DETERMINATION OF PRECISE GEODETIC COORDINATE USING GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) PRECISE POINT POSITIONING METHOD

FAUZIAH BINTI ABDUL RASHID

A project submitted
in fulfill of requirements for the award
of the degree of Master of Science (Geomatic Engineering)

Faculty of Geoinformation and Real Estate
Universiti Teknologi Malaysia

JUNE 2015

This thesis dedicated to my parents,
Mr Abdul Rashid bin Muhammad and Mrs Ramlah binti Mohd Ali.
My lovely husbend Mr Zulkeffli bin Kasmani,
My lovely kids Nurin Sabihah bt Zulkeffli, Izzati Khairina bt Zulkeffli,
Muhammad Hariz Syahmi bin Zulkeffli, Muhammad Aqil bin Zulkeffli and
Muhammad Ariq bin Zulkeffli.

ACKNOWLEDGEMENTS

All praise to His prophet Muhammad S.A.W. Highest praise to Allah Almighty for His blessing that gives me the strength, confidence anbd spirit to finish this study as scheduled.

I would like to express my heartiest gratitude to my supervisor, Dr Zulkarnaini bin Mat Amin for his untiring guidance, invaluable assistance, endless encouragement and strong support throughout this project.

I wish special thanks to Department Survey and Mapping Malaysia, Geodetic Survey Division for providing and supporting all equipments and facilities required in this project. Further thanks also to Mr Soeb bin Nordin who kindly helped to guide for my research

I wish to express here my speacial thanks to my panels Prof Dr Razali Mahmud and Prof Madya Dr Zulkepli Majid, my lectures and to all my friends for giving me all necessary information for completing this project.

Last but not least, I wish to thank to my parents and my husband (Zulkeffli bin Kasmani) who also most deserving in this acknowledgement, for their unselfish and unfailing , take care, affectionate encouragement and constant prayers. To all whose names too many to be mentioned here but have rendered me their assistance in so many ways during this project. I also most sincerely acknowledge my thanks. Without the time and effort of these individuals this project would have been impossible to complete. May Allah bless all of you.

ABSTRACT

Presently the Precise Point Positioning (PPP) enables users to dual-frequency GNSS positioning at the decimetre/centimetres in kinematic mode using static and/orbit of the satellite. PPP has the ability to determine position in rural areas far from GNSS reference stations that do not have network RTK. This study aimed to examine the suitability of the PPP as an alternative to RTK network using VRS method. The existing GNSS reference station that is ARAU, GETI, CAME, KLAW, JUML and LAB1 used in this study. The selection of reference GNSS stations based on geographic distribution and weather conditions at the time. Data collection at the reference stations is the Trimble GPS 5700, Trimble NetR5 and Trimble NetR9 GNSS system. The data observed for 24 hours a day with 30 seconds interval for three consecutive days were used for this project. For the purposes of the data processing, WayPoint GrafNav 6.0 software used. Overall, the objective of this project was accomplished. Based on the analysis, the coordinate difference ±2cm for northing, and easting ±2cm also for height ±6cm. The value of accuracy are allowed as statedin the circular Department Survey and Mapping Malaysia volume 6/2009. The results from this study can be used as a benchmark to see the accuracy of Precise Point Positioning method compared to the existing VRS network correction method for cadastral and mapping purposes.

Key words: GNSS, PPP, CORS, FKP, VRS, MAC

ABSTRAK

PPP membolehkan pengguna GNSS dwi-frekuensi untuk menentukan kedudukan di peringkat decimetre/sentimeter dalam mod kinematik/statik menggunakan jam dan orbit satelit yang tepat. PPP berkeupayaan dalam penentuan kedudukan di kawasan pedalaman yang jauh daripada stesen rujukan GNSS yang tidak mempunyai jaringan RTK. Kajian ini bertujuan untuk mengkaji kesesuaian PPP sebagai alternatif kepada rangkaian RTK yang menggunakan kaedah VRS. Stesen rujukan GNSS sedia ada iaitu ARAU, GETI, CAME, KLAW, JUML and LAB1 digunakan dalam kajian ini. Pemilihan stesen rujukan GNSS berdasarkan taburan geografi dan keadaan cuaca pada masa tersebut. Pengumpulan data di stesen-stesen rujukan adalah penggunaan penerima GPS Trimble 5700 , sistem Trimble NetR5 GNSS dan Trimble NetR9 GNSS. Data yang dicerap selama 24 jam sehari dengan sela epok 30 saat selama tiga hari berturut-turut telah digunakan bagi projek ini. Bagi tujuan pemprosesan data, perisian WayPoint GrafNav6.0 digunakan. Secara keseluruhan, objektif projek ini adalah tercapai. Berdasarkan analisis, perbezaan koordinat utaraan ±2cm dan timuran ±2cm serta ketinggian ±6cm. Nilai ketepatan yang diperolehi adalah dibenarkan seperti mana yang telah di tetapkan dalam Pekeliling Jabatan Ukur dan Pemetaan Malaysia bilangan 6/2009. Hasil daripada kajian ini boleh digunakan sebagai penanda aras untuk melihat ketepatan kaedah PPP terutamanya dalam pengukuran kadaster dan pemetaan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

L1	Phase measurements on L1, GPS frequency of 1575.42 MHz
C1	Pseudorange using C/A code on L1
L2	Phase measurements on L2, GPS frequency of 1227.60 MHz
P2	Pseudorange using P-Code on L2

LIST OF ABBREVIATIONS

GPS	Global Positioning System
DGPS	Differential Global Positioning SystemSF
GNSS	Global Navigation Satellite System
VRS	Virtual Reference System
MAC	Master Auxialary Concept
RTK	Real-Time Kinematic
NRTK	Network RTK
PPP	Precise Point Positioning
CORS	Continuously Operating Reference Station (CORS)
DSMM	Department Survey and Mapping Malaysia
MyRTknet	Malaysian Real Time Kinematic Network System
SF	Single Frequency
SPS	Standard Positioning Service
DoD	Department of Defense
PRS	Publicy Regulated Services
USAf	US Air Force
OTF	On-the-fly
RTCM	Radio Technical Commision for Maritime Services
TEC	Total Electron Content
NGS	National Geodetic Survey
GCP	Ground Control Points
TEQC	Translating, Editing and Quality Checking
RMS	Root Mean Square

CHAPTER 1

INTRODUCTION

1.1 Background

Malaysian Real-Time Kinematic Network System (MyRTKnet) is the infrastructure that has been formed by the Global Navigation Satellite System (GNSS) reference stations and Control Centre to provide the GNSS data in order to give the position in real time. MyRTKnet service has been developed since 2003 that consist of 27 GNSS reference stations throughout the country. In endeavor to give a better service to the user, another 51 GNSS reference stations have been established by Department of Survey and Mapping Malaysia (DSMM) in 2006 until 2008 and the total number of reference stations now are 78 stations as stated in JUPEM circular volume 1/2005.

Fifty GNSS reference stations are located in Peninsular Malaysia whilst 28 stations in Sabah and Sarawak. The distance between the stations is from 30 to 150 km. The stations track GNSS signals and send them via dedicated data lines to a central network server at DSMM Geodesy Section, which manages and distributes GNSS correction data to subscribers in real time. Right now, the centimeter accuracy can be achieved to all users in Peninsular Malaysia, Kuching (Sarawak) and Kota

Kinabalu (Sabah). The user also can get the DGPS correction anywhere in Malaysia as long as the telecommunications coverage is there.

The MyRTKnet service provides the data as stated in Table 1.1. The data that have been supplied to the user comprising of real time and post-processed data depend on the objective of work. The post-processed data consist of RINEX and Virtual RINEX data. The data can be downloaded via DSMM website in interval from 0.1 to 60 seconds. In order to get a good result, user should follow the Director General Circular No. 6/2009 which can be viewed in DSMM website or summarized in Table 1.1.

Table 1.1: MyRTKnet Services

	Data Type	**Data Feature**
1	Virtual Reference Station (VRS) Correction	Real Time
2	Single Base Correction	Real Time
3	Network Base DGPS Correction	Real Time
4	Virtual RINEX Data	Post-Processed
5	RINEX Data	Post-Processed

The accuracy for Single Base correction, according to the Department Survey and Mapping Circular Volume 9/2009 , within the limits of MyRTKnet Reference Stations, an accuracy of ±1 to ±3 cm horizontally and ±3 to ±6cm vertically. For VRS Correction, the limits of MyRTKnet Dense Network, with an accuracy of ±1 to±3cm horizontally and ±3to±6cm vertically.

Until recently, GNSS is the most popular technique to determine three dimensional coordinate quickly and accurately. As reported by the European GNSS Supervisor Authority (GSA) the GNSS market has been growing enormously in the last decade (Katrin Huber, 2010). The value of the GNSS worldwide market of all applications is evaluated to be worth around 40 Billion USD in 2006 and expected to pass the 90 Billion USD by 2011. Some 3 billion satellite navigation receivers should be in service by 2020.

GNSS applications vary from transport and communication over land survey to agriculture and tourism. Nowadays the majority of GNSS users have sensors available at low prices. Normally those single frequency (SF) low-cost sensors perform single point positioning with code, which allows estimating a position with a horizontal accuracy ≤13 m and a vertical accuracy ≤22 m (GPS standard positioning service (SPS) specifications) or even better.

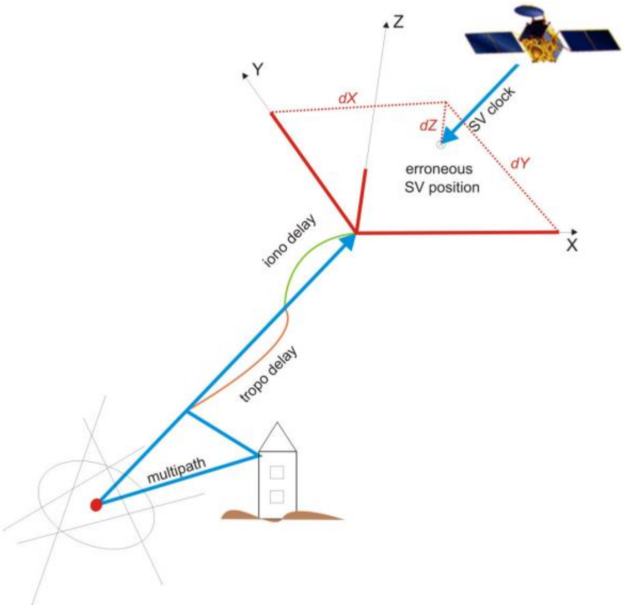

Figure 1.1 Main GNSS error sources

(Source: http://www.fig.net/resources)

The main limiting factors of GNSS positioning accuracy are errors in broadcast satellite orbits, clock errors and atmospheric influences which are in general made up of ionospheric and tropospheric refraction (Figure 1.1).

\

Precise Point Positioning (PPP) however is an enhanced single point positioning technique for code or phase measurements using precise orbits and clocks instead of broadcast data. To compensate for ionospheric effects, dual frequency measurements are used for an ionosphere free combination (see equations (1.1) and (1.2)). In the case of single frequency observations some kind of ionosphere modeling has to be applied.

The precise data and ionospheric models are provided by organizations like the International GNSS Service (IGS). PPP is considered as a rather cost efficient technique as it enables precise positioning with a single GNSS receiver. By applying PPP to dual frequency measurements even centimeter to decimeter accuracies can be achieved.

The concept of PPP was first introduced in the 1970's, whereby the theoretical foundation of PPP is documented in Zumberge et. al.(1997). Following Hofmann-Wellenhof et. al. (2008), the basic mathematical model underlying dual frequency PPP is defined by the desired ionosphere free combination of code pseudoranges

$$\frac{R_1 f_1^2}{f_1^2 - f_2^2} - \frac{R_2 f_2^2}{f_1^2 - f_2^2} = \rho + cdt_r + \Delta_{trp} \tag{1.1}$$

and carrier phases

$$\frac{\lambda_1 \Phi_1 f_1^2}{f_1^2 - f_2^2} - \frac{\lambda_2 \Phi_2 f_2^2}{f_1^2 - f_2^2} = \rho + cdt_r + \Delta_{trp} + \frac{\lambda_1 N_1 f_1^2}{f_1^2 - f_2^2} - \frac{\lambda_2 N_2 f_2^2}{f_1^2 - f_2^2}\,. \tag{1.2}$$

The unknown parameters to be determined are the point position contained in ρ, the receiver Clock dt_r , the tropospheric delay Δ_{trp} , and the ambiguities *N*

Compared to DGPS (differential GPS) and RTK systems, PPP has several advantages: a PPP client is completely independent, since no base station or network of base stations is necessary. Therefore PPP can save a lot of time, resources and data volumes which have to be usually transferred between reference and rover. There is no need for simultaneous observations and no tight limit in range thanks to globally and regionally valid correction data (satellite orbits, clock corrections, ionospheric delays in case of SF data).

Thus, it is imaginable that in the near future PPP will be able to substitute not only post processing of network solutions but also real-time differential GPS or even RTK in many applications. Nowadays PPP is used in the agricultural industry for precision farming, in hydrography and deformation monitoring. Further PPP applications are sensor positioning in seafloor mapping and marine construction as well as airborne mapping Bisnath et. al. (2009).

The main focus of this project research is to enhance the actual achievable accuracy of PPP in cadastral survey and mapping. PPP is a form of GPS data post-processing that does not use a base station for differential corrections. It is performed using the observation data from one receiver, in conjunction with precise satellite orbit and clock files, which serve to minimize the error sources. The most obvious difference between PPP and differential processing is that a base station is not needed for PPP. Differential processing requires that a point with known coordinates be observed concurrently with the observations at an unknown point or remote trajectory.

In PPP, only the observations associated with the unknown points are needed. The method of GNSS PPP will be used in cadastral survey and mapping. This method is expected to be more accurate, faster and cheaper. Finally several fields of application, where the PPP technique is nowadays used and can be used in the future are presented.

1.2 Problem Statement

At present, the cadastral survey and mapping services using MyRTKnet system involves only the Real-Time or Post-Process Virtual Reference Station (VRS) method as set out in the Director General of Survey and Mapping Circular No. 6 of 2009. The PPP method has not yet been applied which is capable of providing more precise and accurate results, even faster and cheaper.

Method of Network-Based Real-Time Kinematic (RTK) requires at least three (3) Continuously Operating Reference Station (CORS) to calculate the Virtual Reference Station based on the location of the user (rover).There are instances where CORS experience difficulties due to equipment or telecommunication lines.

This will because the Control Centre automatically select other CORS to calculate the VRS correction data. The question that arises is about the accuracy of the VRS correction data when different CORS network were used to maintain 2cm positioning accuracy, CORS need to be located within 50km distance and equally distributed.

Advancement of real-time algorithm, another technique that currently tested is zero Differencing or widely known as Precise Point Positioning. According to

Wubbena (2011), the PPP method can achieve accuracy up to ±3cm using data collected at the rover only with data from CORS situated even 200km among for the purpose of modelling the ionospheric and troposheric correction. Users can get accurate coordinate anywhere and the government can save costs because it does not need the dense network for CORS stations.

1.3 Objective

The aim of this research is to test and evaluate the accuracy of PPP generated outside the MyRTKnet. To achieve this research aim, the following objectives were developed:

i. To study the theoretically and achievable accuracy off PPP
ii. To compare the precision and consistency of PPP

1.4 Scope Of Study

In order to achieve the research objectives, the scope of works involve the following procedures:

i. To study and analyse the capability of PPP method for surveying and mapping per purpose
ii. Observations and data processing for GPS project in Peninsular and Sabah.

iii. Data Processing using Waypoint GrafNav version 6.0 Software
iv. Evaluation, analyses and summarisation of the results.

There are various types of GPS positioning that are being implemented around the world to correct GPS observations. The PPP system is just one of these methods. This research identifies the best services for GPS positioning of correcting GPS observations to the user (rover). The CORS stations will be used for this research is operated by Department Surveying and Mapping Mapping (DSMM) called MyRTKnet. In Peninsular the CORS are involved for this research ARAU, GMUS, CAME and JUML, KLAW and LAB1 in Sabah. The selection of CORS based on the geographical distribution and weather in year 2014.

According to Meteorology Department in November 2014, Northeast Monsoon is one of the main monsoons for our country that started on November until March every year (Monthly Weather Bulletin, Nov 2014). This weather system build up with cold surge from Siberian areas and brought heavy rainfall continuously that caused flooded for the some areas especially Northeast Peninsular Malaysia included East Johor for the beginner of monsoon and the end of monsoon is expected occur over Sarawak and West Sabah.

Last November 2014, for Peninsular Malaysia especially Terengganu, Selangor, Negeri Sembilan, Malacca and West Johor has experienced humid condition where rainfall anomaly is from 20% to more than 60% above average with the total amount rainfall is 400 mm to 900 mm. For the same period, there are some area experienced dry conditions, there are the middle part of Pahang which received rainfall more than 60% below average with total amount less than 200 mm. Meanwhile, others area has received normal rainfall (Monthly Weather Bulletin, Nov 2014).

For the Sarawak, generally almost all areas received normal rainfall with total amount between 300 mm and 500 mm. But, Sibu and Bintulu Divisions was experienced wet condition with anomalies rainfall between 20% and 60% above average with total amount between 500 mm and 600 mm. Otherwise, Sri Aman Division has experienced dry condition which is anomaly rainfall decrease as much as from 20% until 40% below average with total amount less than 300 mm (Monthly Weather Bulletin, Nov 2014).

Mostly all areas over Sabah received normal rainfall for the last month with total amount between 200 mm and 300 mm. But there are some areas received less rainfall especially Kudat and Sandakan Divisions were rainfall anomaly decrease about 20% to 40% below average. All information about the weather is especially needed for this study to find out how far the weather will impact the observation data at certain area.

1.5 Significance of The Study

The contribution of this study is summarized as follows. Firstly, the precise GNSS PPP survey techniques are utilized to provide sub-decimeters precision for the cadastral survey and mapping also will promote the accuracy of PPP to surveying community. Secondly, will help in implementing and operationalize PPP in Malaysia to obtain the consistency and precise accuracy coordinate using GNSS PPP techniques.

Previously using Network RTK, MAC method the short correction observation need at least minimum three CORS operated within 50km distances between station to archive ±2cm accuracy for Horizontally and vertically especially for cadastral survey and mapping. But using the PPP method, accuracy up to ±1 cm for three dimensional can be archived anywhere in any situation. Consequently, horizontal control in cadaster will improve 50% accuracy. For vertical component it is expected to increase ±6cm to ±1cm accuracy.

This research is important for DSMM to identify which are the best services to provide to users or customers outside in anywhere situation to maintain the accuracy as per request especially in cadastral survey and mapping. Nowadays, DSMM have multi user from private sector, government agency and University. As we know MyRTKnet is the backbone of DSMM, so we need to improve the best services to end users outside.

1.6 General Research and Methodology

This research aim is to test and evaluate the accuracy and consistency of PPP positioning in cadastral survey and mapping. In order to determine how well the PPP perform, research methodology will develop with respect to the following steps (Figure 1.2):

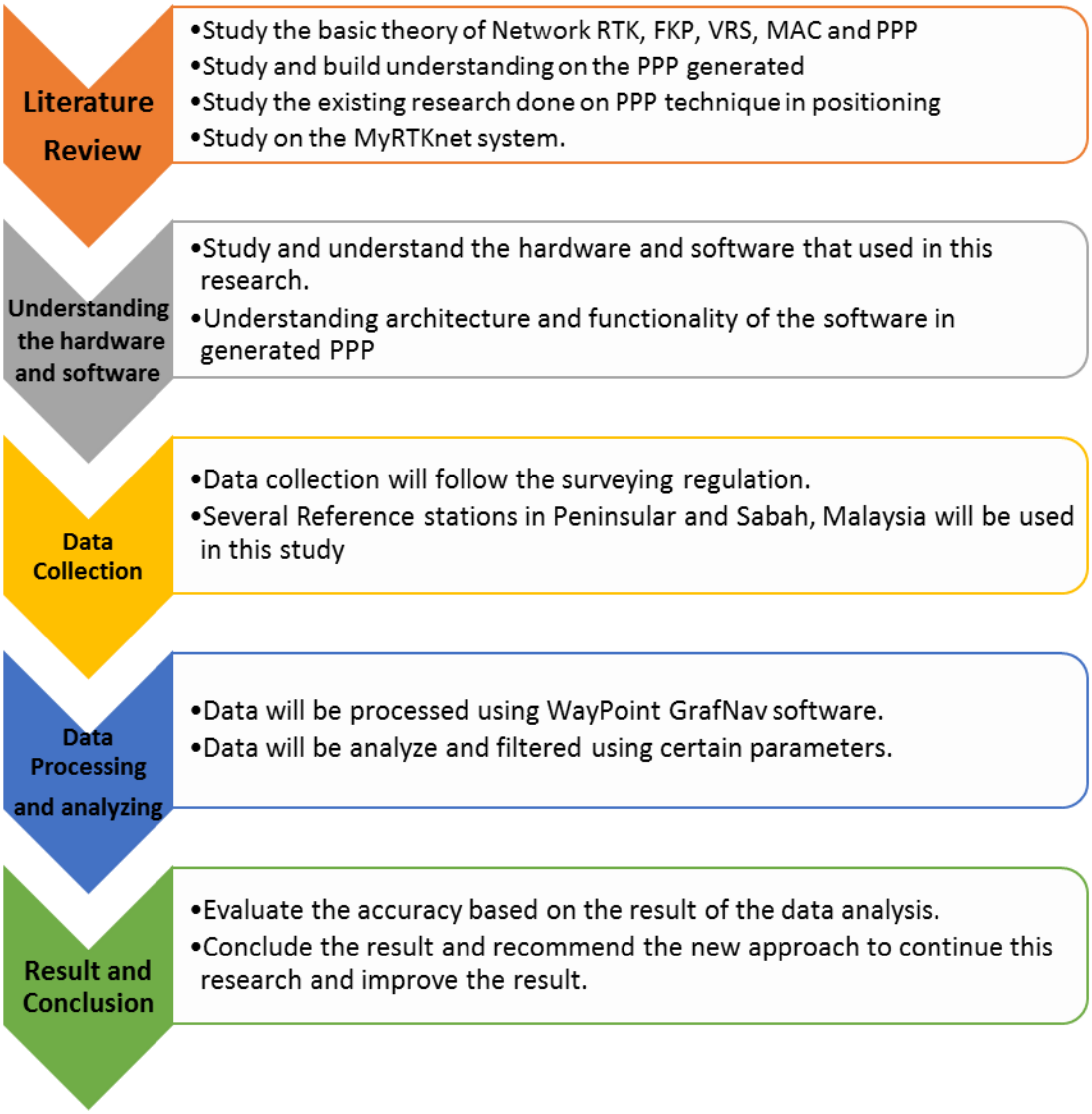

Figure 1.2 Research Approach

1.6 Thesis Outline

Chapter 1 briefly tells clearly matters involved throughout this study and methodology used for ensuring the success of this study. Chapter 1 clearly explains the background of the introduction of the study. Where there are many measurement methods that can achieve a high of accuracy and precision in measurement of cadastral and mapping in particular. Chapter 1 also tells expression problem or motivation, objectives, advantages and scope of the study. This topic further explains the process methodology begins with a detailed research planning, by understanding the existing measurement methods, hardware and software that will be used as well as the data collection of the most important for the success of this study. Chapter 1 describes an overview of the whole background briefly about the content thesis. Include a brief explanation about project overview, problems encountered, the objective, the scope of the study area and the advantages also the benefits this research to the public. The chapter ends the outline of the methodology and outline of chapters to summarize the thesis action.

In Chapter 2, some note and literature reviews from previous study or journals that highlighted about the PPP approach in order to compute three dimensional coordinate that conducted by other researchers will be reviewed. Also review the error in GPS such as atmosphere, satellite orbit, clock error, multipath and noise. Also discusses the common positioning technique are use Network RTK such as The Area Parameter Corrections-Flachenkorrerktur-parameter (FKP), Virtual Reference Station (VRS), Master Auxiliary Concept (MAC) and Precise Point Positioning (PPP). For the PPP method also review the concept of PPP, mathematical model of PPP, existing research project using PPP. Existing research project using PPP such as the application of GPS precise point positioning technology in aerial triangulation in Guangzhou China (2009). PPP and its application in mining deformation monitoring, a comparative study for accuracy assessment of PPP technique using GPS and GLONASS in urban areas and Waypoint Base Station Coordinate Determination using PPP Performance Analysis April 2014.

Chapter 3 demonstrates a research methodology on how to obtain three dimensional coordinate using Precise Positioning Method for this research. This chapter begins with an introduction of research methodology followed by elaboration of instrumentations which is hardware and software will be use in this study. The data acquisition, the study area and data collection. Then followed by data processing in order to achieve the first and second objective which are involved input data, data conversion, combine data and output.

Chapter 4 will focus on result and analysis description. The chapter starts with the introduction section which details location of this research. The chapter continues with the types of analysis which a core section in this project writing. And all the results of observations will describes and explains through the form of tables and graphs. In clearly and effectively result presentation, the illustration and diagrams will be employed to demonstrate the findings besides statement analysis. The chapter ends with the conclusion of the short three type's analysis and review the findings.

Lastly, the emphasis on Chapter 5 is about making conclusion of the research findings. According to another chapter, this chapter will begins with an intro, accompanied by an overview of the summary of findings and end with the recommendations based on findings and for future research. Some other element in conclusion of this research includes restatement of the objectives, implications of findings, limitations of the research and recommendations and suggestions for the following studies.

LIST OF ABBREVIATIONS

GPS	Global Positioning System
DGPS	Differential Global Positioning SystemSF
GNSS	Global Navigation Satellite System
VRS	Virtual Reference System
MAC	Master Auxialary Concept
RTK	Real-Time Kinematic
NRTK	Network RTK
PPP	Precise Point Positioning
CORS	Continuously Operating Reference Station (CORS)
DSMM	Department Survey and Mapping Malaysia
MyRTknet	Malaysian Real Time Kinematic Network System
SF	Single Frequency
SPS	Standard Positioning Service
DoD	Department of Defense
PRS	Publicy Regulated Services
USAf	US Air Force
OTF	On-the-fly
RTCM	Radio Technical Commision for Maritime Services
TEC	Total Electron Content
NGS	National Geodetic Survey
GCP	Ground Control Points
TEQC	Translating, Editing and Quality Checking
RMS	Root Mean Square