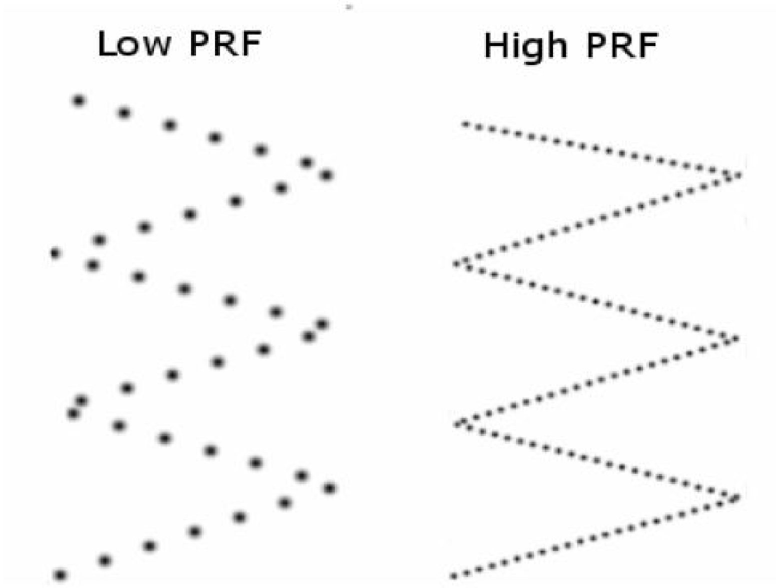


Figure 4.2: Variation of Pulse Repetition Frequency (PRF)

b) Beam Divergance

The beam divergence is defined as the angular area that contains 68% of the laser pulse energy. Narrow beam divergence settings contain a higher concentration of energy within a smaller pulse footprint which is beneficial for penetrating through canopy or for high altitude surveys. Beam divergence does not affect point spacing in a predictable way, however if the energy level is not sufficient to provide a return then significant dropouts will occur and the point density will suffer.

c) Vehicle Speed

Speed of vehicle is an important factor which affects the accuracy. Within the equal span no of point clouds with X, Y and Z readings changes. It also impacts on the co-ordination between Laser scanner and the camera of the LiDAR system. It is important to keep constant speed while the survey. With constant speed for long spans LiDAR is supposed to give good results in terms of accuracy.

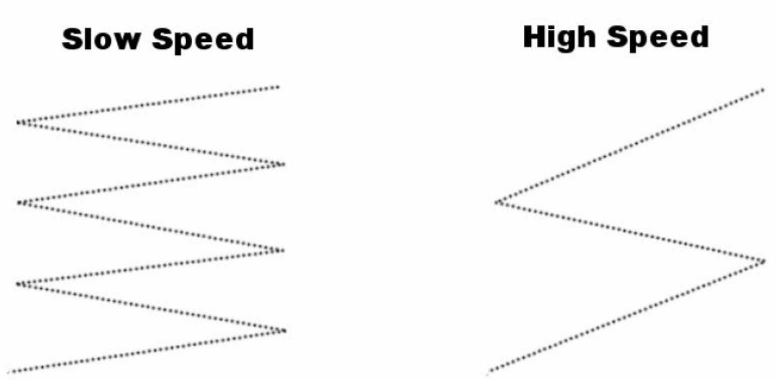


Figure 4.3: The effect of vehicle speed on point spacing

So, these were the parameters which causes differences as compared to traditional Total Station method. But the basic of every parameter is in vehicle speed. Vehicle speed changes with different tarrain and road conditions. Here, for accuracy we have examined the differences of output data.
1) By taking observation for same span with both technologies.
2) By checking design implications on different projects.

4.2 By taking observation for same span with both technologies

At the project of Trimbak-Ghoti, first LiDAR survey is carried out for the span of 2 kms. Then by using total station topographic survey is carried out on same span. Here same control points were used for both types of surveys. In this process final output survey data in AutoCAD format is focused considering centerline evaluated X, Y and Z co-ordinates by both the methods for the chainages at uniform intervals of 20 meters. Again horizontal and vertical distance between both the centerlines also measured at 20 m interval.
Plan and profile is plotted for the better visualization of horizontal and vertical difference of centerline. Plan and profile are as follows.

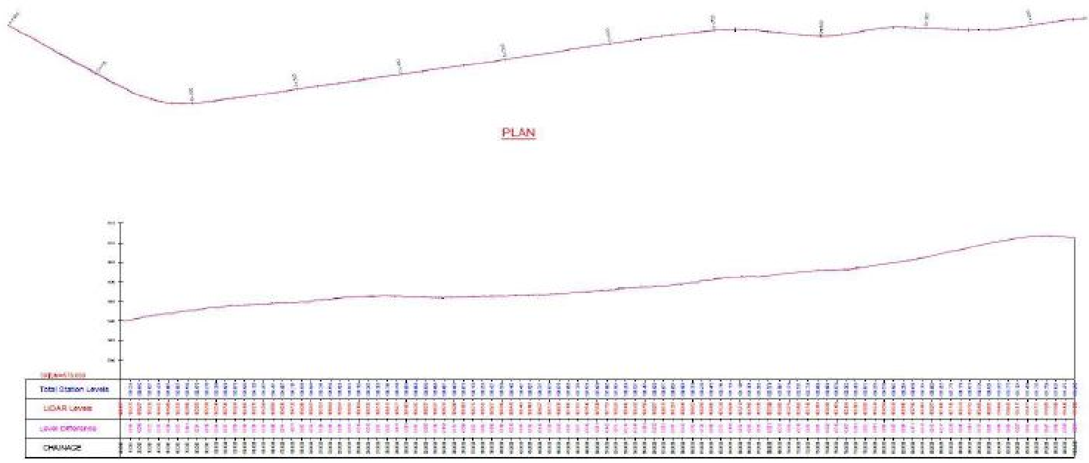


Figure 4.4: chainage 0+000 to 1+000

Figure 4.5: chainage 1+000 to 2+000

In figure 4.4 and 4.5, it is plan and profile of ceterlines by both the methods. Here, blue line indicates centerline occured by Total Station and red line indicates centerline occured by LiDAR. From AutoCAD drawing and plan and profile X, Y and Z co-ordinates are evaluated.

Table 4.1: X,Y, Z readings with different speeds

Avg.speed in kmph	Chainage	Total Station			LiDAR		
		X	Y	Z	X	Y	Z
30	20	355124.69	2183025.30	590.64	355124.74	2183025.27	590.59
	40	355135.23	2183008.32	591.43	355135.30	2183008.27	591.54
	60	355145.19	2182990.93	592.01	355145.89	2182991.32	592.32
	80	355155.63	2182973.87	592.67	355156.45	2182974.40	592.95
	100	355166.37	2182957.01	593.30	355167.01	2182957.41	593.54
20	120	355177.11	2182940.13	593.88	355177.60	2182940.46	593.93
	140	355188.48	2182923.69	594.12	355188.84	2182923.77	594.28
	160	355201.28	2182908.37	594.44	355201.41	2182908.49	594.50
	180	355217.19	2182896.37	594.79	355217.00	2182896.08	594.72
	200	355235.19	2182887.89	594.94	355235.22	2182887.97	595.27
40	220	355254.20	2182881.70	595.52	355254.33	2182882.15	595.68
	240	355273.47	2182876.35	596.02	355273.61	2182876.86	596.00
	260	355292.86	2182871.42	596.36	355292.93	2182871.69	596.32
	280	355312.26	2182866.57	596.36	355312.25	2182866.55	596.41
	300	355331.66	2182861.62	596.08	355331.67	2182861.74	596.08
	320	355350.98	2182856.54	596.04	355351.06	2182856.82	596.04
	340	355370.29	2182851.34	596.07	355370.42	2182851.83	595.91
	360	355389.63	2182846.22	596.07	355389.77	2182846.61	596.06
	380	355408.97	2182841.13	596.25	355409.10	2182841.61	596.33
	400	355428.30	2182836.01	596.24	355428.40	2182836.39	596.40
	420	355447.64	2182830.92	596.46	355447.73	2182831.25	596.46
	440	355466.97	2182825.79	596.74	355467.04	2182826.04	596.63
	460	355486.30	2182820.65	596.88	355486.37	2182820.90	596.84
	480	355505.64	2182815.55	597.33	355505.71	2182815.80	597.36
	500	355525.02	2182810.62	597.63	355525.04	2182810.68	597.64
	520	355544.43	2182805.78	597.95	355544.40	2182805.65	598.03
	540	355563.81	2182800.86	598.54	355563.80	2182800.78	598.29
	560	355583.23	2182796.04	598.83	355583.22	2182796.01	598.60
	580	355602.63	2182791.19	599.03	355602.61	2182791.13	599.23
	600	355621.97	2182786.10	599.71	355621.98	2182786.14	599.95
	620	355641.31	2182781.01	600.47	355641.32	2182781.05	600.47
	640	355660.68	2182776.05	601.13	355660.64	2182775.89	600.94
	660	355679.95	2182770.67	601.31	355679.91	2182770.54	601.36
	680	355699.16	2182765.12	601.57	355699.09	2182764.88	601.59
	700	355718.14	2182758.84	602.28	355718.16	2182758.91	602.28

Avg. speed in kmph	Chainage	Total Station			LiDAR		
		X	Y	Z	X	Y	Z
35	720	355736.63	2182751.27	602.73	355736.88	2182751.80	602.75
	740	355754.49	2182742.29	603.06	355754.61	2182742.50	603.01
	760	355771.51	2182731.80	603.30	355771.68	2182732.06	603.19
	780	355788.38	2182721.05	603.67	355788.46	2182721.98	603.69
	800	355805.96	2182711.59	604.52	355805.68	2182710.98	604.60
	820	355824.75	2182704.98	605.29	355824.66	2182704.56	605.36
	840	355844.24	2182700.48	606.10	355844.20	2182700.31	606.09
	860	355863.58	2182695.40	607.20	355863.59	2182695.43	607.19
	880	355881.96	2182681.61	608.18	355882.10	2182681.89	608.22
	900	355899.75	2182678.49	609.22	355899.80	2182678.57	609.40
	920	355917.50	2182669.28	610.34	355917.50	2182669.28	610.40
	940	355935.21	2182660.11	611.12	355935.31	2182660.18	611.12
	960	355953.44	2182651.78	611.71	355953.36	2182651.53	611.73
	980	355972.47	2182645.63	611.62	355972.30	2182645.05	611.67
	1000	355991.75	2182640.37	611.25	355991.70	2182640.13	611.10
40	1020	356011.10	2182635.30	610.36	356011.16	2182635.20	610.45
	1040	356030.29	2182629.68	609.13	356030.40	2182629.83	609.12
	1060	356048.96	2182622.56	607.90	356049.32	2182623.61	606.98
	1080	356068.33	2182617.55	606.81	356068.41	2182617.89	606.98
	1100	356087.60	2182612.22	606.15	356087.66	2182612.39	606.10
35	1120	356106.49	2182605.69	604.79	356106.60	2182605.97	604.77
	1140	356123.98	2182596.13	603.97	356125.07	2182597.71	603.89
	1160	356140.79	2182585.29	603.27	356140.96	2182585.55	603.20
	1180	356157.27	2182573.88	601.95	356157.06	2182573.04	602.29
	1200	356174.59	2182564.04	601.22	356174.46	2182563.78	601.39
40	1220	356192.79	2182555.79	600.44	356192.76	2182555.73	600.49
	1240	356211.37	2182548.39	599.36	356211.39	2182548.44	599.95
	1260	356229.93	2182540.93	598.52	356229.91	2182540.89	598.53
	1280	356248.49	2182533.50	597.54	356248.49	2182533.49	597.78
	1300	356267.06	2182526.07	596.85	356267.00	2182525.91	596.92
	1320	356285.58	2182518.51	596.32	356285.50	2182518.32	596.31
	1340	356304.05	2182510.84	595.75	356303.99	2182510.69	595.82
	1360	356322.52	2182503.17	595.54	356322.53	2182503.19	595.50
	1380	356341.01	2182495.56	595.46	356340.98	2182495.48	595.55
	1400	356359.41	2182487.72	595.10	356359.42	2182487.74	595.60
	1420	356377.84	2182479.95	595.66	356377.90	2182480.09	595.74

Avg. speed in kmph	Chainage	Total Station			LiDAR		
		X	Y	Z	X	Y	Z
40	1440	356396.31	2182472.26	595.90	356396.40	2182472.50	595.90
	1460	356414.84	2182464.99	595.80	356414.96	2182465.05	596.03
	1480	356433.32	2182457.11	595.78	356433.46	2182457.43	595.96
	1500	356452.01	2182449.98	595.00	356452.05	2182450.09	595.32
20	1520	356470.57	2182442.53	594.50	356470.75	2182442.99	594.68
	1540	356488.60	2182433.98	593.61	356488.72	2182434.16	593.56
	1560	356502.67	2182419.95	592.84	356503.17	2182420.29	592.87
	1580	356512.30	2182402.45	592.56	356512.89	2182402.76	592.72
	1600	356520.17	2182384.11	592.42	356520.33	2182384.17	592.74
40	1620	356526.72	2182365.21	592.31	356526.77	2182365.23	592.81
	1640	356532.89	2182346.19	592.68	356532.81	2182346.16	592.88
	1660	356538.95	2182327.13	592.79	356539.03	2182327.15	592.81
	1680	356545.16	2182308.12	592.25	356545.31	2182308.17	592.47
	1700	356551.50	2182289.15	591.79	356551.51	2182289.15	592.03
	1720	356557.92	2182270.21	591.28	356558.00	2182270.23	591.49
	1740	356564.37	2182251.27	590.83	356564.25	2182251.54	591.07
	1760	356570.81	2182232.34	590.83	356570.55	2182232.25	590.62
	1780	356576.83	2182213.27	590.06	356576.81	2182213.26	590.09
	1800	356583.19	2182194.31	589.33	356583.06	2182194.26	589.47
	1820	356589.52	2182175.34	588.50	356589.47	2182175.32	588.66
	1840	356595.75	2182156.33	587.42	356595.77	2182156.34	587.73
	1860	356601.95	2182137.32	586.81	356602.02	2182137.34	586.80
	1880	356608.09	2182118.28	585.82	356608.13	2182118.29	586.10
	1900	356614.23	2182099.25	585.08	356614.25	2182099.26	585.34
	1920	356620.45	2182080.24	584.31	356620.55	2182080.27	584.46
	1940	356626.84	2182061.29	583.41	356626.85	2182061.30	583.58
	1960	356633.45	2182042.41	582.64	356633.30	2182042.44	582.71
	1980	356639.87	2182023.47	581.75	356639.78	2182023.44	582.05
	2000	356646.26	2182004.52	581.40	356646.30	2182004.53	581.50

In table 4.1, with respect to speed total span is divided in different cases. Each case gives different results in terms of difference in both the readings. Results varies with speed at which vehicle was driven. The main intension was to drive vehicle at speed nearby 40-45 kmph. The description and results in each and every case are as follows-

Case A. Chainage 0+000 to 0+100(30 kmph)

Table 4.2: Case A

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
30	0+020	0.0483	0.03	0.055
	0+040	0.0755	0.0471	0.117
	0+060	0.7045	0.3963	0.315
	0+080	0.8169	0.5234	0.283
	0+100	0.6339	0.3999	0.244
Average Difference		0.45582	0.27934	0.2028

Sample Calculations:-

$$\text{Speed of vehicle}=\frac{Distance}{Time}$$

$$. \qquad 29.78=\frac{100}{3.33}$$

From Table 4.2, it is observed that survey started from chainage 0+000 and intension was to drive vehicle upto the speed of 40 kmph. From initial stage upto 100 meters the average speed of vehicle was 30 kmph due to the raising grdient. Within this span maximum average difference in X reading was found among all the cases and here second highest mean difference was observed.

Case B. Chainage 0+100 to 0+200(20 kmph)

Table 4.3: Case B

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
22	0+120	0.4963	0.3293	0.0580
	0+140	0.3610	0.0731	0.1580
	0+160	0.1296	0.1194	0.0660
	0+180	0.1871	0.2921	0.0710
	0+200	0.0264	0.0767	0.3230
Average Difference		0.2401	0.1781	0.1352

In table 4.3, data taken at the horizontal curve. Due to presence of horizontal curve average speed was reduced to 22 kmph. This slow speed resulted in very dense point clouds with X, Y and Z values, that makes processing quite difficult.

Case C. Chainage 0+200 to 0+700(40 kmph)

Table 4.4: Case C

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
40	0+220	0.1273	0.4531	0.165
	0+240	0.1301	0.5104	0.022
	0+260	0.0708	0.2793	0.043
	0+280	0.0047	0.0196	0.052
	0+300	0.0112	0.117	0.001
	0+320	0.075	0.2782	0.003
	0+340	0.1224	0.488	0.154
	0+360	0.1395	0.3885	0.009
	0+380	0.1253	0.4773	0.082
	0+400	0.1026	0.3851	0.161
	0+420	0.0884	0.3331	0.004
	0+440	0.0676	0.2537	0.11
	0+460	0.0672	0.2523	0.042
	0+480	0.0671	0.255	0.027
	0+500	0.0147	0.0594	0.011
	0+520	0.032	0.1257	0.074
	0+540	0.018	0.0732	0.244
	0+560	0.0073	0.0297	0.232
	0+580	0.016	0.064	0.197
	0+600	0.0105	0.0388	0.243
	0+620	0.0109	0.0399	0
	0+640	0.0448	0.1605	0.192
	0+660	0.0354	0.1288	0.053
	0+700	0.0245	0.0677	0.003
Average Difference		0.059256	0.22052	0.08576

In table 4.4, there was a continuous and long span with almost constant speed of 40 kmph. In this case, quite less difference observed between TS and LiDAR survey.

Case D. Chainage 0+700 to 1+000(35 kmph)

Table 4.5: Case D

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
35	0+720	0.2556	0.5271	0.018
	0+740	0.1284	0.2089	0.053
	0+760	0.1637	0.2643	0.108
	0+780	0.0816	0.9306	0.013
	0+800	0.2802	0.6085	0.086
	0+820	0.0962	0.4228	0.066
	0+840	0.0452	0.1729	0.013
	0+860	0.008	0.0291	0.017
	0+880	0.1399	0.2727	0.046
	0+900	0.0436	0.0828	0.179
	0+920	0	0	0.069
	0+940	0.0952	0.07	0.007
	0+960	0.0849	0.2481	0.014
	0+980	0.173	0.5779	0.048
	1+000	0.0466	0.2406	0.145
Average Difference		0.109473	0.31042	0.0588

In table 4.4, due to some small radius of horizontal curves the average speed reduced from 40 kmph to 35 kmph. Within this studied span point on which X and Y had zero difference in its readings at chainage 0+920 with negligible elevation difference of 69mm. Within this span found minimum average difference in elevation.

Case E. Chainage 1+000 to 1+100(40 kmph)

In table 4.6, it was the span for only 100 meter in which average speed was maintained at 40 kmph. Within this shorter span of 100 m span due gradual increase in speed large difference occurred.

Table 4.6: Case E

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
40	1+020	0.0539	0.1034	0.088
	1+040	0.1077	0.1495	0.007
	1+060	0.3589	1.0528	0.917
	1+080	0.0835	0.3337	0.174
	1+100	0.0544	0.1767	0.05
Average Difference		0.13168	0.36322	0.2472

Case F. Chainage 1+100 to 1+200(35 kmph)

Table 4.7: Case F

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
35	1+120	0.1112	0.2799	0.014
	1+140	1.089	1.5757	0.076
	1+160	0.1707	0.2644	0.078
	1+180	0.2069	0.8376	0.342
	1+200	0.1317	0.2609	0.172
Average Difference		0.3419	0.6437	0.1364

In table 4.7, constant speed of 35 kmph was maintained for 100m span. Observed large difference between TS and LiDAR survey.

Case G. Chainage 1+200 to 1+500(40 kmph)

Here, it was continuous and long span with steep slope at constant speed of 40 kmph. Here less difference observed between TS and LiDAR survey. In table 4.8, close readings are observed as that of Total Station.

Table 4.8: Case G

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
40	1+220	0.0254	0.0639	0.054
	1+240	0.0199	0.0484	0.591
	1+260	0.0139	0.0347	0.008
	1+280	0.0061	0.0148	0.232
	1+300	0.0645	0.1583	0.076
	1+320	0.0793	0.1941	0.012
	1+340	0.0633	0.1541	0.068
	1+360	0.007	0.0173	0.032
	1+380	0.0302	0.0724	0.097
	1+400	0.0101	0.024	0.496
	1+420	0.0607	0.1433	0.085
	1+440	0.0964	0.2383	0.001
	1+460	0.1292	0.062	0.228
	1+480	0.1335	0.3233	0.174
	1+500	0.0428	0.1142	0.319
Average Difference		0.05215	0.11087	0.16486

Case H. Chainage 1+500 to 1+600(20 kmph)

Table 4.9: Case H

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
20	1+520	0.1842	0.4514	0.181
	1+540	0.1222	0.1879	0.047
	1+560	0.5019	0.3371	0.023
	1+580	0.5891	0.3138	0.161
	1+600	0.1569	0.0577	0.316
Average Difference		0.31086	0.26958	0.1456

In table 4.9, due to presence of horizontal curve average speed was reduced to 20 kmph. This slow speed resulted in very dense point clouds with X, Y and Z values, that makes processing quite difficult.

Case I. Chainage 1+600 to 2+000(40 kmph)

Table 4.10: Case I

Avg. Speed in kmph	Chainage	Axis		
		X	Y	Z
40	1+620	0.0491	0.0158	0.498
	1+640	0.0799	0.0251	0.193
	1+660	0.0729	0.0238	0.02
	1+680	0.15	0.0489	0.212
	1+700	0.0125	0.0043	0.235
	1+720	0.0836	0.0272	0.203
	1+740	0.1141	0.2625	0.235
	1+760	0.2543	0.0863	0.216
	1+780	0.0291	0.0091	0.027
	1+800	0.1241	0.0426	0.14
	1+820	0.045	0.0148	0.164
	1+840	0.0266	0.0084	0.308
	1+860	0.0743	0.0241	0.011
	1+880	0.0403	0.013	0.285
	1+900	0.0214	0.007	0.259
	1+920	0.1048	0.0325	0.15
	1+940	0.0111	0.011	0.169
	1+960	0.1582	0.0264	0.07
	1+980	0.0878	0.0301	0.294
	2+000	0.0407	0.0142	0.104
Average Difference		0.07899	0.036355	0.18965

In table 4.10, it was continuous span of length 400 meter with falling gradient. Here vehicle was driven at average speed of 40 kmph. It was found that the best results came in this case.

Here nine cases were considered which differs in ground conditions and average speed of vehicle. Purpose was to determine the impact of speed of vehicle on the difference between the readings of LiDAR and TS.

Table 4.11: Casewise average difference

Case	Chainage	Length in m	Avg. Speed in kmph	Difference			
				X	Y	Z	Average
A	0+000 to 0+100	100	30	0.456	0.279	0.203	0.3127
B	0+100 to 0+200	100	22	0.240	0.178	0.135	0.1845
C	0+200 to 0+700	500	40	0.059	0.221	0.086	0.1218
D	0+700 to 1+000	300	35	0.109	0.31	0.059	0.1596
E	1+000 to 1+100	100	40	0.132	0.363	0.247	0.2474
F	1+100 to 1+200	100	35	0.342	0.644	0.136	0.374
G	1+200 to 1+500	300	40	0.052	0.111	0.165	0.1093
H	1+500 to 1+600	100	20	0.311	0.27	0.146	0.242
I	1+600 to 2+000	400	40	0.079	0.036	0.19	0.1017
Minimum Difference				0.052	0.036	0.059	0.1017
Maximum Difference				0.456	0.644	0.247	0.374

In table 4.11, results of all the nine cases explained earlier are summarized averages of X, Y and Z readings are taken from each case. Observed minimum average difference was from case I where vehicle was driven at approximate speed of 40 kmph for span of 400 meters which are supposed to be closest result to the total station readings among all nine considered cases and maximum average difference observed from case F, where vehicle was driven at approximate speed of 35 kmph for the span of 100 meters.

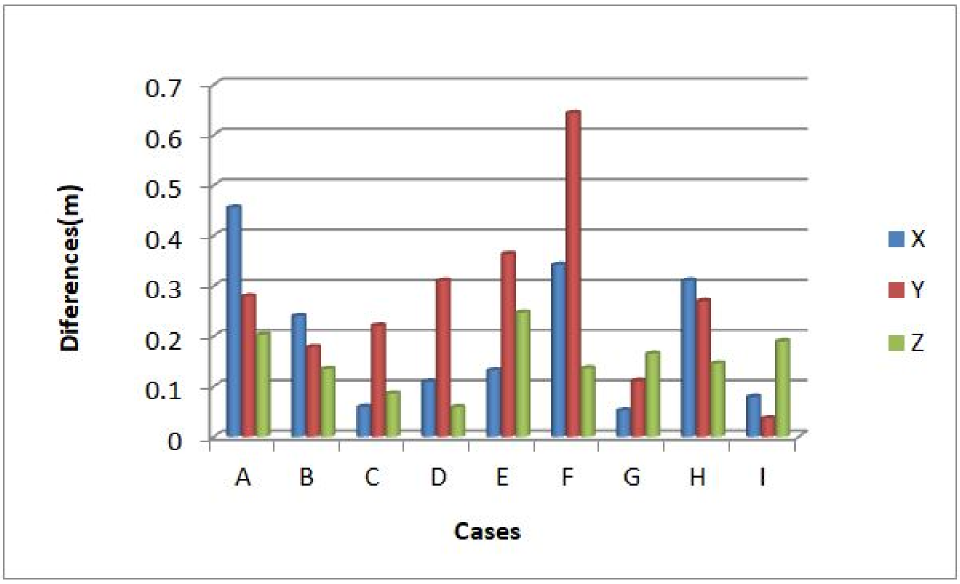


Figure 4.6: Comparison of average differences in different cases

Figure 4.6 is a graphical representation of table 4.11, in which X, Y and Z differences for different cases are shown. Here it can be seen that, high speed and large span results close readings as that of Toatal Station.

Table 4.12: Average differences with respect to speed

Speed Range	Length(m)	X	Y	Z	Avg.
20-25	200	0.2755	0.2238	0.1404	0.213
30-35	500	0.3024	0.4112	0.2243	0.313
40	1300	0.0805	0.1827	0.1719	0.145

In table 4.12, all the spans of different speed added to find average differences with respect to speed. Here it is observed that, high speed for short span gives closer readings with Total Station than that of high speed for short span or low speed for short span.

4.3 By checking design implications on different projects

Here, results from the plan and profile of two projects was compared. Final output of OGL(Original Ground Level) readings for different terrain conditions and structures involved in project studied. Case studies are taken on two different road projects as follows:-
1) AU115-Patonda to Basamba(Hingoli District)
2) NSK 70A-Karjat to Bhigwan Road(Ahmadnagar District)
From these projects different terrain conditions, curves and structures are considered. conditions considered here are as follows,

A. Plain Terrain

Table 4.13: Plain Terrain

Project	Chainage	LiDAR	Total Station	Avg. Diff	Datum diff	Actual diff
AU 115	39+460	471.606	477.979	6.373	5	1.373
	39+480	471.849	478.245	6.396	5	1.396
	39+500	472.064	478.442	6.378	5	1.378
	39+520	472.263	478.645	6.382	5	1.382
	39+540	472.376	478.735	6.359	5	1.359
	39+560	472.542	478.889	6.347	5	1.347
	39+580	472.68	479.048	6.368	5	1.368
	39+600	472.735	479.033	6.298	5	1.298
	39+620	472.693	478.98	6.287	5	1.287
	39+640	472.605	478.881	6.276	5	1.276
	39+660	472.409	478.649	6.24	5	1.24
	39+680	472	478.225	6.225	5	1.225
	39+700	471.636	477.907	6.271	5	1.271
	39+720	471.408	477.695	6.287	5	1.287
	39+740	471.241	477.54	6.299	5	1.299
	39+760	471.218	477.595	6.377	5	1.377
	39+780	471.398	477.784	6.386	5	1.386
	39+800	471.536	477.911	6.375	5	1.375
	39+820	471.628	477.915	6.287	5	1.287
	39+840	471.528	477.914	6.386	5	1.386
NSK 70A	95+360	593.138	597.383	4.245	5.5	1.255
	95+380	593.082	597.334	4.252	5.5	1.248
	95+400	592.994	597.291	4.297	5.5	1.203
	95+420	592.942	597.195	4.253	5.5	1.247
	95+440	592.786	597.152	4.366	5.5	1.134
	95+460	592.578	597.041	4.463	5.5	1.037
	95+480	592.489	597.003	4.514	5.5	0.986
	95+500	592.543	597.245	4.702	5.5	0.798
	95+520	592.559	596.963	4.404	5.5	1.096
	95+540	592.576	597.02	4.444	5.5	1.056
	95+560	592.552	597.007	4.455	5.5	1.045
	95+580	592.541	596.908	4.367	5.5	1.133
	95+600	592.538	596.955	4.417	5.5	1.083
	95+620	592.548	596.079	3.531	5.5	1.969
	95+640	592.49	596.815	4.325	5.5	1.175
	95+660	592.498	596.888	4.39	5.5	1.11
	95+680	592.649	597.109	4.46	5.5	1.04

In table 4.13, for plain terrain very less difference is observed. For project AU 115 the observed average difference was 1.32985 and for NSK 70A the average difference was 1.1504444.

B. Steep Slope

Table 4.14: Steep Slope

Project	Chainages	LiDAR	Total Station	Avg. Diff	Datum diff	Actual diff
AU 115	32+560	473.199	481.239	8.04	5	3.04
	32+580	474.509	481.787	7.278	5	2.278
	32+600	474.925	482.512	7.587	5	2.587
	32+620	475.397	483.338	7.941	5	2.941
	32+640	475.999	484.378	8.379	5	3.379
	32+660	476.777	485.797	9.02	5	4.02
	32+680	477.788	487.732	9.944	5	4.944
	32+700	479.019	489.45	10.431	5	5.431
	32+720	480.809	490.857	10.048	5	5.048
	32+740	482.709	492.075	9.366	5	4.366
	32+760	484.243	493.193	8.95	5	3.95
	32+780	485.499	494.332	8.833	5	3.833
	32+800	486.647	496.397	9.75	5	4.75
	32+820	487.741	496.332	8.591	5	3.591
	32+840	488.871	497.438	8.567	5	3.567
	32+860	489.848	498.87	9.022	5	4.022
	32+880	490.849	500.575	9.726	5	4.726
	32+900	492.141	502.466	10.325	5	5.325
	32+920	493.723	504.312	10.589	5	5.589
	32+940	495.549	506.337	10.788	5	5.788
NSK 70A	107+060	569.175	573.527	4.352	5.5	1.148
	107+080	568.674	572.983	4.309	5.5	1.191
	107+100	567.769	572.138	4.369	5.5	1.131
	107+120	567.023	571.397	4.374	5.5	1.126
	107+140	566.519	570.785	4.266	5.5	1.234
	107+160	565.771	570.136	4.365	5.5	1.135
	107+180	565.093	569.422	4.329	5.5	1.171
	107+200	564.263	568.594	4.331	5.5	1.169
	107+220	563.416	567.722	4.306	5.5	1.194
	107+240	562.674	566.975	4.301	5.5	1.199
	107+260	562.059	566.33	4.271	5.5	1.229
	107+280	561.489	565.745	4.256	5.5	1.244
	107+300	560.795	564.938	4.143	5.5	1.357
	107+320	560.058	564.404	4.346	5.5	1.154

In table 4.14, very large difference is observed in steep slope condition. At AU 115 it was a ghat section with steep slope therefore, consistent huge difference observed at this project. At project NSK 70A is 1.1928 m and at project AU 115 the average difference was 4.255762 m which is considerably huge.

C. Horizontal Curve

Table 4.15: Horizontal Curve

Project	Chainages	LiDAR	Total Station	Avg. Diff	Datum diff	Actual diff
AU 115	29+200	508.897	514.727	5.83	5	0.83
	29+220	508.691	514.96	6.269	5	1.269
	29+240	508.255	515.066	6.811	5	1.811
	29+260	507.603	515.255	7.652	5	2.652
	29+280	507.307	515.503	8.196	5	3.196
	29+300	508.007	515.492	7.485	5	2.485
	29+320	508.507	515.125	6.618	5	1.618
	29+340	509.135	514.676	5.541	5	0.541
	29+360	509.388	514.107	4.719	5	0.281
	29+380	509.468	513.297	3.829	5	1.171
	29+400	509.055	512.076	3.021	5	1.979
NSK 70A	124+300	512.555	517.079	4.524	5.5	0.976
	124+320	512.834	517.271	4.437	5.5	1.063
	124+340	513.058	517.411	4.353	5.5	1.147
	124+360	513.41	517.737	4.327	5.5	1.173
	124+380	513.759	518.136	4.377	5.5	1.123
	124+400	513.877	518.394	4.517	5.5	0.983

In table 4.15, at the center point of arc highest disturbance in observed for both the project.

D. Vertical curve

Table 4.16: Vertical Summit Curve

Project	Chainages	LiDAR	Total Station	Avg. Diff	Datum diff	Actual diff
AU 115	29+620	504.295	510.928	6.633	5	1.633
	29+640	504.67	512.128	7.458	5	2.458
	29+660	505.896	513.036	7.14	5	2.14
	29+680	507.059	512.689	5.63	5	0.63
	29+700	506.71	511.501	4.791	5	0.209
	29+720	505.414	510.017	4.603	5	0.397
	29+740	504.095	509.24	5.145	5	0.145
NSK 70A	100+480	575.776	580.223	4.447	5.5	1.053
	100+500	575.844	580.279	4.435	5.5	1.065
	100+520	575.95	580.334	4.384	5.5	1.116
	100+540	575.86	580.279	4.419	5.5	1.081
	100+560	575.644	580.071	4.427	5.5	1.073
	100+580	575.436	579.905	4.469	5.5	1.031

Table 4.17: Vertical Valley Curve

Project	Chainages	LiDAR	Total Station	Avg. Diff	Datum diff	Actual diff
AU 115	31+780	469.178	474.35	5.172	5	0.172
	31+800	468.605	474.309	5.704	5	0.704
	31+820	468.326	474.101	5.775	5	0.775
	31+840	468.21	474.225	6.015	5	1.015
	31+860	468.177	474.92	6.743	5	1.743
	31+880	467.974	475.33	7.356	5	2.356
	31+900	468.201	475.589	7.388	5	2.388
	31+920	468.771	475.79	7.019	5	2.019
NSK 70A	100+180	572.821	577.172	4.351	5.5	1.149
	100+200	572.774	577.147	4.373	5.5	1.127
	100+220	572.369	577.146	4.777	5.5	0.723
	100+240	572.748	577.183	4.435	5.5	1.065
	100+260	572.817	577.265	4.448	5.5	1.052

In tablee 4.16 and table 4.17, no similar behavior is observed for both the project and each type of vertical curve.

E. Junction

Table 4.18: Junction

Project	Chainages	LiDAR	Total Station	Avg. Diff	Datum diff	Actual diff
AU 115	26+000	525.889	532.365	6.476	5	1.476
	26+020	526.062	532.296	6.234	5	1.234
	26+040	526.239	532.148	5.909	5	0.909
	26+060	526.418	531.956	5.538	5	0.538
	26+080	526.408	531.79	5.382	5	0.382
	26+100	526.4	531.593	5.193	5	0.193
	26+120	526.297	531.362	5.065	5	0.065
	26+140	526.118	531.138	5.02	5	0.02
	26+160	525.892	531.174	5.282	5	0.282
	26+180	525.739	531.554	5.815	5	0.815
NSK 70A	119+340	511.398	515.846	4.448	5.5	1.052
	119+360	511.208	515.651	4.443	5.5	1.057
	119+380	511.069	515.505	4.436	5.5	1.064
	119+400	510.875	515.451	4.576	5.5	0.924

In table 4.18 it is observed that, with different barriers at some chainages extremely good and bad results occurred in case of difference between LiDAR and Total station readings.

F. Major Bridges

Table 4.19: Major Bridges

Project	Chainages	LiDAR	Total Station	Avg. Diff	Datum diff	Actual diff
AU 115	45+380	443.744	450.337	6.593	5	1.593
	45+400	443.775	450.343	6.568	5	1.568
	45+420	443.78	450.352	6.572	5	1.572
	45+440	443.784	450.348	6.564	5	1.564
	45+460	443.772	450.373	6.601	5	1.601
NSK 70A	119+880	503.884	508.528	4.644	5.5	0.856
	119+900	503.795	507.979	4.184	5.5	1.316
	119+920	503.702	508.066	4.364	5.5	1.136
	119+940	503.576	508.077	4.501	5.5	0.999

In table 4.19, Major bridge is considered here as one of the case for study of survey. It is the most straight profile for both horizontal and vertical alignment. With this difference between LiDAR and Total Station for some terrains and road conditions is studied.

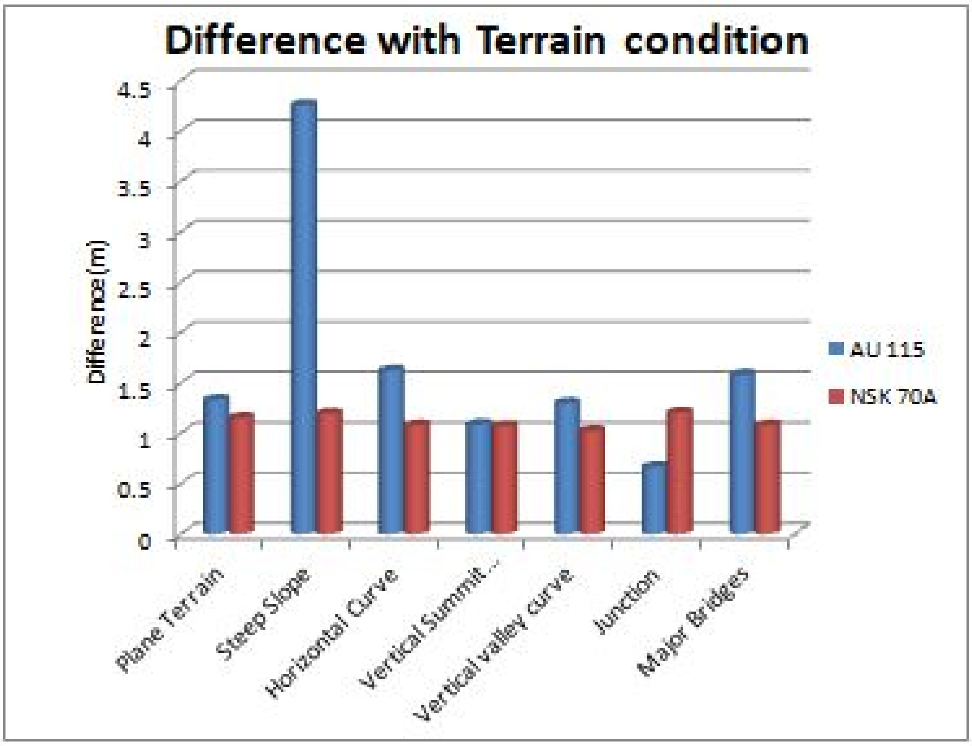


Figure 4.7: Difference with Terrain condition

In figure 4.7, average difference in differnt terrain condition is shown. In this figure, the difference at steep slope of AU115 observed considerably large by comparing other terrains. It is because it was a ghat section.

4.4 Closure

This chapter was focused on accuracy of LiDAR by considering difference between LiDAR observations and Total station observations. Three case studies considered for different projects i.e. Ghoti-Trimbak, AU115 and NSK 70A. Among these three at ghoti-trimbak actual survey was performed. For NSK 70A and AU115 plan and profile was studied. It is found that the accuracy of LiDAR changes with different conditions.

Chapter 5

COST AND TIME

5.1 Introduction

Time and cost are very important factors of project management. Without these factors feasibility study is not possible. This are the factore which decides the economy of the project. LiDAR saves tremendous time as it completes survey 70-80 kms per day and on the other hand Total station can achieve target of maximum 2-3kms. But, for LiDAR initial investment is almost 30 times greater than that of Total Station.

5.2 Important Facts

• According to leica officials LiDAR technology is only feasible for any organization only if they can have continuous frequency of projects of more than at least 250kms otherwise the instrument can become white elephant.
• Initial cost of latest and most accurate LiDAR system is 3,50,00,000 INR.
• Operation cost LiDAR vendors charges approximately 25,000/km. LiDAR is made compulsory for NH DPR project.
• Skilled office staff is required because to give final output of survey first LiDAR data comes in size as 1km=1GB.
• GIS professionals are very important for processing of data.
• On site there is very few requirement of manpower as compared to TS survey.

5.3 Return on Investment

It is the very essential factor for every project. Productivity and profitability of an investment is decided by ROI.

Mobile LiDAR Technology with higher Return Of Investment (ROI) :

- ROI with the Mobile LiDAR Technology for 1000 Km :
- Cost of the System in Rs = 3,50,00,000/-
- (Pegasus Hardware & Software)
- Returns Generated in Rs = 2,50,00,000/-
- (Assuming rate of Rs 25,000/- per Km)
- Actual Expenses for execution in Rs = 1,50,00,000/-
- Net Returns in the above = Rs 1,00,00,000/-
- Number of days required = 26 days (13 + 13).
- (Assuming average survey of 75 Km / day)
- Profit or Return per day = Rs 4,34,783/-
- Profit or Return in 85 days = Rs 3,69,56,555/-
- **ROI** = 3,69,56,555 / 3,50,00,000 x 100 = **105 %**
- i.e. The cost of the LiDAR system is already recovered in 85 days of continuous work in different projects & thereby achieving more work experience & three times the turnover compared to Total Stations.

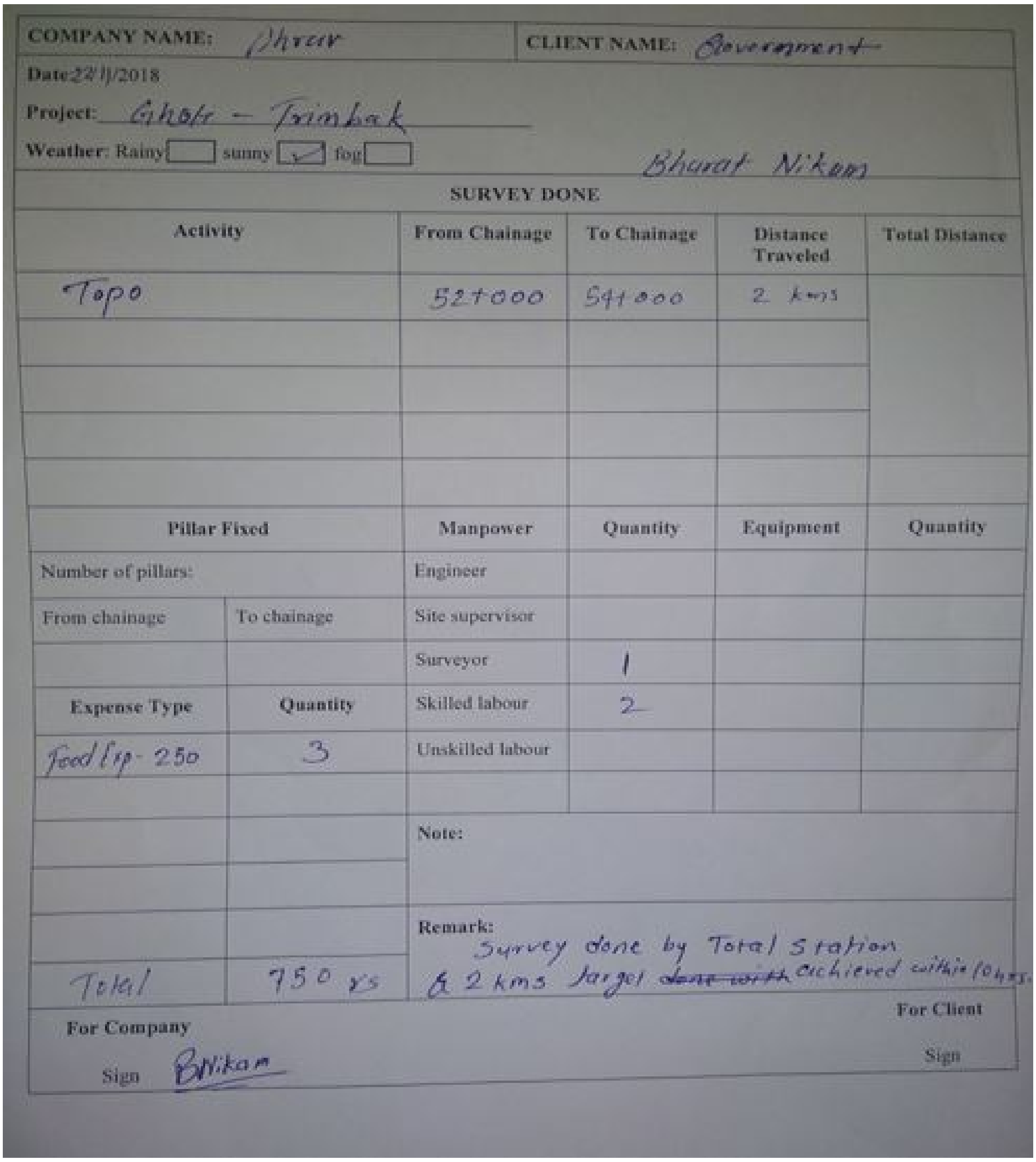
- ROI with the primitive Total Station for 1000 Km :
- Cost of the Total Station in Rs = 70,00,000/-
- (10 Total Station Hardware & Software)
- Returns Generated in Rs = 2,00,00,000/-
- (Assuming rate of Rs 20,000/- per Km)
- Actual Expenses for execution in Rs = 1,60,00,000/-
- Net Returns in the above = Rs 40,00,000/-
- Number of days required = 85 days (80 + 5).
- (Assuming average survey of 1.25 Km / day x 10 TS)
- Profit or Return per day = Rs 47,058/-
- Profit or Return in 85 days = Rs 40,00,000/-
- **ROI** = 40,00,000 / 70,00,000 x 100 = **57 %**
- i.e. The cost of the Total Stations is just 57 % recovered in 85 days of continuous work in one project only thereby achieving lesser work experience and three times lesser turnover compared to LiDAR.

Figure 5.1: Return on Investment of LiDAR vs Total station

In figure 5.1, Return on investment is shown from the vendor's point of view. LiDAR is giving return on investment as 105% and on the other hand 10 total station compared giving return on investment of 57%. Again from clients point of view it seems a better deal. It takes only 5000 INR more for the LiDAR survey than TS with saving of tremendous time which will result in benefits. Another advantage of LiDAR is negligible human error. While working with total station some errors takes place which comes in consideration at the time plan and profile. These errors takes two to three days to get fixed on site. In this way LiDAR is proved to be economically viable.

5.4 Daily progress reports

For this study we have carried out the survey of 2 kms span of the project Ghoti-Trimbak with both the methods was considered. For this 2 kms per day expenses are evaluated. Daily progress report collected from site as follows-



COMPANY NAME: Dhruv | CLIENT NAME: Government

Date 22/11/2018

Project: Ghoti – Trimbak

Weather: Rainy [ ] sunny [✓] fog [ ]

Bharat Nikam

SURVEY DONE

Activity	From Chainage	To Chainage	Distance Traveled	Total Distance
Topo	52+000	54+000	2 kms	

Pillar Fixed		Manpower	Quantity	Equipment	Quantity
Number of pillars:		Engineer			
From chainage	To chainage	Site supervisor			
		Surveyor	1		
Expense Type	Quantity	Skilled labour	2		
Food Exp- 250	3	Unskilled labour			

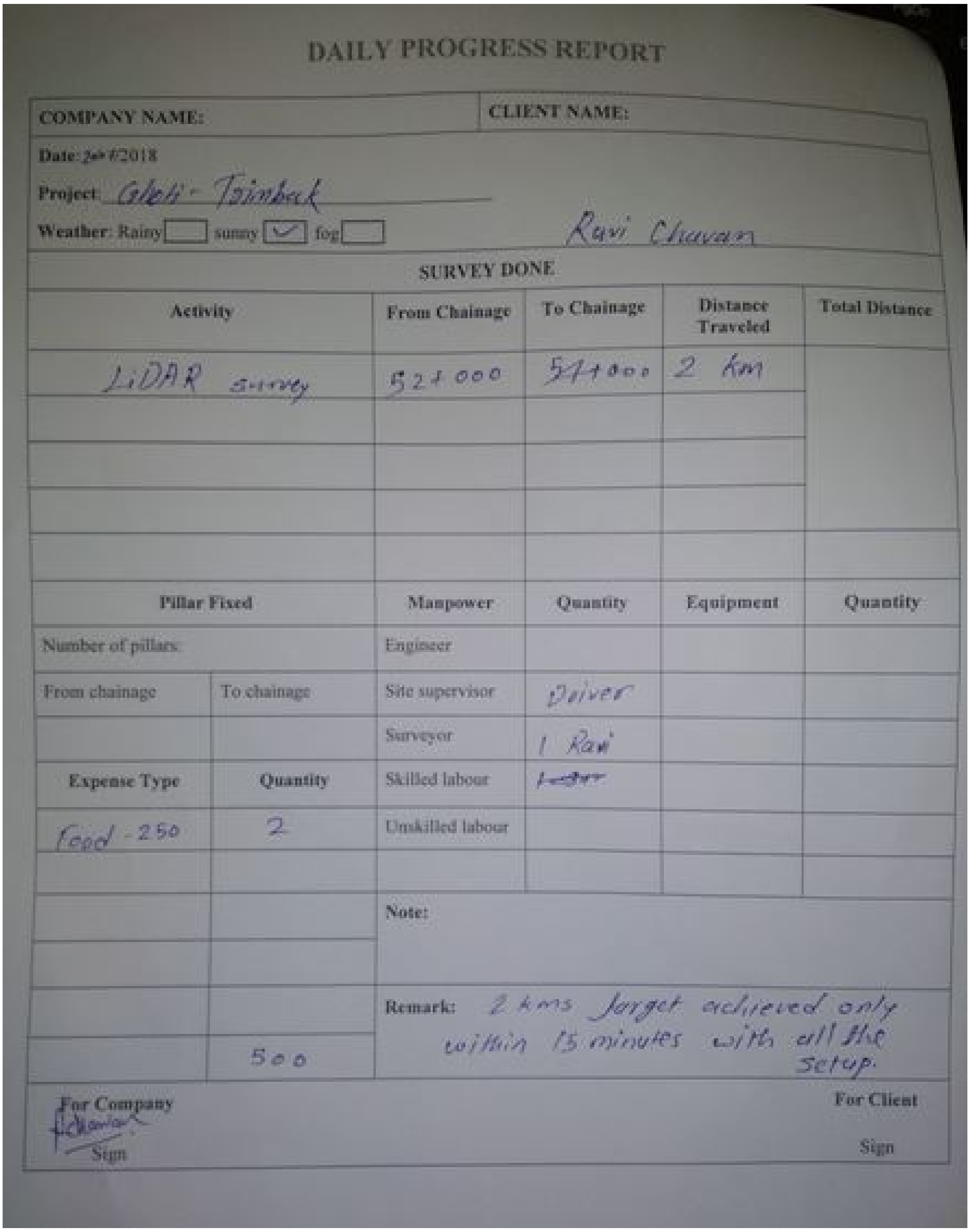
		Note:
		Remark: Survey done by Total Station & 2 kms target ~~done with~~ achieved within 10 hrs.
Total	750 rs	

For Company | For Client

Sign B.Nikam | Sign

Figure 5.2: Daily progress report with Total Station Survey

In Figure 5.2, it is DPR(Daily progress report) with Total station survey. For 2 kms of topographic survey one team of total station taken 10 working hours and this was at its best. It means with consistent efforts of 250 hours will be needed to complete the survey of 50 kms.



DAILY PROGRESS REPORT

COMPANY NAME: CLIENT NAME:

Date: [illegible]/2018

Project: Gholi - Trimbak

Weather: Rainy [ ] sunny [✓] fog [ ]

Ravi Chavan

SURVEY DONE

Activity	From Chainage	To Chainage	Distance Traveled	Total Distance
LiDAR survey	52+000	54+000	2 km	

Pillar Fixed		Manpower	Quantity	Equipment	Quantity
Number of pillars:		Engineer			
From chainage	To chainage	Site supervisor	Driver		
		Surveyor	1 Ravi		
Expense Type	Quantity	Skilled labour	~~Labor~~		
Food - 250	2	Unskilled labour			
	500				

Note:

Remark: 2 kms target achieved only within 15 minutes with all the setup.

For Company
Sign

For Client
Sign

Figure 5.3: Daily progress report with LiDAR Survey

Here, 2 kms of survey was carried out by using LiDAR. In only 15 minutes 2 kms of survey was carried out. Within a day LiDAR can complete survey of 100-150 kms.

So, LiDAR founds as less time consuming than that of Total station because it gives output on the basis of point clouds directly within the range of 5-10 kms and another main reason is the survey gets carried out with the speed of vehicle, then LiDAR will give better results if time is considered.

5.5 Closure

In the current chapter, discussion regarding the cost and time taken by both the technologies carried out. By ROI comparison and DPR(Daily Progress Report) it can be clearly concluded that for high scale projects LiDAR is always feasible.

Chapter 6

RESULTS AND DISCUSSION

6.1 Introduction

In this research, it was intended to conduct a feasibility study of LiDAR over Total Station Survey by considering Accuracy, Cost and Time as a prime factors. For accuracy two studies carried out. First was to collect actual survey data for same span with same bench marks. In this study average X, Y and difference with respect to speed was evaluated. Another study was done on the plan and profile taken for different project with different technologies. For Time and cost, information collected from surveyors, designers, engineers and some Leica executives. If there is a confirm frequency of high scale project then only LiDAR is profitable.

6.2 Feasibility study

Feasibility study is a vital part in every project. Feasibility study further affects on the decision making. Important factors involved in feasibility study are cost, time , quality, functionality, applicability and productivity. There are four types of feasibility study considered for this research.

6.2.1 Technical Feasibility

Technical feasibility is related with the technological aspects of the project. The industrial possessions may assemble capability. Based on the results it decides whether the technical team is able to convert the idea into real [8].

As Total Station in more accurate than LiDAR it adds certain advantage in account of Total station. But, LiDAR provides the detailed results, which excels in relative accuracy due to close point clouds. Another factor is probability of errors. In total station there is a great probability of errors because of more involvement of manpower. On the other hand, In actual operation LiDAR is not having so much manpower involved. So, in the execution stage LiDAR does not give much more error. But, accuracy is dependent on the processing of raw data. It affects on accuracy of LiDAR. So, here in case of total station there is more probability error. In technical feasibility LiDAR found as better.

6.2.2 Economic Feasibility

Before the start of any project economic feasibility study carried out by considering initial cost, operation cost and all other kind of expenditure. This study also improves project reliability [9]. It is also helpful for the decision-makers to decide the planned scheme processed latter or now, depending financial condition of the organization [10]. This evaluation process also studies the price benefits of the proposed scheme.
As cost comparison and return on investment is studied earlier. So, here LiDAR seems economically feasible.

6.2.3 Operational Feasibility

Operational Feasibility may employ the responsibility to examine and also decide whether the proposed methods fulfill all kind of business requirements [11]. It actions forecast all possible schemes to recognized and resolves troubles [12]. This studies may also examine and verify how the project planed guarantee the method development is feasible or not.
LiDAR is less accurate than Total station. But, LiDAR survey is currently being done for different highway projects. It highly recommended as a less time consuming alternative for Total station.

6.2.4 Schedule Feasibility

A very significant part of feasibility study is scheduling Feasibility. It is also play an important roles to complete the project in its schedule time [17]. Project some time not be unsuccessful if it is not finished in its bounded time frame. Here we may predict the time requirement to complete various task of the entire project. Disturbance of schedule is very common problem in Total station because of human and instrumental error and climatic conditions. But, probability for disturbance of schedule is very less in case of LiDAR.

6.3 Closure

In this chapter, the results of different studies were discussed. Feasibility study is carried out by considering operational, technical and economic feasibility. LiDAR founds feasible in all types of feasibility.

Chapter 7

CONCLUSION

7.1 Introduction

The chapter comprises of the conclusions which are obtained after the comparative analysis of LiDAR and Total Station and the discussion of the results ocurred with different studies.

7.2 Conclusion

1. From data collection of LiDAR and conversation with technocrats involved in survey projects it is clear that their is considerable difference between the accuracy evaluated during project and accuracy evaluated in ideal conditions.
2. LiDAR is less time consuming than that of Total Station. Initial investment of LiDAR is 30 times more than Total station, but it can generate more return on investment with frequant projects. Total station is more accurate than LiDAR but in relative accuracy LiDAR gives better results and less errors.
3. By studying output data of both the technologies it can be concluded that LiDAR gives results close to Total station with constant speed and long span with less barriers. LiDAR gives better results on flat surfaces.
4. LiDAR is observed as feasible method in all four types of feasibility.

7.3 Future scope

1. The focus of this research was only on output data from both the technologies, the reserch can be made on the improvement of processes involved in survey

like execution, data joining and data processing.

2. There must be some guidelines to be proposed for the LiDAR survey to get better results.

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[1] Anilkumar R. Jetti, D. S. Patil, "Feasibility Study of LiDAR over Total Station for Topographic survey of road projects", *International Journal of Science Technology and Management*, Vol. 8, Issue:7, 2319-8354, July 2019.

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