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Quantifying Terrain Factor Using GIS Applications for Real Estate Property Valuation

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Master thesis, 30 credits, *Geomatics*

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Abstract

This thesis studies the use of GIS applications to derive adjustment figures for the terrain factor in property valuation tasks. It aims at suggesting a quantitative approach alternative to evaluate the terrain factor as opposed to traditional methods and current industry practices where terrain is qualitatively judged based on visual observation at site and subjected to individual opinion.

In this study, the terrain factor is considered by analysing the slope and surface roughness elements of terrain. To achieve this, slope and surface roughness values are generated from available open source digital elevation models (DEMs) within the Esri ArcGIS software environment. For the purposes of this study, the Shuttle Radar Topography Mission (SRTM) DEM developed by National Geospatial-Intelligence Agency (NGA) and United States National Aeronautics and Space Administration (NASA), as well as the Advance Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global DEM jointly developed by Ministry of Economy, Trade and Industry, Japan (METI) and NASA, were used to derive terrain values.

The output adjustments were tested on several hypothetical valuation cases, consisting of small and large properties, to see the effects of DEM resolution upon the results.

In order to test the accuracy of the proposed-adjustment outputs and applicability of the study methods, feedbacks from industry experts were collected via an online survey for analysis. Upon analysing the feedbacks, this study finds that industry experts are of the opinion that the terrain adjustments proposed by this method are reasonable for use in the industry practice, although some apprehensions were also noted, as property valuers tend to exercise caution when using automated valuation methods.

The proposed method is simple to apply and does not require advanced knowledge of GIS functions to operate. Therefore, considering the positive feedback from the valuation community, it could pave way towards future incorporation of geostatistical methods/ components in value analysis.

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Abstrak

Tesis ini mengkaji kegunaan aplikasi GIS untuk mendapatkan pekali pelarasan bagi faktor rupabumi dalam kerja-kerja penilaian. Maksud kajian adalah untuk mencadangkan pendekatan kuantitatif bagi mempertimbangkan faktor rupabumi sebagai alternatif kepada kaedah tradisional dan amalan semasa industri yang bersifat kualitatif, yang mana faktor rupabumi diputuskan berdasarkan pemerhatian visual di tapak dan tertakluk kepada pendapat peribadi.

Dalam kajian ini, faktor rupabumi dipertimbangkan melalui analisis ke atas elemen kecerunan dan kekasaran permukaan rupabumi. Nilai kecerunan dan kekasaran rupabumi dijana daripada model aras digital (DEM) yang diperolehi daripada sumber terbuka (open source) menggunakan pakej perisian Esri ArcGIS. Untuk tujuan kajian ini, nilai elemen cerun diperolehi dari DEM Shuttle Radar Topography Mission (SRTM) yang dibangunkan oleh National Geospatial-Intelligence Agency (NGA) dan United States National Aeronautics and Space Administration (NASA) serta DEM Advance Spaceborne Thermal Emission and Reflection Radiometer (ASTER) yang dibangunkan melalui usahasama Kementerian Ekonomi, Perdagangan dan Industri, Jepun (METI) dan NASA.

Cadangan pelarasan yang dijana (output) daripada kajian ini diuji dalam beberapa kes penilaian andaian (hypothetical) yang terdiri daripada harta tanah bersaiz kecil dan besar, bagi mengkaji kesan perincian resolusi DEM ke atas penilaian.

Bagi menguji ketepatan output pelarasan yang disyorkan dan kesesuaian aplikasi syor pelarasan oleh kaedah-kaedah kajian, maklum balas daripada pakar-pakar industri dikumpul melalui soal-selidik atas talian (online) untuk dianalisis. Berdasarkan maklum balas soal-selidik, pakar-pakar industri pada umumnya berpandangan kadar pelarasan faktor rupabumi yang disyorkan oleh kaedah-kaedah kajian ini adalah munasabah untuk digunakan walaupun beberapa keraguan turut dikesan, tetapi ini adalah kerana penilai berjaga-jaga dengan nilaian janaan komputer.

Kaedah yang dicadangkan oleh kajian ini adalah mudah untuk diaplikasi dan tidak memerlukan pengetahuan yang mendalam tentang GIS untuk digunapakai. Oleh itu, memandangkan maklum balas yang diterima daripada komuniti penilai adalah positif, kaedah kajian mungkin dapat membuka langkah bagi memasukkan (include) komponen analisis geostatistik dalam analisis nilai di masa hadapan.

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In memory of my mother who had always been a source of strength and wisdom.

Dahlia Mudzaffar Ali
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List of Abbreviations

ASTER..................Advanced Spaceborne Thermal Emission and Reflection Radiometer
DEM...Digital Elevation Model
GDEM..Global Digital Elevation Model
GIS ....Geographic Information Systems
GTOPO30 ....Global 30 Arc-second Elevation
JPPH.......................................Department of Valuation and Property Services, Malaysia
JUPEM...Department of Survey and Mapping, Malaysia
SRTM..Shuttle Radar Topography Mission
SBM ....Standard Benchmark
VRM ....Vector Ruggedness Measure

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1. Introduction

According to classical economic theory, land is regarded as one of the three factors of production, alongside labour and capital (Smith, 1904). This is especially evident in an agrarian social structure, where land is required for farming activities to generate income. As society transitions into the industrial age, land is developed to house manufacturing premises and often used as collateral to gain additional business capital. In modern times, land is being managed more strategically as it is scarce in supply and costly to obtain (Pearce and Turner, 1990).

Within the context of ownership, land is often referred as real estate or real property. English Common Law, for instance, recognizes real property to include improvements and/or attachments on its surface such as buildings, crops and/or timber (forests). Attachments underneath the surface are also considered as part of the property, namely minerals and geological materials (Tiffany, 1920) such as metal, coal and petroleum, including buried treasure, although those are still subject to national policies and statutory provisions. Around the world, legal interpretations of real property would vary but essentially revolve around similar terms.

Property valuation is one of the branches in the surveying line of work. The term is also used interchangeably with the terms “property appraisal” or “valuation survey” to address one of the job scopes of that particular profession, which is the application of certain procedures and techniques for estimating the value of an identified property. In the technical context, value is estimated subject to a specific reason (or purpose) and at a specific point of time (Bonbright, 1937).

Property is tied to location, which makes it both geographical and spatial in nature. But despite the advancement of geospatial technology, particularly in the development of scientific programmes such as geographical information systems (GIS) applications, the valuation profession has thus far been unable to fully incorporate spatial analyses and geostatistical methods to perform value estimation tasks. This challenge is difficult to overcome because property is highly heterogeneous - no two properties can be considered as the exact same (Ting, 2008) - making it difficult to identify sufficient, firm and measurable factors that are usually required to define parameters of algorithm-based analytical models. In addition, property valuation is not an exact science. Although there are principles and standards that have to be complied with in estimating value, room is also given to inject justifiable valuer opinions during value analysis.

1.1 Research Interest

While acknowledging the existence of qualitative factors affecting value, there are also quantifiable factors that may be addressed using spatial solutions when estimating value. For that reason, this study will focus on finding a way to suggest terrain factor adjustments (to be used in the comparative method of valuation) using GIS applications. Terrain elements such as slope, aspect and roughness affect value as they have a direct impact on the expenses associated with preparing a site for development.

While terrain conditions have a great influence on making location decisions in urban development, within the context of traditional property valuation approaches, the terrain factor is often analysed “as-it-is”, as an independent factor affecting value. In other words, consideration of the terrain factor is purely on its physical characteristics, void of any external influences. As a comparison, the location factor which has the most impact on property value is highly influenced by the position of business districts and transportation networks, while the time factor is subjected to market conditions and economic policies.

The terrain factor’s independence from other external influences makes it suitable for this experiment as interference from those influences is avoided. In addition, this study makes use of available remote sensing products such as digital elevation models (DEMs) to allow the possibility of viewing terrain factor quantitatively.

1.2 Problem Statement

Part of the standard operating procedure in property valuation involves site investigation. This includes physically inspecting the site(s) of interest. With regard to terrain condition, observations are noted and photographic evidences are taken for the record. However, valuers are not land surveyors and inspections are not typically accompanied with gadgets to measure elevation height or slope. Therefore, opinion on terrain condition is highly dependent on the valuer’s interpretation, based on his/her visual judgement and background work experience.

Insistence on visual evaluation and individual knowledge has brushed aside efforts to incorporate statistically-backed and technology-aided methods for terrain analysis in the property valuation field, even though such methods are already being applied in other technical fields.

In addition, observation during site inspection can be severely limited. While it is possible to have an overview of a one-hectare plot (a little over the size of a football field), it is quite difficult to have a complete picture of the site when the plot size is considerably larger. Things are made to be more difficult when there are barriers in the line of sight such as trees, man-made structures etc. This situation results in opinions that are formed based on a fraction of the “seen” reality which may not quite accurately resemble the actual property.

Some obstructions also affect inspection in terms of accessibility. This is a common issue when the property is located at an interior location, far from road access or across bridgeless rivers.

Considering those issues, this study hopes to offer an alternative or at least a complimentary solution to assist terrain evaluation for property valuation using GIS applications.

1.3 Significance of Research

With respect to the terrain factor, this study will improve valuer accuracy on terrain interpretations by narrowing the variances in terrain perception with the establishment of scaled terrain measurements.

In the broader sense and relevant to the research objectives, this study promotes the use of quantitative methods over qualitative approaches when dealing with quantifiable factors. A major advantage of using quantitative methods is the ability to adopt statistical methods into the analysis. In addition, measurability allows every valuer equal view of the factor in question regardless of their background and work experience.

This study is also an opportunity to bridge the knowledge gap in the valuation profession regarding geospatial technology. With the exception of those that have undertaken GIS training, most valuers are not exposed to GIS applications. In fact, GIS subjects are only included in the property management (degree and/or diploma) programmes in the past few years. Alongside recent (GIS-trained) valuation graduates, this study hopes to produce results that will persuade the valuation profession to actively include spatial analysis methods in their tasks.

1.4 Research Objectives

The valuation profession has already benefited from geospatial technology with the development of navigational products and solutions for spatial data management. GIS applications are also widely used to produce maps for valuation reports and presentations. However, for the most part, spatial analysis functions of GIS applications are largely being overlooked.

This study aims to change that by:

- Using open source DEMs to derive slope and surface roughness values using GIS applications. It should be noted that calculation and analysis of terrain aspect may also be performed using this study method but is disregarded for this particular research due to reasons explained in paragraph 2.4 in Chapter 2;

- Producing slope and surface roughness weights/indices for property units within the study area;
- Proposing terrain factor adjustments to be used in the comparative method of valuation based on the slope and surface roughness weights/indices calculations.

In addition, this study will also:

- Conduct accuracy assessment of the proposed terrain adjustments generated using the study methods by collecting feedback from industry experts via questionnaire survey method;
- Assess the accuracy of available DEMs by comparing with elevation values of observed sample points within the study area.

1.5 Research Questions

This research is conducted to answer the following questions, which will be addressed in the process of the study.

- How is terrain factor adjusted according to valuation theories and practice?
- Is there a huge variance in terrain interpretation among valuers?
- Is there a relationship between work experience and how terrain is perceived?
- How huge is valuer-dependency on visual observation when evaluating the terrain factor?
- Based on expert feedback, how accurate are the terrain adjustment rates proposed by the study methods?
- How does DEM resolution affect the output value?
- How does the valuation community react to the idea of using remote sensing resources and geospatial methods in value adjustments?

1.6 Study Area

The study area is situated roughly at longitude 100°E from Meridian Greenwich in the south-east Asia country of Malaysia. Malaysia is mainly divided into the major land masses of Peninsula Malaysia, Sabah and Sarawak. Peninsula Malaysia is directly connected to mainland Asia via the Kra Isthmus while Sabah and Sarawak is located on the island of Borneo. These two (2) major parts of Malaysia is divided east-west by the South China Sea (Figure 1.1).

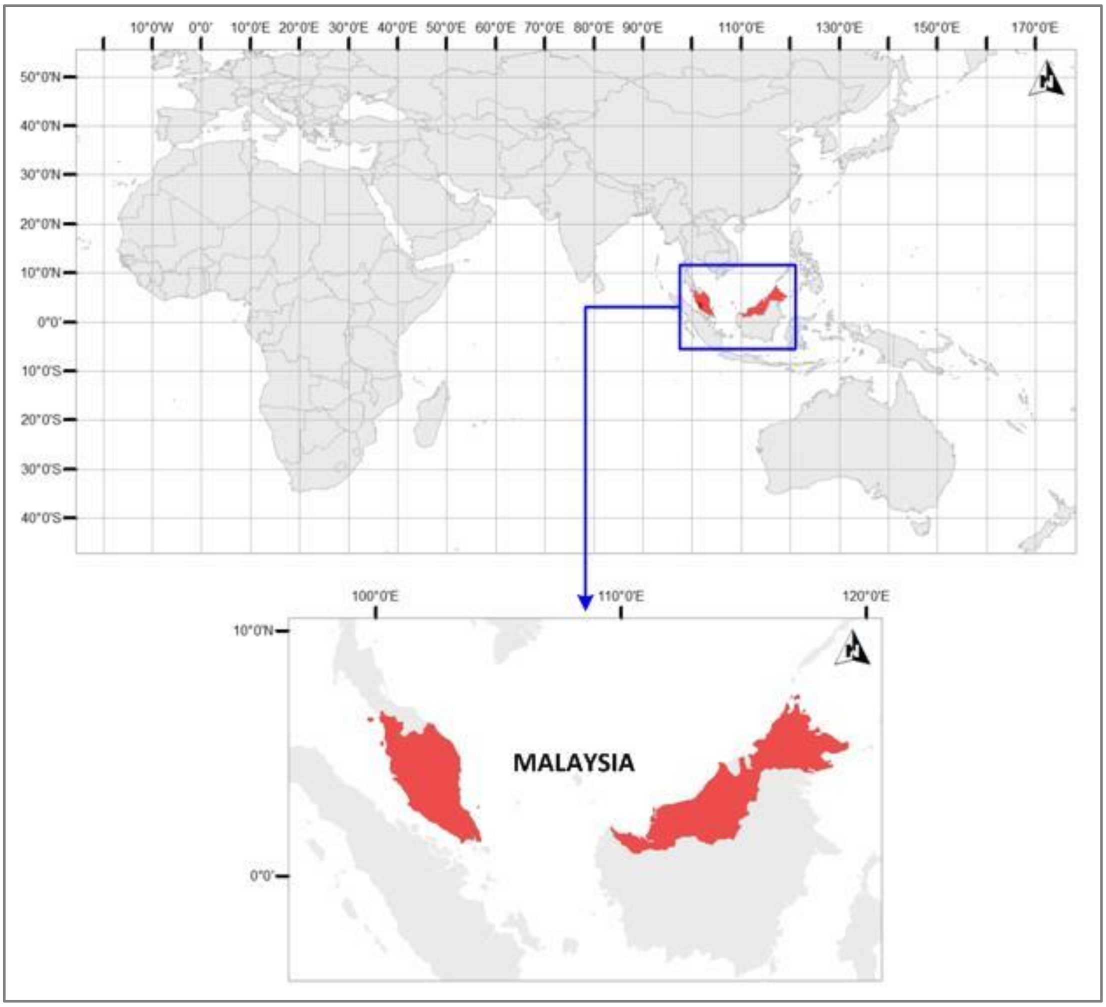

Figure 1.1: The study area is located in Malaysia, in south-east Asia.

For the purpose of this study, the selected area of interest is narrowed down to the districts of Gombak and Hulu Selangor, situated in the central region of Peninsula Malaysia (Figure 1.2).

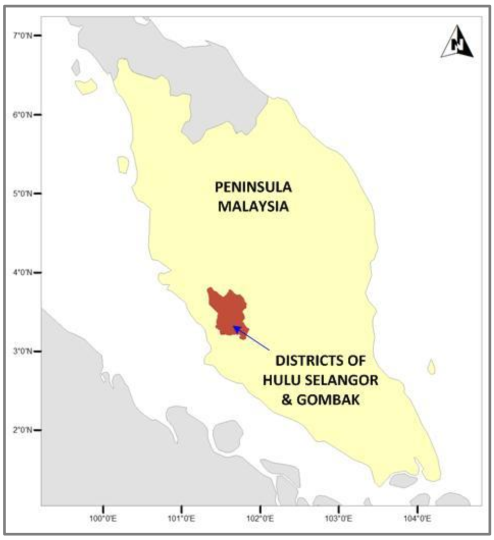

Figure 1.2: Location of the study area in the central region of Peninsula Malaysia.

The district of Gombak is adjacent to the district of Hulu Selangor at its northern boundaries and the Federal Territories of Kuala Lumpur at its southern boundaries. The study area has a combined size of about 239,055 hectares extending 75 kilometres in the north-south direction and 55 kilometres in the east-west direction. The centre of the study area is located approximately at longitude 101.5°E and latitude 3.5°N (Figure 1.3).

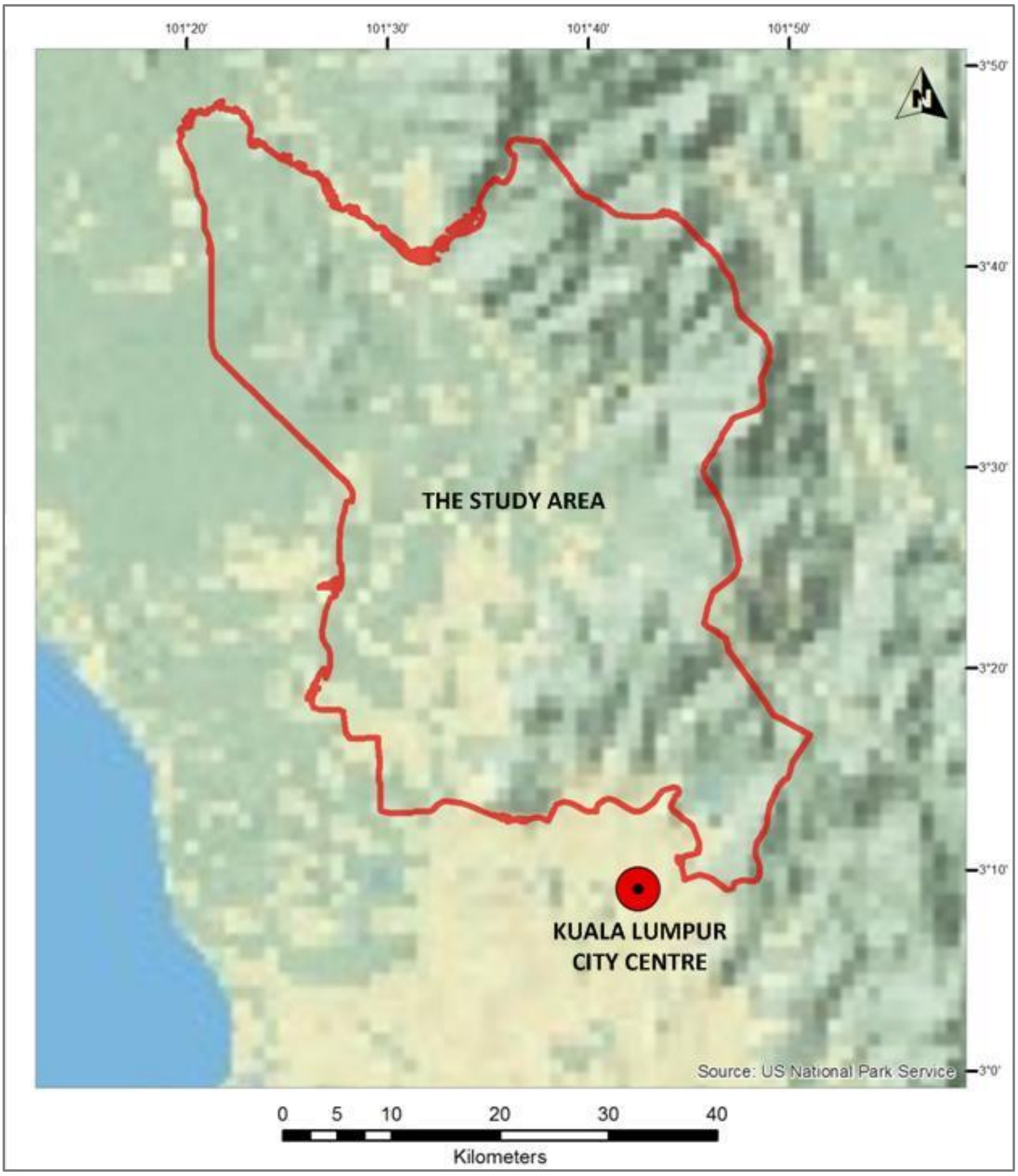

Figure 1.3: The study area in the districts of Hulu Selangor and Gombak, Malaysia which is located to the north of the former capital city Kuala Lumpur. The world physical map background show hilly terrains on the eastern half of the study area compared to flatter western half.

The study area is selected due to its diverse landscape. Half of the area consists of highlands with hilly terrain extending into the Titiwangsa mountain range in its eastern boundaries while the western half is generally made of flat lowlands. The highlands are mostly gazetted as forest reserves or catchment areas and are not applicable for development activity. On the other hand, the lowlands, especially in northwest quadrant of the study area, are generally cultivated with agricultural commodities such as oil palm, paddy (rice) and rubber. Development mostly takes place along the southern boundaries of the study area due to its proximity to the Kuala Lumpur city centre as well as along major trunk roads and highway intersections.

The Köppen-Geiger climate classification system classifies the study area and the rest of Malaysia as having a tropical rainforest climate that experiences uniform temperature, high humidity and copious rainfall all year round.

1.7 Limitations of Research

This study is based on terrain features extracted from the Shuttle Radar Topographic Mission DEM and Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (henceforth referred as SRTM DEM and ASTER GDEM respectively). Thus, the output of the analysis is largely dependent on the data quality of those DEMs. The elevation values of the DEMs are compared with observed values at sample points provided by the Department of Survey and Mapping Malaysia for accuracy assessment.

In addition, due to the DEM spatial resolutions of 30 meters (900 square metres per cell) and 90 meters (8,100 square metres per cell) respectively, the study methods are only tested on properties measuring at least than 10,000 square meters (one hectare) in size.

Unless otherwise stated, references to the legal, technical and ethical aspects of property valuation within the context of this study are as defined by Malaysian laws and the Board of Valuers, Appraisers and Estate Agents, Malaysia as the governing body of the Malaysian valuation profession.

1.8 Research Outline

This study was conducted over a period of 18 weeks beginning with references to literary and web resources to form and develop the general concept and idea. A general overview of the study process is as shown in Figure 1.4.

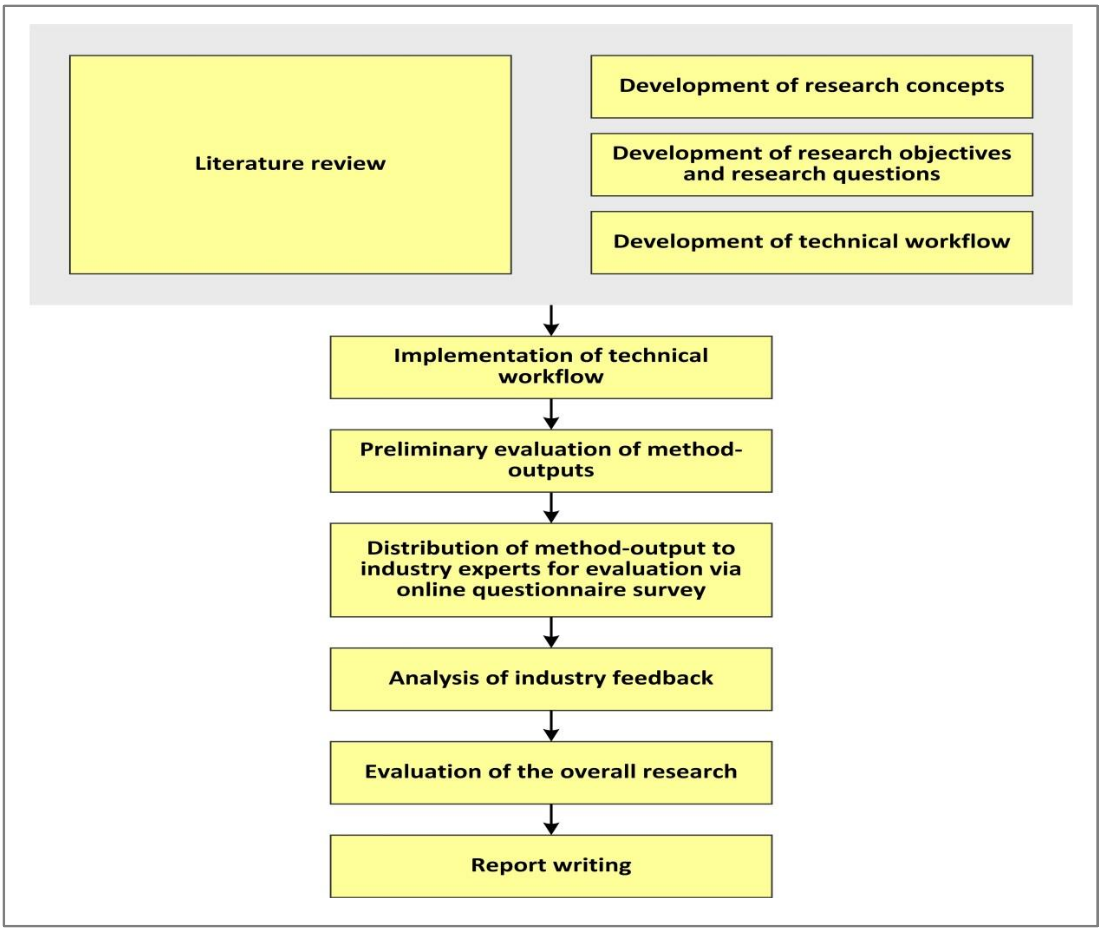

Figure 1.4: General flow of the research process.

2. Property Valuation and GIS Applications

2.1 Property Valuation

2.1.1 Definitions

Bonbright (1937) stated that in the context of appraisal, valuation refers to the "procedure and technique of estimating the value of a specific property at a stated time and place". Millington (2013) offers a more detailed explanation by interpreting valuation as "the art or science of estimating the value for a specific purpose of a particular interest in property at a particular moment in time, taking into account all the underlying economic factors of the market, including the range of alternative investments".

Pagourtzi et al. (2003) defined real property as "all the interest, benefits, rights and encumbrances inherent in an ownership of physical real estate, where real estate is the land together with all improvements that are permanently affixed to it and all appurtenances associated thereto" while statutory provisions provide legal interpretations of real estate to be applied within national jurisdiction.

On the other hand, "value", by itself is a little more complex to decipher.

The layman often equates value with price, cost or worth. But even these terms carry a different meaning when they are used in different context.

In the context of property valuation, cost is the expenses required to manufacture or obtain a product of value. It comprises of the amount paid to acquire a property and, in cases with built-upon structures, would include the material, labour and financing. Price is comprised of the costs of the product of value, added with some "rewards" to the manufacturer for taking the risks (in time and capital) to produce the product. The reward is reflected as profit margin, and may differ from one manufacturer to another. This means that price is a policy, unlike cost, which is a fact.

Worth is usually defined from the perspective of an owner or investor. It is the expectation of a selling price in the event of sale or the amount needed to replace the property. Value is closely related to worth and is complicated by individual scales of preference (Ring, 1972). Value is also affected by scarcity (Millington, 2013) especially with regards to market demand for its usefulness.

Bonbright (1937) further mentioned that two prevailing problems accompany every valuation request. The first is the “definition of value” - commonly expressed as basis of valuation. The purpose of valuation, either for sale or mortgage etc., decides the correct basis of value.

Valuation theories regard this as a fundamental issue and valuation standards always include a technical definition for the bases. One of the most common and important basis (or definition) of value is market value, defined by the Malaysian Valuation Standards (BOVAEA, 2011) as “the estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arm’s-length transaction after proper marketing, wherein the parties had each acted knowledgeably, prudently and without compulsion”.

The second problem concerns the systematic treatment to estimate value as defined by the first problem. Selection of the correct method is dependent on the purpose and basis of valuation.

Added together, property valuation may be defined as the methods or approaches to estimate the monetary equivalent of legal rights (which includes advantages, profits and responsibility) attached to a specific real estate at a particular point of time. Grissom (1985) provides a succinct view on the matter by stating that “valuation theory is the method of estimating, measuring or predicting a defined value”.

2.1.2 Applications

Property valuation is not an unusual process. It is often requested by governments, organisations and private individuals to assist in making business or financial decisions. Some purposes which require property valuation are:

- Sale and/or purchase for investment or self-occupancy;
- Mortgage and collateral;
- Auction;
- Property taxation;
- Revision of asset in financial report;
- Compensation for land acquisition.

2.1.3 Property Valuation Approaches and Methods

To protect and maintain the professionalism and integrity of the property valuation profession, several efforts have been made to organise valuation methods according to specific standards. In 2011, the International Valuation Standards Council (an independent, non-profit, private organisation that governs international valuation standards) revised the methodologies in valuation to encompass three basic approaches.

The first is a comparative approach that derives value by analysing sales of similar or substitute properties within the related property market (IVSC, 2011). In this approach, appropriate adjustments are made to account for any feature differences. This approach is generally suitable for most valuation cases, in particular for those involving properties that are commonly transacted in the market. The traditional comparative method is a subset of this approach.

The second approach utilises a capitalisation strategy by projecting the income expected by a property over its productive lifetime (IVSC, 2011). It is an accounting method, and is generally used for income generating properties such as retail units, office spaces, mines and plantations. It is also able to consider liabilities by working out the cash flows to service liabilities until repayment is fulfilled. Methods that use the capitalisation strategy are the investment and profit methods. Cash flow analysis is also considered a method that follows this approach.

The third approach is based on the basic economic principle where a buyer will pay no more than the cost of obtaining a similar item either by purchase or manufacture (construction) (IVSC, 2011). This approach is usually applied for properties that are not commonly traded in the market such as public amenities (schools, hospitals and town halls), airports and bus terminals as well as for buildings with extremely unique designs that uses custom material. It is based on the prevailing expenses to build the same structure at present cost with discounts are awarded for age as well as wear and tear factor.

Further subsets of the three approaches are specific methods to be used depending on the purposes of valuation and interest to be valued. Depending on the rules and regulations required by country-specific national valuation standards, valuers are typically required to use two methods for each valuation task that may apply the same or different approaches.

All three approaches make decisions based on the principles of the valuation theory, although the terrain adjustments proposed by the methods of this study are meant to be used in conjunction with the comparative method, which falls under the first approach described above.

2.1.4 The Comparative Method

The comparative method uses a direct market comparative approach discussed in paragraph 2.1.3 above and relies on the availability of sale evidences that have similar characteristics to derive value. In reality, no two properties may be considered as exactly the same, unlike mass-produced items, which is why property and real estate are often described as unique. Due to this heterogeneity factor, valuers have to exercise judgement in their analysis by reducing variability with justified and reasonable adjustments (Adair and McGreal, 1987).

According to property valuation theories and practices, there are several features that are looked upon while applying the comparison method. The greatest emphases are almost always given to location, time and title conditions. Other factors that are given due consideration include the physical characteristics of the property, of which surface terrain is a subset.

In the comparison method, the differences between the subject property (term used to refer the property which value is being determined) and the sale evidences (or comparable property) are scrutinised and adjusted appropriately. All adjustments must be accompanied with reasonable justification.

This study will be based on the application of this method, with a focus on terrain as the adjustment factor of interest.

2.2 GIS Applications

2.2.1 Definitions

Smith et al. (1987) defines geographical information systems (GIS) as "a database system in which most of the data are spatially indexed, and upon which a set of procedures [are] operated in order to answer queries about spatial entities in the database". Cowen (1988) describes it as "a decision support system involving the integration of spatially referenced data in a problem solving environment" while Parker (1988) simply states that GIS is "an information technology which stores, analyses and displays both spatial and non-spatial data".

The Open Geospatial Consortium describes GIS application as "the use of capabilities, including hardware, software and data, provided by a geographic information system specific to the satisfaction of a set of user requirements" (OGC, 2015).

Literary resources provide many more similar definitions but all are an explanation about the same things - that GIS application is the use or utilisation of an interactive information system encompassing hardware, software and data, that is able to store, display, query, process, model and manipulate geographical data that are spatially indexed, whereby the processes and retrieval of such data is subject to the fulfilment of certain user requirements.

2.2.2 Applications

GIS applications are most commonly used in the following areas:

- Cartography and mapping;
- Remote sensing applications;
- Environmental studies (e.g. hydrology, waste management and climate studies);
- 3D surface modelling;
- Voluntary GIS initiatives;
- Spatial data management at national and organisational levels.

Some notable programmes that are developed based on geospatial technology and GIS applications are:

- ArcGIS packages by Esri
  - A commercial desktop application used for creating maps, analysing geographic data, managing spatial data etc. based on geospatial technology.
- PostGIS
  - An open source programme under the GNU General Public License (GPL) that is a spatial extension of PostgreSQL object relational database.
- OpenLayers
  - An open source initiative under the Berkeley Software Distribution (BSD) license than provides an application programming interface (API) and a JavaScript library for designing web-based geographic applications.
- GeoServer by OpenGeo
  - An open source server under the GNU-GPL written in Java that allows sharing, processing and editing of geospatial data.

2.3 GIS and the Property Valuation Field

GIS have been made available to real estate practitioners since the late 1990s. It began to attract attention with the publication of aerial images through web applications such as Google Earth and Yahoo Maps that helps to convey the location factor effectively. In addition, these are more versatile and easier to manage than static paper maps that are set in scale and size.

In the United States, this basic form of GIS technology was initially embraced by tax assessors and this eventually paved the way to the development of automated valuation models (AMVs). However, such functions lack the sophistication needed by the appraisal (valuation) community and made little impact in property valuation work. Despite that, the assessor community are extremely welcoming of the benefits and potential of GIS technology and are active in trying to link GIS with their computer-aided mass appraisal (CAMA) software (Linné and Cirincione, 2010).

Linné and Cirincione (2010) further added that with the improvements that GIS had brought to the assessor community, the adoption or incorporation GIS solutions in valuation works increases in appeal. However, producing an interactive valuation model (IVM) that is able to consider spatial attributes and analyse the effects of such attributes close to how traditional valuation methods deal with them is extremely challenging. As it is, a competent IVM that is linked with GIS is still under development, and GIS applications in property valuation are confined to tasks that do not require any spatial processing.

Putting aside the desire for a functional IVM-GIS combination, it is hardly arguable that GIS's largest contribution to property valuation is the enabling of interactive value map creations. Howes (1980) describes a value map as “a cartographic tool or spatial representation of statistical data which reflects the value of property”. Before the availability of GIS tools, traditional value maps were difficult to prepare due to the rigidity of the manual paper mapping structure. GIS is able to address this issue by allowing the inclusion of a wider array of data for analytical purposes. In addition GIS offers interactive display of data and allows timely update of data in a fast, systematic and manageable manner.

GIS also enables the creation of a spatial property information system that takes storage, data manipulation and property analysis functions (spatially and aspatially) into consideration (Wyatt, 1996). This is a vast improvement compared to previous practice, as it allows for systematic data management and efficient time management. However, property is spatially distinct and is not simply a matter of spatial autocorrelation and thus at times requires alternative methods for spatial factor adjustments. Figure 2.1 below provides an overview of the methodology of a GIS-aided valuation process.

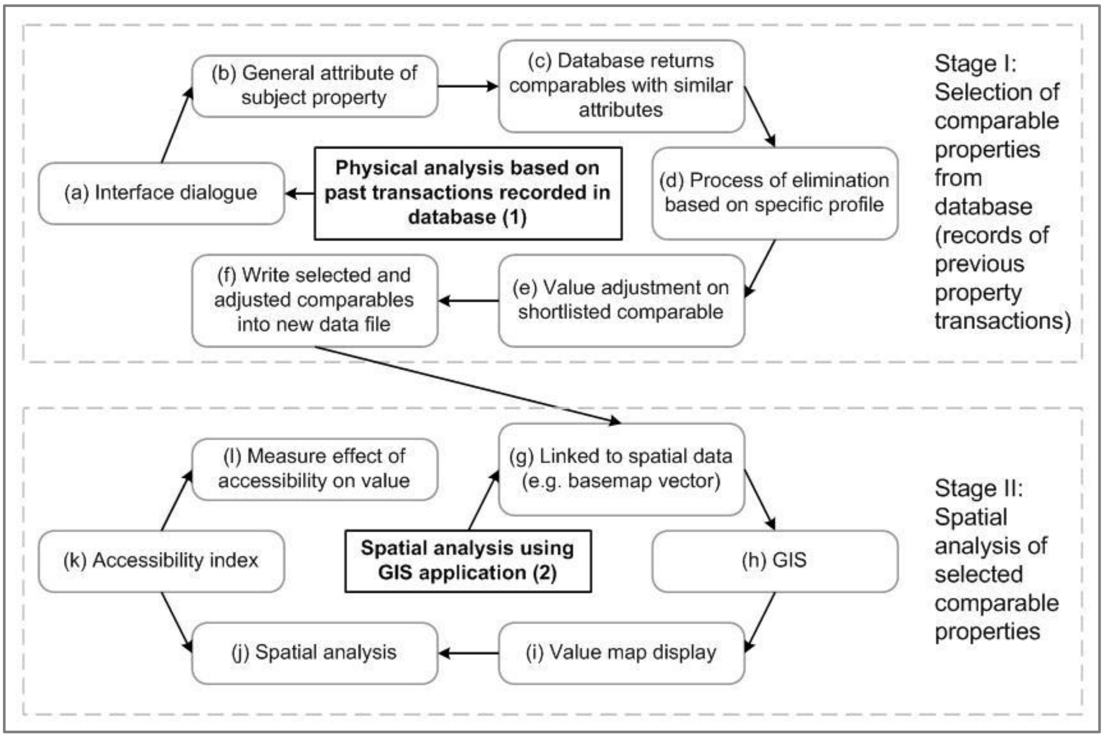

Figure 2.1: General outline of a GIS-aided valuation process based on Wyatt (1996).

The first part of the process involves the adjustment on physical factors of the subject property through a dialogue interface (a). The user (valuer) would provide information on the general profile of the physical characteristics (b) and the property database is searched to find records of previous transactions and returns a list of properties that match the input characteristics (c). The list is refined by the system by asking the user about details that are more particular to measure the difference of similar factors between the subject property and potential comparable which eliminates those with huge and significant differences (d). The shortlisted comparable are further analysed and adjustments are made where applicable (e). The shortlisted comparable are then written into a new adjusted data file for GIS-backed spatial analysis (f).

At this point GIS technology is used to aid the valuation process (g and h). Typically, the first step is to display the positions of the subject and comparable property on a map to visually demonstrate the spatial (locational) values of the properties (i). Adjustments are then made to account for spatial features followed by the decision on the subject value estimate (Wyatt, 1996). Wyatt (1996) provides the feature "accessibility" (k and l) as an example of the spatial feature being analysed by the model.

The GIS-aided valuation methods are still not widely applied due to difficulties in manipulating spatial data. As spatial factors are traditionally examined implicitly, the valuation community still prizes professional individual judgements over simulated outputs.

2.4 GIS and the Terrain Factor

This study aims at using a GIS application to produce weights or indices that would reflect the terrain factor in value adjustments. Features of surface terrain that will be studied are:

- Elevation
- Slope
- Surface roughness

In addition to the three features above, another feature that is interesting to include using the methods in this study is the terrain aspect, particularly in relation to shading from sunrise and sunset angles. This is an especially important feature at locations far from the Equator, particularly in countries that experiences severe seasonal changes. For example, in Scandinavian countries, properties shaded by the terrain shadows may not be preferred compared to their opposite as such properties are unable to benefit from solar rays especially during cold weather.

However, this study overlooked the aspect feature due to the proximity of the study area to the equator. Regions along the equator receive abundant solar exposure all year long. Thus, aspect feature is regarded as having extremely little effect to property value and is viewed as a negligible factor in the current property valuation practice in Malaysia.

For the purpose of this study, values of the terrain features will be extracted and generated from available open source DEMs, using surface analysis functions provided in GIS applications.

2.5 Digital Elevation Models

2.5.1 Definition

According to Aronoff (1989), a DEM is a set of elevation measurements for locations distributed over the land surface that carries different names: digital elevation model (DEM), digital terrain model (DTM), or digital terrain data (DTD) are all equivalent. This is disputed by Meijerink et al. (1994) who argued that DTM is a derivative of DEM. While a DEM contains elevation data, a DTM additionally contain data regarding terrain attribute such as slope, aspect soil type and others.

Essentially, a DEM is a 3D digital representation of terrain elevation data.

2.5.2 Application

Elevation data extracted from DEMs are important in generating DEM derivatives in land surface analyses. It is used in watershed and ecosystem studies, hydrological modelling and assessment of land resources.

2.5.3 Types

DEMs are widely available in raster formats. However, some DEMs are also made of vector data such as a point and a line model DEM. The following are some formats that are associated with DEMs.

- Raster
  - DEMs are most commonly available in this format. Raster DEMs provide elevation data via an array at regularly spaced intervals. Compared to vector formats, raster formats handle continuous data more efficiently. Nevertheless, there are also several disadvantages that come with this format. As the accuracy of raster data is decided by the spatial resolution, in a situation where there is a huge variance in elevation or when there are linear features at a fine scale, information between pixels could be lost. In addition, computer memory is wasted when there are large areas with level or uniformly sloped terrain, although this issue has been appropriately dealt with encoding techniques of modern GIS applications.
- Point model
  - In point model DEMs, elevation is represented at specific coordinate locations. Point models may be used as an input to interpolation to produce an estimate of the elevation values at unknown points.
- Line model
  - A representation of the line model is a contour map. Elevation in the line model is represented by contour lines at constant elevation intervals. Like the point model, elevation values between contour lines may also be predicted using interpolation methods.
- Triangular irregular network (TIN)
  - A TIN DEM is produced by applying the Delaunay triangulation approach using point data. Lines are drawn between points in close proximity without any intersection to create non-overlapping triangular facets of irregular size and shapes. If raster stores elevation data in rectangular cells, TIN stores them in the triangular facets. A TIN DEM provides

efficient data storage and terrain elements such as slope and aspect are better displayed. The downside is data processing will be less efficient than with raster grid models (Esri, 2015).

For the purpose of this study, the SRTM DEM and ASTER GDEM will be used to generate surface elevation values.

2.6 SRTM DEM

The Shuttle Radar Topography Mission (SRTM) is an international effort lead by the National Geospatial-Intelligence Agency (NGA) and United States National Aeronautics and Space Administration (NASA) with the aim of producing high-resolution digital topographic data of the Earth's surface. SRTM utilizes a technique called radar interferometry where a radar image pair of a particular area is captured from slightly different viewing angles. The differences between the two images allow for the calculation of surface elevation or change. The radar sensors were attached to space shuttle Endeavour that orbited the Earth on an 11-day mission to capture Earth surface images (CGIAR-CSI, 2008).

2.6.1 The SRTM Sensor

The SRTM utilises a radar sensor to collect remotely sensed data. A major benefit of a radar sensor over the optical alternative is its independence from light reflectance. Thus, radar sensors remain operable in the absence of light. Therefore, radar sensors are still able to collect data during the darkness (night time). In the case of the SRTM sensors, this means that data collection continued even when the space shuttle transporter was on the dark side of the planet. Additionally, radar sensors are able to efficiently penetrate cloud cover which is a problem often faced by optical sensors.

Instead of using specifically built radar sensors, the SRTM employs two previously used radar sensors to collect data. This was made possible using NASA's Shuttle Imaging Radar-C (SIR-C) and X-Band Synthetic Aperture Radar (X-SAR) which was a joint collaboration between the German and Italian space agencies. Both radars had proven track records during earlier space missions in the 90s.

The main antenna of the radar sensors is located within the payload bay of the space shuttle, together with the SIR-C and X-SAR radar. The SRTM instrument also includes an outboard antenna, which is separated from the main antenna by a 60-meter deployable mast that extends outwards from the space shuttle (Figure 2.2). While the main antenna has dual functionality - as transmitter and receiver of radar signals, the outboard antenna is merely a receiver of incoming signals.

The instrument is set up in such a way so that the distance between the two antennas remains constant even in the event that the distance between the antenna and the surface changes. By minimising the independent variable in this setting, accurate calculation of surface elevation can be achieved.

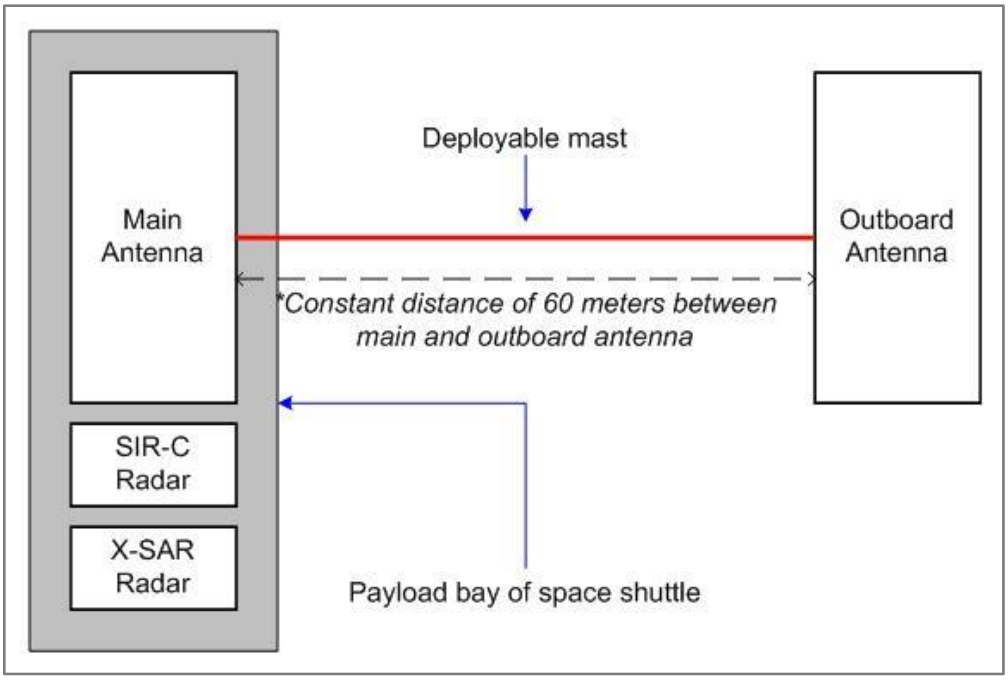

Figure 2.2: The main components of the SRTM sensor (U. S. Geological Survey, 2010).

2.6.2 Collection of Topographic Data

The SRTM is a fixed-baseline interferometry mission, where two radar datasets are collected simultaneously at a fixed distance as described above in paragraph 2.6.1. The main antenna will transmit radar waves to the Earth's surface. Similar to light rays, the radar waves will scatter in different directions once they hit the surface (Figure 2.3).

The main and outboard antennas of the SRTM instrument then collect the scattered radar waves. For the reflected radar beams, the path and timing of radar returns for the same location would slightly differ between beams collected by the two antennas due to separated distance.

Using the information about the constant distance of the two antennas and the differences in the reflected radar wave signals, it is possible to accurately calculate surface elevation.

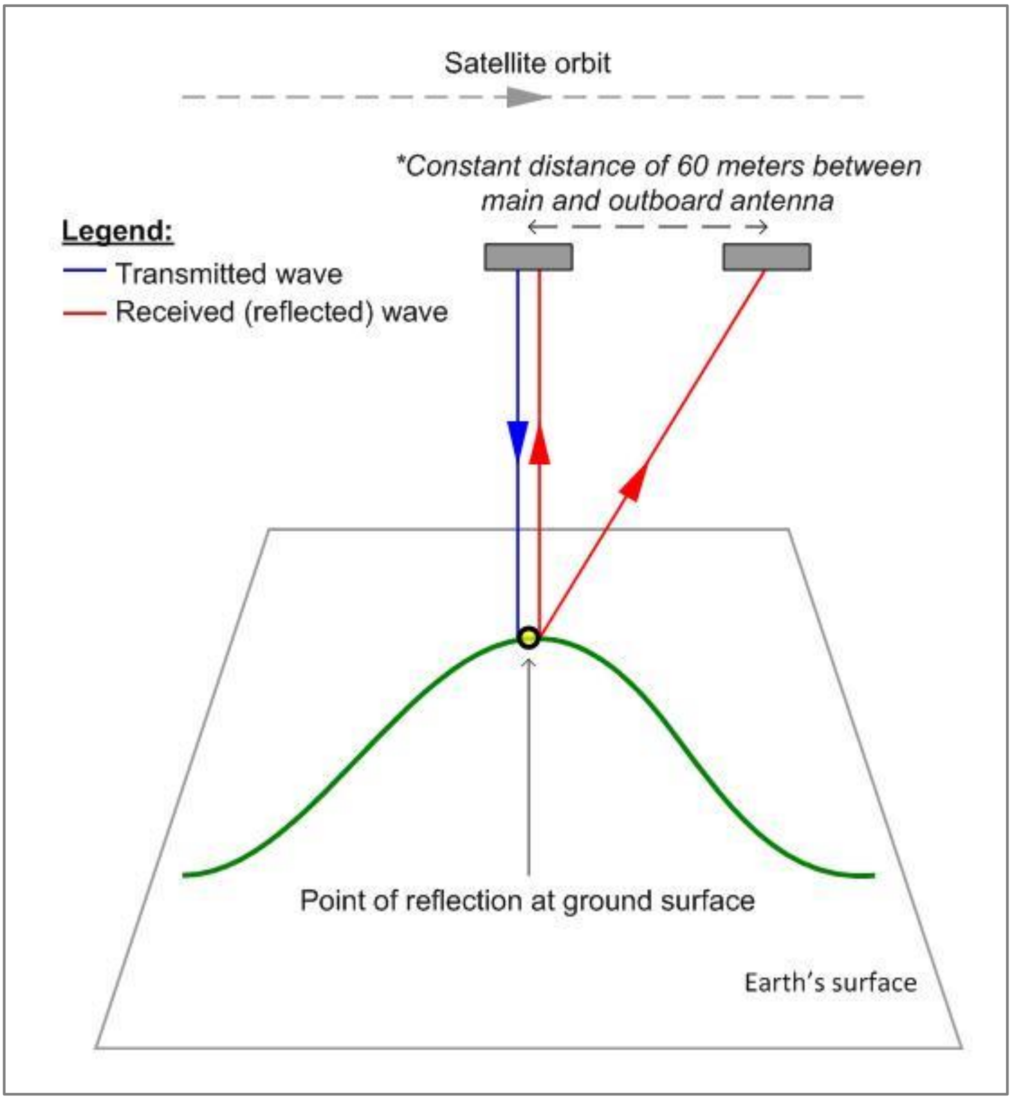

Figure 2.3: Transmission of radar signal waves and reflection by ground surface (U. S. Geological Survey, 2010).

2.6.3 The SRTM DEM

The SRTM DEM was produced using the data collected by the SIR-C (C-band) radar during the 11-day mission and post-processing took about two years to complete. It began by copying the C-band tapes to be processed using the Ground Data Processing System (GDPS) which was developed by the Algorithm Development and Verification (ADV) team. The GDPS first converts the raw C-band data into a height map and radar image strips which are later mosaicked according to the data's continent location. Finally, the mosaics are tested for quality and accuracy using a verification system. Once the accuracy is verified, the outputs are loaded for systematic processing of the full SRTM data set using super computers at JPL (CGIAR-CSI, 2008).

The continent-based outputs are then sent to NGA for final quality control before public distribution via the U. S. Geological Survey's EROS Data Centre (EDC).

The SRTM DEM used in this study taken from the CGIAR-CSI website, which further processed the initial SRTM DEM. The initial SRTM data contained regions of "No Data" due to insufficient texture detail from the C-band data to produce a 3D elevation data. This is particularly evident in mountainous regions such as the Himalaya and Andes mountain range and desert regions such as the Sahara, as well as over water bodies like lakes and (U. S. Geological Survey, 2010).

In the hole-filling process, the 1° tiles are merged into a continuous elevation surface in ArcGRID format and small holes are filled iteratively. The data is also cleaned to reduce pits and peaks from the surface data. Next, a range of methods are used to interpolate the holes based on their size and surrounding landforms. This process was performed on a void-by-void basis.

In the event that a high resolution auxiliary DEM is available, point coverage within the void area is produced from the centre cell elevation value of the auxiliary DEM for interpolation using the TOPOGRID algorithm in Arc/Info. TOPOGRID is based upon algorithms developed by Hutchinson (1988, 1989) to produce hydrologically sound DEMs.

In the absence of high resolution auxiliary DEM, the most suitable interpolation method is selected based on void size and landform topology. For instance, the Kriging method is applied for small or medium size voids in low-lying areas while Triangular Irregular Network is used for large voids in flat areas while the Spline (ANUDEM) method is used when terrain conditions are more varied.

The interpolated DEMs are then combined with the original DEM to make a continuous elevation surface free from No Data regions using overlapping tiles to ensure smooth topographical transition for the large void areas.

Specifications of the SRTM DEM are as shown in Table 2.1 below.

Table 2.1: Specifications of the SRTM 90m DEM v4.1 (CGIAR-CSI, 2008).

Attribute	Details
Tile size	(5°-by-5°)
Posting interval	3 arc-second
Geographic coordinates	Geographic latitude and longitude
DEM output format	ASCII GeoTIFF, signed 16 bits
Spatial reference	WGS84/EGM96 geoid
Coverage	North 60° to south 60°
Spatial resolution	Approximately 90 meters
Expected accuracy	20 meters (horizontal) 16 meters (vertical)
Release date	19 August 2008

2.7 ASTER GDEM

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) was jointly developed by the Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA). The ASTER GDEM was derived from satellite images captured by the ASTER sensor which was launched on board NASA's Terra satellite on 18 December 1999.

2.7.1 The ASTER Sensor

The ASTER sensor is an optical sensor which records data based on spectral data. It was designed to have a high spatial and radiometric resolution with broad spectral coverage. The sensor is capable of utilising 14 different image bands which are divided into three subsystems - VNIR (Bands 1 until 3), SWIR (Bands 4 until 9) and TIR (Bands 10 until 14). Each subsystem has a spatial resolution of 15, 30 and 90 meters respectively. The sensor is also equipped with stereo capability for the same path. Due to its significantly smaller 60-kilometer swath width, ASTER employs tilt-able telescopes to catch up with the Terra satellite's 172-kilometer orbiting span. When operating in full mode (all bands in operation), ASTER sensors are able to collect up to 780 scenes of daytime data per day. Detailed specifications of the ASTER sensor are as listed in Table 2.2 below:

Table 2.2: Specifications of the ASTER sensor (Japan Space Systems, 2011).

Attribute	Details
Spectral coverage	0.52~11.65 µm
Spatial resolution	15 meters (Bands 1 - 3) 0.52~0.86 µm 30 meters (Bands 4 - 9) 1.60~2.43 µm 90 meters (Bands 10 - 14) 8.12~11.65 µm
Radiometric resolution	≤ 0.5% NEDr (Bands 1 - 3) ≤ 0.5-1.3% NEDr (Bands 4 - 9) ≤ 0.3K NEDT (Bands 10 - 14)
Absolute radiometric accuracy	≤ 4%
Absolute temperature accuracy	≤ 3k (200-240 K) ≤ 2k (240-270 K) ≤ 1k (270-340 K) ≤ 2k (340-370 K)
Signal quantization level	8 bits (Bands 1 - 9) 12 bits (Bands 10 - 14)
Base-to-height ratio of stereo capability	0.6 (along-track)
Swath width	60 km
Total coverage in cross-track direction by pointing function	232 km
Mission life	5 years
MTF at Nyquist frequency	0.25 (across-track) 0.20 (along-track)
Peak data rate	89.2 Mbps
Weight	406 kg
Peak power	726

As of June 2014, only the VNIR and TIR subsystems are still in operation. The SWIR subsystem however, has stopped providing science data since April 2008 due to its inability to maintain detector temperature (NASA, 2015).

2.7.2 Collection of Topographic Data

The ASTER sensor produces two types of data. The first data type contains original image data values with radiometric and geometric coefficients as well as other auxiliary data supplied separately. The second type has those coefficients readily applied onto the image data. Each type is respectively referred as Level 1A data, formally defined as reconstructed, unprocessed data at full resolution and Level 1B data. DEM products are manufactured using Level 1A data as they contain validated geometric parameters of the ASTER sensor and DEM data that are processed using these parameters are generally of high accuracy.

Topographic information is gathered from the stereo configuration of Band 3N and 3B pair of the VNIR subsystem. This dual-telescope configuration - a nadir-viewing telescope and a backward-viewing telescope - allows stereoscopic viewing capability in the along-track direction and enables a large base-to-height ratio of 0.60 with minimum pass. Considering the Earth's curvature, the angle of the backward telescope, β, is set at 27.60° from the nadir. This makes the base-to-height radio as a tangent of the angle between the nadir and the backward direction at a point on the Earth's surface, α. Figure 2.4 below shows the stereo configuration.

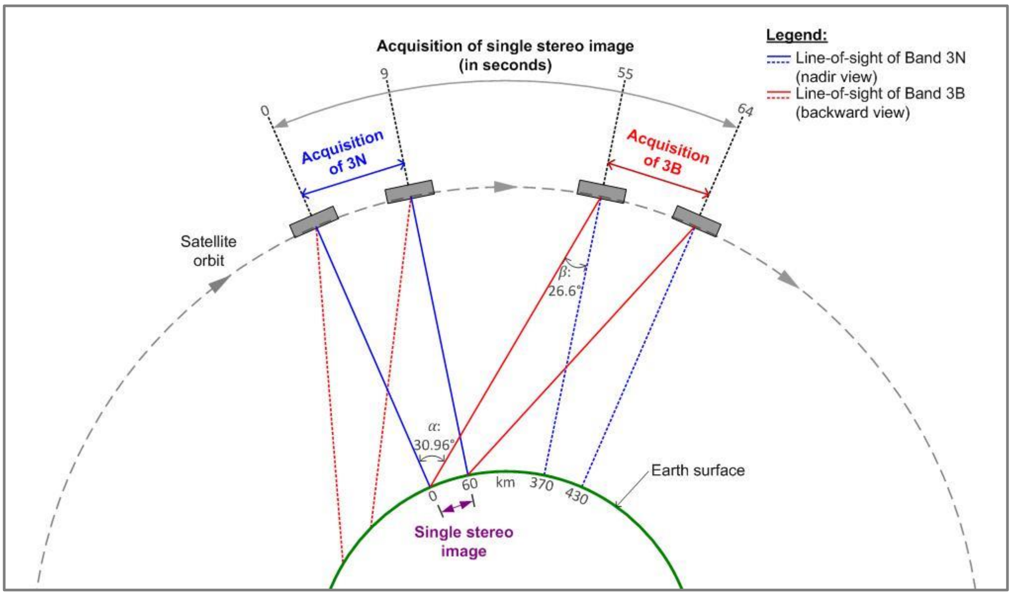

Figure 2.4: Acquisition of surface data by ASTER sensor (U. S. Geological Survey, 2014).

Extractions of topographic features require the search for corresponding points between the stereo pair. The search uses correlation coefficient as a search index to find the point. Once the corresponding point is found, the LOS vectors for Band 3N and 3B can be calculated by interpolating the values at the lattice points which are included in Level 1A products. The cross point between the LOS vectors will be the ground observation point (Figure 2.5).

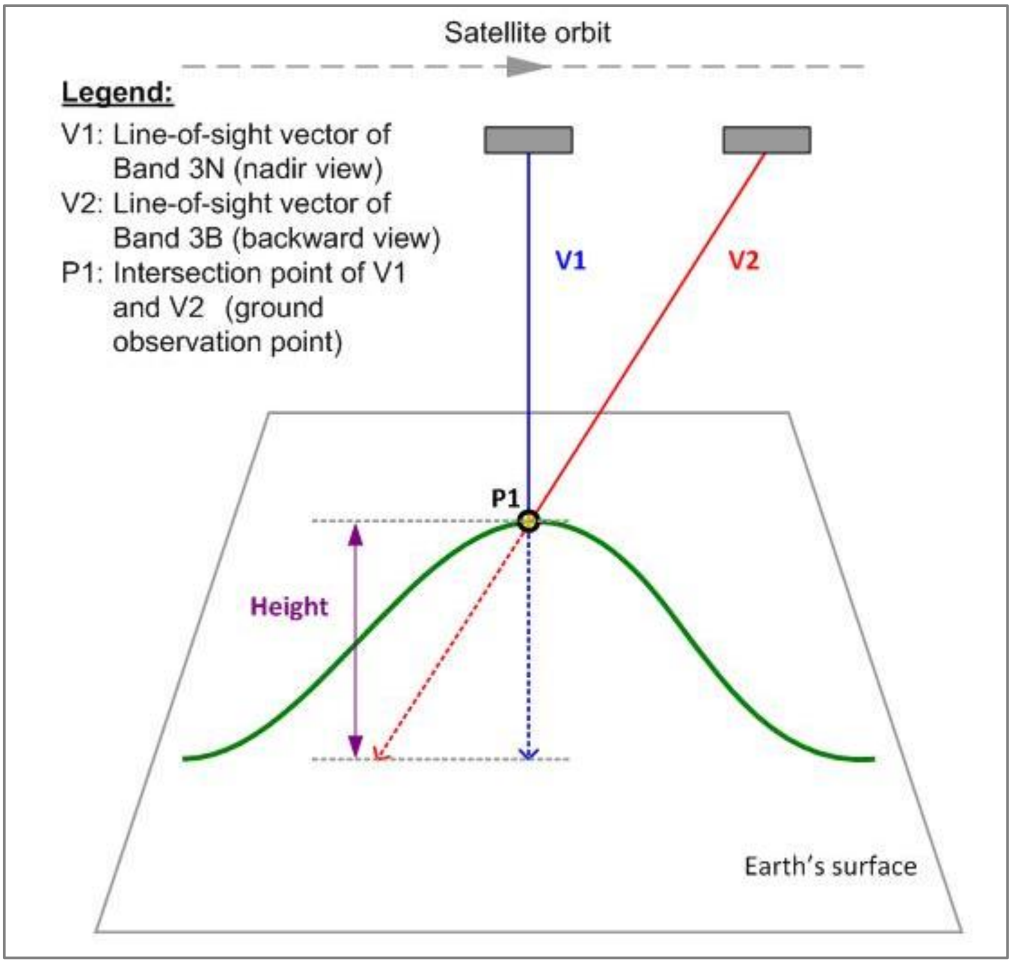

Figure 2.5: Extraction of topographic feature by ASTER sensor (U. S. Geological Survey, 2014).

2.7.3 The ASTER GDEM

The ASTER GDEM was generated using automated processing methods which included stereo-correlation. The process utilised the entire set of scenes in the ASTER archives to produce 1,514,350 individual scene-based DEMs. This is an increase of almost 20% compared to the Version 1 input scenes. The process began with the Level 1A data and coarse DEM - such as the Global 30 Arc-second Elevation, GTOPO30 - database inputs. The GTOPO30 is a digital elevation map produced by the United States Geological Survey (USGS) with a coarse resolution of one kilometre.

Next, radiometric correction coefficients were applied to the image data. The outputs were used to produce scaled-down images at 1/2 and 1/4 reduction rates for coarse image matching. Each correlation window was then evaluated for their possibility of image matching. At the same time, clouds, bodies of water and incomplete scene edge windows were removed. Then, the first stage of image matching was performed using the 1/4 compressed image followed by a second stage image matching using the 1/2 compressed image and the first stage image matching data. In both stages the parallax were calculated. Image distortions due to terrain errors were corrected before the third stage image matching process was performed using the full resolution image and second stage image matching data at a 5-by-5 correlation window size. Once those processes were completed, the x, y and z data for the observation points of every 30 meters (two pixels at 15 meter resolution) were calculated to produce the XYZ data output expressed as Earth-Centred Rotating (ECR) coordinates, which were then used to generate the ellipsoid base elevation (height) data. The elevation data were then resampled using a selected map projection in order to get the projected Z data (elevation). Figure 2.6 illustrates the automated process of generating the ASTER GDEM.

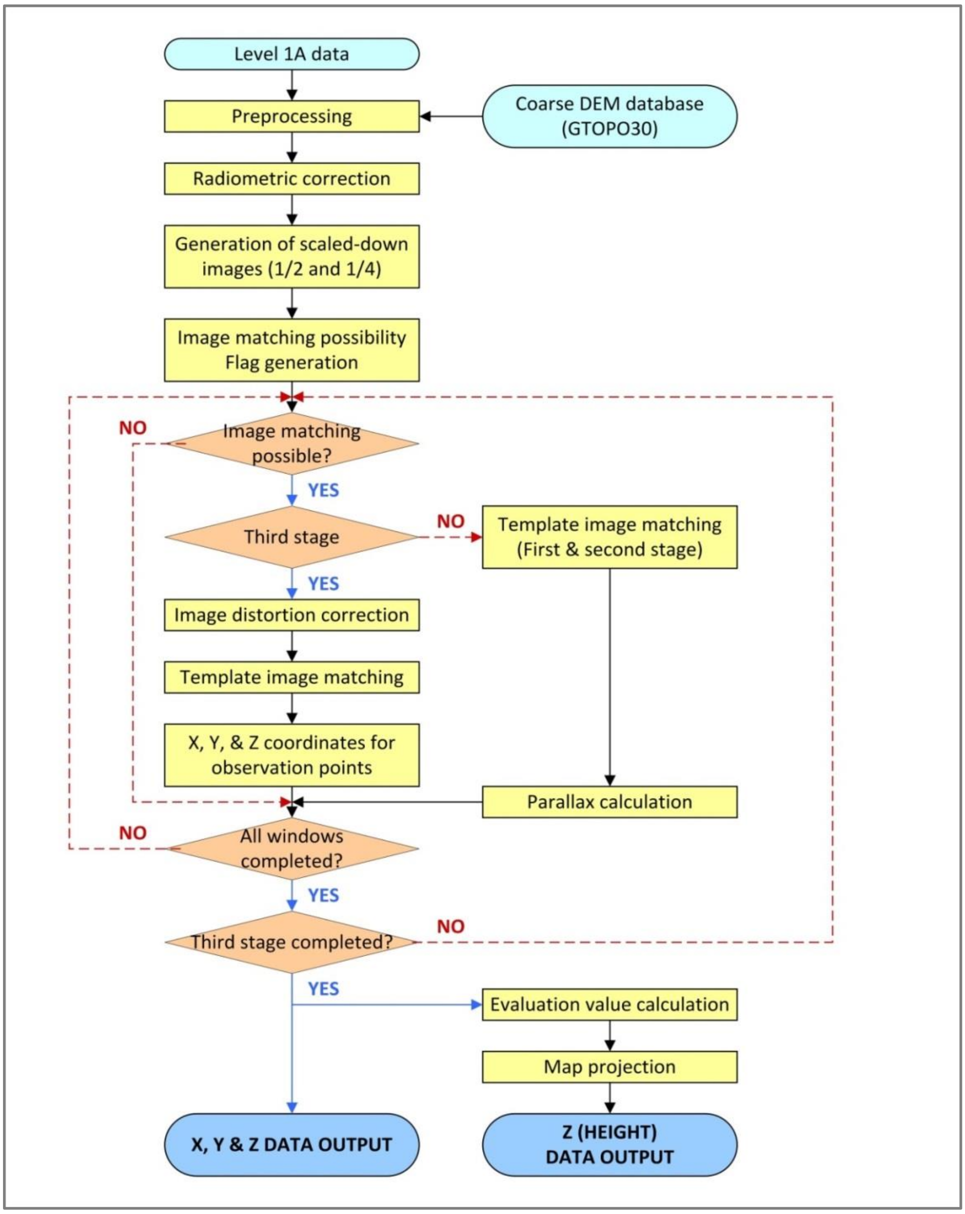

Figure 2.6: Process of producing ASTER GDEM (U. S. Geological Survey, 2014).

The technical specifications of ASTER GDEM are provided in Table 2.3.

Table 2.3: Specifications of the ASTER GDEM Version 2 (Japan Space Systems, 2011)

Attribute	Details
Tile size	3601 x 3601 (1°-by-1°)
Posting interval	1 arc-second
Geographic coordinates	Geographic latitude and longitude
DEM output format	GeoTIFF, signed 16 bits
DN values	1m/DN referenced to the WGS84/EGM96 geoid -9999 for void pixels 0 for sea water body
Coverage	North 83° to south 83° 22,702 tiles
Spatial resolution	Approximately 30 meters
Expected accuracy	20 meters (horizontal) 17 meters (vertical)
Release date	17 October 2011

2.8 DEM Accuracy Assessment

If the SRTM sensor minimizes independent variable by maintaining a constant distance between the main and outboard antenna even if distance between antenna and surface changes, the ASTER sensor achieve this by having its telescopes at nadir and constant backward viewing angles. By minimizing the effects of other variables, the accuracy of the data collected would be increased.

However, the accuracy of the SRTM and ASTER elevation values will only be ascertained by comparing them with elevation measurements at ground surface (Longley, 2005). For this reason, SRTM and ASTER elevation values will be compared with elevation measurements at corresponding sample points obtained from the Department of Survey and Mapping, Malaysia.

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3. Materials and Methods

3.1 Data

The spatial data used in this study are as listed in Table 3.1 below.

Table 3.1: Spatial data used in this study

Data	Description	Remark
SRTM DEM CGIAR-CSI Version 4.1 (Figure 3.1)	DEM Format: GeoTIFF Spatial resolution: 3 arc-second (approximately 90 metres) Reference system: WGS 1984/EGM96 geoid Source: CGIAR-CSI (2008)	Main data for terrain analysis Last update: 19 August 2008
ASTER GDEM Version 2 (Figure 3.1)	DEM Format: GeoTIFF Spatial resolution: 1 arc-second (approximately 30 meters) Reference system: WGS 1984/EGM96 geoid Source: METI & NASA (2011)	Main data for terrain analysis Last update: 17 October 2011
Cadastral survey (Figure 3.2)	Registered property units basemap Format: Esri shapefile (polygon) Reference system: Kertau RSO Malaya (projected coordinate system) Source: Department of Survey and Mapping, Malaysia (JUPEM)	Used as “cookie-cutter” for property analysis Last update: 19 December 2014
Standard Benchmarks (SBM) (Figure 3.2)	Surveyed elevation data at ground points Format: Esri shapefile (point) Reference system: Kertau RSO Malaya (projected coordinate system) Source: Department of Survey and Mapping, Malaysia (JUPEM)	Used to evaluate DEM accuracy

The position of the SRTM DEM and ASTER GDEM tile in relation to the study area is shown in Figure 3.1, while Figure 3.2 shows the vector data for the study area obtained from the relevant authorities.

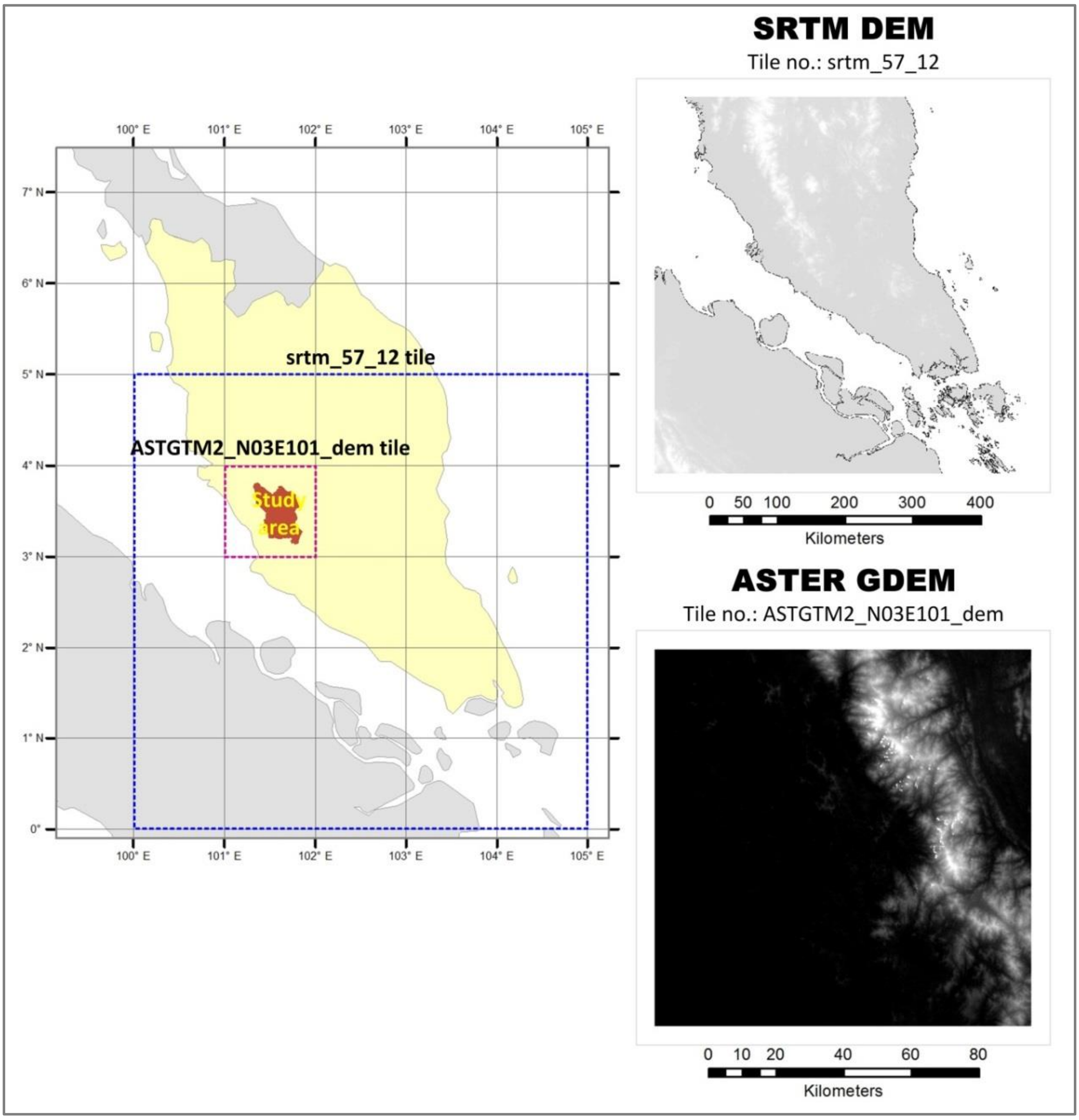

Figure 3.1: DEM tile positions (left) DEM tile position relative to the study area; (top-right) SRTM DEM (CGIAR-CSI, 2008) and (bottom-right) ASTER GDEM (METI and NASA, 2011).

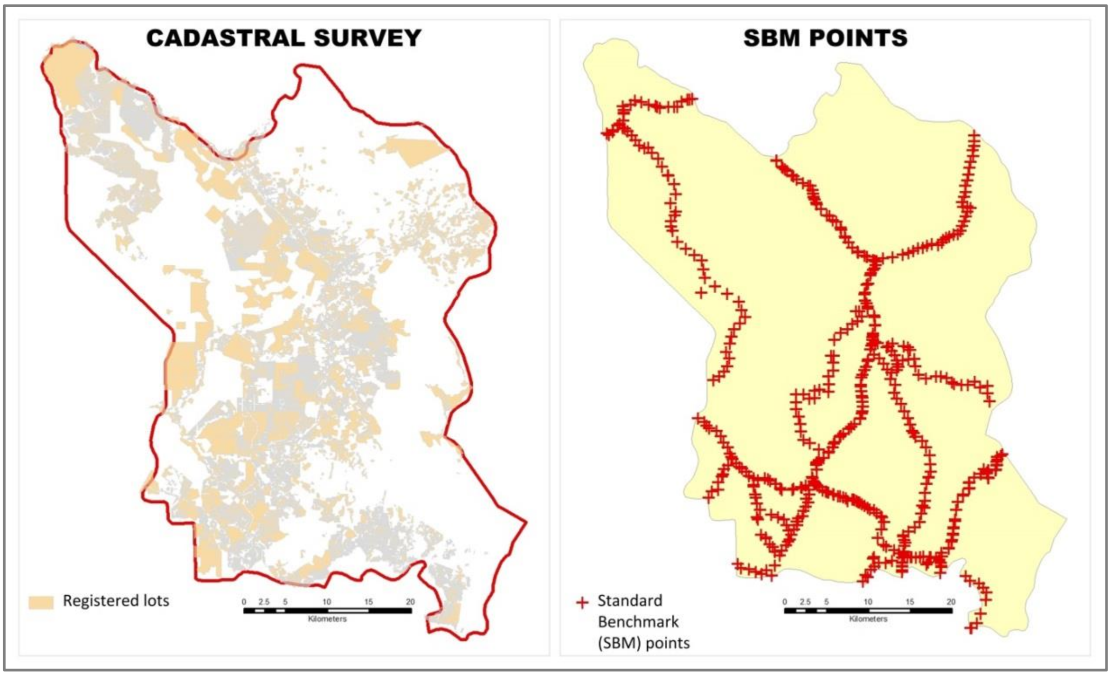

Figure 3.2: Vector data of the study area.
(left) Cadastral survey of registered property lot;
(right) Location of Standard Benchmarks (SBM) (JUPEM, 2014)

In addition to the raster and vector data, property sale evidences are supplied by the Department of Valuation and Property Services (JPPH), Malaysia (Appendix A). It contains attribute information such as title details and sales registration information to be used in the valuation part of this study.

3.2 Software and Analysis Tools

The software used within this study includes the following:

- ArcGIS 10.2 Desktop packages with "Spatial Analyst" extensions
    - This GIS product is developed by Environmental Systems Research Institute (Esri) and has the capability visualise, explore and analyse data spatially. The Spatial Analyst extension provides tools to derive surface functions needed for this study.
- Terrain Tools_92 for ArcGIS
    - This spatial analyst tool for surface analysis was developed by Sappington et al. (2007) to calculate surface roughness. The output is described as a Vector Ruggedness Measure (VRM) index from "0.00" for flat and smooth surface to "1.00" for extremely rugged surface. The algorithms in Python script are as attached in Appendix B.

- R i136 3.0.2 software environment for statistical computing
    - This is a GNU-GPL initiative based on the R programming language that is widely used for statistical analysis and data mining purposes. The “rasterVis”, “rgdal” and “rgl” packages were used to generate 3D-images and interactive graphics of surface terrain based on DEM elevation values for the survey questions.
- SurveyMonkey online survey development cloud
    - This programme hosts online surveys and offers tools to create customisable surveys, monitor survey distributions and collect feedback from respondents. It also provides back-end programmes for data analysis and templates to present survey results.

3.3 Methods

3.3.1 Data Preparation

The raster DEMs and ancillary data used in this study were initially defined in the WGS 1984 geodetic reference system. Therefore, those data are first transformed into the projected reference system used for the study area, which is the Kertau Malaya RSO projected coordinate system. The projected coordinate system utilises the Rectified Skew Orthomorphic Natural Origin projection. It is based on the Kertau Geographic Coordinate System which uses the datum Kertau and Everest 1830 (Modified) Spheroid.

Spatial transformations are done in the ArcGIS environment.

3.3.2 Technical Workflow

The process of generating terrain adjustment rates for use with the comparative method of valuation can be divided into three major steps that are comprised of nine (9) operations (Figure 3.3). They are:

- Generation of terrain element weights/indices from DEM and DEM-derivatives;
- Selection of subject and comparable properties to test the method-output;
- Generation of method proposed terrain adjustment rates.

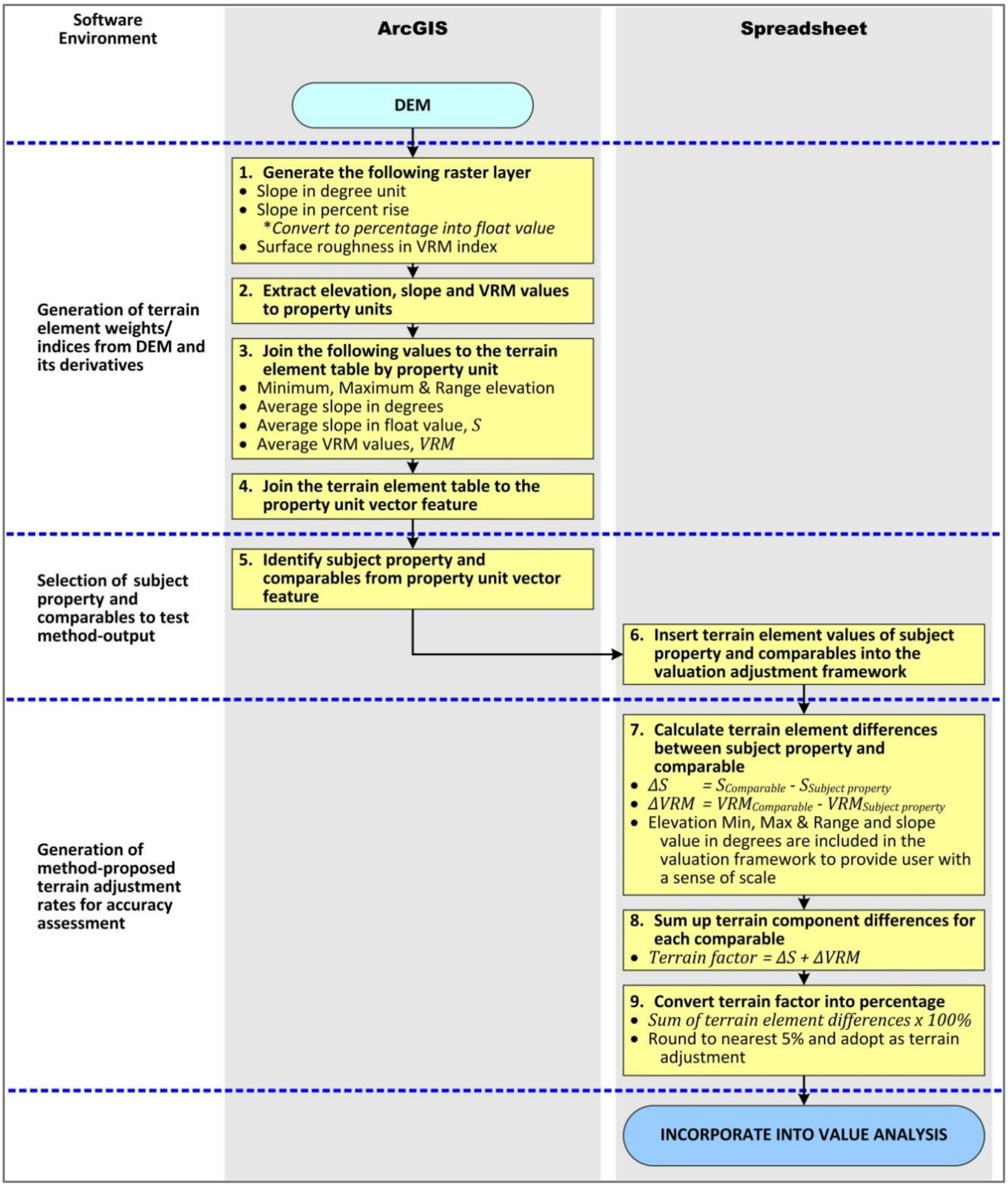

Figure 3.3: Technical workflow of the methodology process.

The following are step-by-step descriptions of the operations that are performed in the ArcGIS environment with the Spatial Analyst extension and spreadsheet.

1) First, slope values (in degrees and percent rise) are generated from the DEM using the “Slope” function in ArcMap. The outputs are slope raster layers with cell values from 0 to 90 (in degree units) and between 0 and infinity (in percent rise). The slope values in the percent rise are converted into floating point numbers using the “Raster Calculator” function.

Next, a similar operation is performed using the "Terrain" tool developed by Sappington et al. (2007) to obtain a surface roughness raster layer. For ease of reference, the roughness measurement is addressed as Vector Ruggedness Measure (VRM). The output is an index between 0.00 (for a flat and smooth surface) and 1.00 (extremely rough surface)

2) The elevation, slope and VRM values are then extracted for each registered property unit using the "Zonal Statistics to Table" function, using the cadastral survey vector feature as a "cookie-cutter" (i.e. to delineate zones).

3) The following values from the output tables are joined to create a terrain element table for corresponding property units:
    - Minimum, Maximum and Range elevation values;
    - Average slope values (in degrees and float numbers);
    - Average VRM values.

4) The terrain values table is joined to the basemap (cadastral survey) layer as newly added attribute fields.

5) Based on available sale evidences, several properties are selected from the basemap layer to test the method-output. For the purpose of this experiment, selections of subject properties are made according to the following categories. Distinguishing between size categories is required to study the impact of DEM spatial resolution to the output.
    - Small properties: Measuring less than 3 hectares (30,000 square meters)
    - Large properties: Measuring more than 100 hectares (1,000,000 square meters)
    - To reduce the influence of factors other than terrain, selection is made between properties that are most similar with respect to other factors.

6) Terrain weights/indices obtained from (4) are inserted into the terrain portion of the valuation adjustment framework (Table 3.2 below).

Table 3.2: Terrain data portion in the valuation adjustment framework.

Property	**Subject property**	**Comparable *i***
Property ID		
Min elevation (meter)		
Max elevation (meter)		
Range (meter)		
Mean slope of property unit (degree)		
Mean slope-rise of property unit (%)		
Mean slope-rise (float), ΔS		
Surface roughness index, *VRM*		

7) Computation of terrain element differences between subject and comparable properties are made using the following formula:
    - Slope difference, $\Delta S = S_{Comparable} - S_{Subject\ property}$
    - Roughness difference, $\Delta VRM = VRM_{Comparable} - VRM_{Subject\ property}$
    - Note: No calculations are made involving the minimum, maximum and range elevation values or slope in degree unit. However, that information is included into the valuation framework to provide user with a sense of scale regarding the terrain condition.

8) The slope (ΔS) and roughness (ΔVRM) differences are added together to obtain the sum of terrain differences and converted into percentage.

9) The amount is rounded to the nearest 5% and adapted as the adjustment rate on the terrain factor as per the usual way to perform adjustments in the comparative method (Table 3.3).

Table 3.3: Computation of slope (ΔS) and surface roughness (ΔVRM) differences between subject property and the comparable.

Property	**Subject property**	**Comparable *i***
$\Delta S = S_{Comparable\ i} - S_{Subject}$		
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		
$\Delta S + \Delta VRM$		
$\Delta S + \Delta VRM$ (%)		
Proposed terrain adjustment (to the nearest 5%)		

3.4 Accuracy Assessments

3.4.1 Output Evaluation

To evaluate the adjustment rates proposed by this study method, feedback from practicing property valuers have been obtained using an online questionnaire survey. The survey questions are divided into five sections.

- Section A: Respondent background
  - This section is comprised of questions to establish the demographics of respondents based on their involvement in the property valuation field.
- Section B: Factors in value adjustments
  - This section attempts to observe how much emphasis is given to a list of factors affecting value (including the terrain factor) by requiring respondents to rank them.
- Section C: Visual perception of terrain factor
  - This section will study the variation of terrain interpretations (among respondents) using terrain photographs, contour plans and 3D-surface image renditions. Feedback from this section will also help to establish the influence of work experience on terrain judgement.
- Section D: Evaluation of proposed adjustment rates
  - This section gathers respondent feedback on the proposed adjustments and will use them as an evaluation of this study method. In the event of disagreement over the method-output, respondents are also requested to provide their own judgement as alternative.
- Section E: GIS application in property valuation
  - This section will observe the response among industry players regarding the inclusion of GIS applications in value analysis.

A copy of the survey question set is as attached in Appendix C.

3.4.2 DEM Accuracy Evaluation

In order to evaluate the accuracy of the DEM, an elevation comparison is made using actual (surveyed) elevation measurements. The elevation values from DEM cells that correspond with the SBM points in the study area are extracted.

The formula used to calculate the RMSE are as follows (Equation 3.1):

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y} - y)^2}{n}}$$ (Equation 3.1)

$y = observed\ value$ (SBM elevation)
$\hat{y} = predicted\ value$ (DEM elevation)
$n = number\ of\ sample$ (SBM points)

The "Root Mean Square Error" (RMSE) of each DEM (SRTM and ASTER GDEM) is then compared for evaluation and further discussion.

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4. Method-Outputs, Questionnaire Survey Results and DEM Accuracy Analysis

4.1 Outputs from Technical Workflow

For the purposes of this study, four sets of proposed terrain adjustments are prepared involving four different subject properties and their comparable. The terrain adjustments are generated by implementing the technical workflow in paragraph 3.3.2 of the previous chapter.

The first two subject properties (HK "A" and DA "A") are small in size. Including the comparable, the properties in these sets have a maximum size of six hectares.

The remaining two subject properties are large estates (LD "A" and LD "B"), with a minimum property size of 150 hectares. However, these two share the same set of comparable due to the scarcity of large estates sales in the property market.

Tables 4.1 to 4.8 are extracts from a full valuation adjustment framework, simplified only to display the terrain portion related to this study. Note that the details in the tables also include elevation, slope and surface roughness values that are derived from the processes of this study.

The first information in the table is the property ID for user reference. The ID would typically contain the property registration number and references to its administrative location (district, locality etc.). In a complete valuation adjustment framework, following the ID would be the property's other attribute information such as the size, location, registered land use and others. The other attributes may or may not be factors in value consideration.

For the extracted terrain portion, which is the focus of this study, the framework lists elevation values regarding the property (minimum, maximum elevation and range) as well as the average slope angle to provide the user with a sense of scale about the property. Included next are slope rise values (converted from percentage to a floating point number) and the VRM index, obtained from the implementation of the technical workflow described in the previous chapter. This information is required for the subject property and the set of comparable.

Next, the slope and VRM differences between the comparable and the subject are calculated. The sum of the slope and VRM differences are then added and adopted as the terrain adjustment factor.

Adjustments in the comparative method of valuation are made by increasing or reducing the declared sales price of a comparable (in price per square unit) based on the adjustment rates. A positive adjustment rate means that the subject is considered to be of a better (favourable) condition, thus the referenced comparable price is increased (positively adjusted), while a negative adjustment rate means that the subject is of a lesser condition, thus the price is reduced (negatively adjusted). In the framework, the adjustment column under the subject property is left empty as its value is the one is being estimated.

Table 4.1: Terrain element values and proposed adjustment for subject HK "A" generated from SRTM DEM.

PROPERTY	**Subject HK "A"**	**Comparable HK1**	**Comparable HK2**	**Comparable HK3**	**Comparable HK4**
Property ID	Lot 1190, Mkm Hulu Kelang	Lot 1174, Mkm Hulu Kelang	Lot 1232, Mkm Hulu Kelang	Lot 584(+2), Mkm Hulu Kelang	Lot 579, Mkm Hulu Kelang
Min elevation (meter)	161	0	98	78	88
Max elevation (meter)	164	0	98	106	139
Range (meter)	3	0	0	28	51
Mean slope of property unit (degree)	2.9331	-	2.9881	8.2819	9.1821
Mean slope-rise of property unit (%)	5.1242	-	5.2199	14.5853	16.1999
Mean slope-rise (float), ΔS	0.0512	-	0.0522	0.1459	0.1620
Surface roughness index, VRM	0.0069	-	0.0020	0.0050	0.0052
$\Delta S = S_{Comparable\ i} - S_{Subject}$		NA	0.0010	0.0946	0.1108
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		NA	(0.0049)	(0.0020)	(0.0018)
$\Delta S + \Delta VRM$		NA	(0.0039)	0.0927	0.1090
$\Delta S + \Delta VRM$ (%)		NA	-0.39%	9.27%	10.90%
Proposed terrain adjustment (to the nearest 5%)		**NA**	**0.00%**	**10.00%**	**10.00%**

Table 4.2: Terrain element values and proposed adjustment for subject HK "A" generated from ASTER GDEM.

PROPERTY	**Subject HK "A"**	**Comparable HK1**	**Comparable HK2**	**Comparable HK3**	**Comparable HK4**
Property ID	Lot 1190, Mkm Hulu Kelang	Lot 1174, Mkm Hulu Kelang	Lot 1232, Mkm Hulu Kelang	Lot 584(+2), Mkm Hulu Kelang	Lot 579, Mkm Hulu Kelang
Min elevation (meter)	181	108	89	83	114
Max elevation (meter)	199	128	113	121	175
Range (meter)	18	20	24	38	61
Mean slope of property unit (degree)	10.0909	20.9035	12.5603	12.3098	16.3494
Mean slope-rise of property unit (%)	17.8281	38.3107	22.4936	21.9118	29.8051
Mean slope-rise (float), ΔS	0.1783	0.3831	0.2249	0.2191	0.2981
Surface roughness index, VRM	0.0132	0.0066	0.0127	0.0057	0.0127
$\Delta S = S_{Comparable\ i} - S_{Subject}$		0.2048	0.0467	0.0408	0.1198
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		(0.0065)	(0.0005)	(0.0074)	(0.0005)
$\Delta S + \Delta VRM$		0.1983	0.0462	0.0334	0.1193
$\Delta S + \Delta VRM$ (%)		0.1983	4.62%	3.34%	11.93%
Proposed terrain adjustment (to the nearest 5%)		**20.00%**	**5.00%**	**5.00%**	**10.00%**

Table 4.3: Terrain element values and proposed adjustment for subject DA "A" generated from SRTM DEM.

PROPERTY	Subject DA "A"	Comparable DA1	Comparable DA2	Comparable DA3	Comparable DA4
Property ID	Lot 9582, Bdr Sg Buloh	PT 9671, Bdr Sg Buloh	PT 9600, Bdr Sg Buloh	PT 9605, Bdr Sg Buloh	Lot 9588, Bdr Sg Buloh
Min elevation (meter)	58	57	59	108	77
Max elevation (meter)	66	66	61	136	77
Range (meter)	8	9	2	28	0
Mean slope of property unit (degree)	5.4676	4.8595	0.9816	18.1805	3.1517
Mean slope-rise of property unit (%)	9.5809	8.5026	1.7135	32.8437	5.5063
Mean slope-rise (float), ΔS	0.0958	0.0850	0.0171	0.3284	0.0551
Surface roughness index, VRM	0.0020	0.0011	0.0016	0.0052	0.0071
$\Delta S = S_{Comparable\ i} - S_{Subject}$		(0.0108)	(0.0787)	0.2326	(0.0407)
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		(0.0010)	(0.0004)	0.0032	0.0051
$\Delta S + \Delta VRM$		(0.0117)	(0.0791)	0.2358	(0.0357)
$\Delta S + \Delta VRM$ (%)		-1.17%	-7.91%	23.58%	-3.57%
Proposed terrain adjustment (to the nearest 5%)		**0.00%**	**-10.00%**	**25.00%**	**-5.00%**

Table 4.4: Terrain element values and proposed adjustment for subject DA "A" generated from ASTER GDEM.

PROPERTY	Subject DA "A"	Comparable DA1	Comparable DA2	Comparable DA3	Comparable DA4
Property ID	Lot 9582, Bdr Sg Buloh	PT 9671, Bdr Sg Buloh	PT 9600, Bdr Sg Buloh	PT 9605, Bdr Sg Buloh	Lot 9588, Bdr Sg Buloh
Min elevation (meter)	53	52	54	103	45
Max elevation (meter)	111	88	81	154	99
Range (meter)	58	36	27	51	54
Mean slope of property unit (degree)	16.4406	11.6643	12.7726	16.6172	20.8384
Mean slope-rise of property unit (%)	30.3220	20.8298	22.9684	29.9728	38.9737
Mean slope-rise (float), ΔS	0.3032	0.2083	0.2297	0.2997	0.3897
Surface roughness index, VRM	0.0165	0.0059	0.0091	0.0060	0.0240
$\Delta S = S_{Comparable\ i} - S_{Subject}$		(0.0949)	(0.0735)	(0.0035)	0.0865
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		(0.0105)	(0.0073)	(0.0105)	0.0076
$\Delta S + \Delta VRM$		(0.1054)	(0.0809)	(0.0140)	0.0941
$\Delta S + \Delta VRM$ (%)		-10.54%	-8.09%	-1.40%	9.41%
Proposed terrain adjustment (to the nearest 5%)		**-10.00%**	**-10.00%**	**0.00%**	**10.00%**

Table 4.5: Terrain element values and proposed adjustment for subject LD "A" generated from SRTM DEM.

PROPERTY	Subject LD "A"	Comparable LD1	Comparable LD2	Comparable LD3	Comparable LD4	Comparable LD5	Comparable LD6
Property ID	Lot 31, Mkm Kuala Kalumpang	Lot 724(+3), Mkm Ampang Pechah & Rasa	Lot 35, Mkm Sg Tinggi	Lot 2566, Mkm Batang Kali	Lot 2418(+22), Mkm Serendah & Rasa	Lot 1899, Mkm Hulu Bernam	Lot 146(+28), Mkm Sg Gumut & Kerling
Min elevation (meter)	52	44	22	132	26	13	52
Max elevation (meter)	146	347	80	511	254	133	135
Range (meter)	94	303	58	379	228	120	83
Mean slope of property unit (degree)	4.79384	9.94562	4.06387	17.88796	7.41632	3.11739	4.45893
Mean slope-rise of property unit (%)	8.40139	17.80320	7.11539	32.71541	13.08753	5.46537	7.81062
Mean slope-rise (float), ΔS	0.0840	0.1780	0.0712	0.3272	0.1309	0.0547	0.0781
Surface roughness index, VRM	0.00223	0.00619	0.00131	0.00971	0.00494	0.00100	0.00214
$\Delta S = S_{Comparable\ i} - S_{Subject}$		0.0940	(0.0129)	0.2431	0.0469	(0.0294)	(0.0059)
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		0.0040	(0.0009)	0.0075	0.0027	(0.0012)	(0.0001)
$\Delta S + \Delta VRM$		0.09798	(0.01378)	0.25062	0.04957	(0.03059)	(0.00600)
$\Delta S + \Delta VRM$ (%)		9.80%	-1.38%	25.06%	4.96%	-3.06%	-0.60%
Proposed terrain adjustment (to the nearest 5%)		**10.00%**	**0.00%**	**25.00%**	**5.00%**	**-5.00%**	**0.00%**

Table 4.6: Terrain element values and proposed adjustment for subject LD "A" generated from ASTER GDEM.

PROPERTY	Subject LD "A"	Comparable LD1	Comparable LD2	Comparable LD3	Comparable LD4	Comparable LD5	Comparable LD6
Property ID	Lot 31, Mkm Kuala Kalumpang	Lot 724(+3), Mkm Ampang Pechah & Rasa	Lot 35, Mkm Sg Tinggi	Lot 2566, Mkm Batang Kali	Lot 2418(+22), Mkm Serendah & Rasa	Lot 1899, Mkm Hulu Bernam	Lot 146(+28), Mkm Sg Gumut & Kerling
Min elevation (meter)	22	22	5	118	9	3	19
Max elevation (meter)	155	352	75	487	271	146	137
Range (meter)	133	330	70	369	262	143	118
Mean slope of property unit (degree)	11.24599	15.17448	8.93023	19.32143	13.54213	7.98425	11.29987
Mean slope-rise of property unit (%)	20.14301	27.83305	15.87916	36.28710	24.56620	14.19639	0.00808
Mean slope-rise (float), ΔS	0.2014	0.2783	0.1588	0.3629	0.2457	0.1420	0.0001
Surface roughness index, VRM	0.00808	0.00992	0.00664	0.01032	0.00944	0.00500	0.00899
$\Delta S = S_{Comparable\ i} - S_{Subject}$		0.0769	(0.0426)	0.1614	0.0442	(0.0595)	(0.2013)
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		0.0018	(0.0014)	0.0022	0.0014	(0.0031)	0.0009
$\Delta S + \Delta VRM$		0.07874	(0.04408)	0.16368	0.04559	(0.06255)	(0.20044)
$\Delta S + \Delta VRM$ (%)		7.87%	-4.41%	16.37%	4.56%	-6.25%	-20.04%
Proposed terrain adjustment (to the nearest 5%)		**10.00%**	**-5.00%**	**15.00%**	**5.00%**	**-5.00%**	**-20.00%**

Table 4.7: Terrain element values and proposed adjustment for subject LD "B" generated from SRTM DEM.

PROPERTY	Subject LD "B"	Comparable LD1	Comparable LD2	Comparable LD3	Comparable LD4	Comparable LD5	Comparable LD6
Property ID	Lot 1, Mkm Peretak	Lot 724(+3), Mkm Ampang Pechah & Rasa	Lot 35, Mkm Sg Tinggi	Lot 2566, Mkm Batang Kali	Lot 2418(+22), Mkm Serendah & Rasa	Lot 1899, Mkm Hulu Bernam	Lot 146(+28), Mkm Sg Gumut & Kerling
Min elevation (meter)	637	44	22	132	26	13	52
Max elevation (meter)	1,335	347	80	511	254	133	135
Range (meter)	698	303	58	379	228	120	83
Mean slope of property unit (degree)	16.2369	9.94562	4.06387	17.88796	7.41632	3.11739	4.45893
Mean slope-rise of property unit (%)	29.5588	17.80320	7.11539	32.71541	13.08753	5.46537	7.81062
Mean slope-rise (float), ΔS	0.2956	0.1780	0.0712	0.3272	0.1309	0.0547	0.0781
Surface roughness index, VRM	0.0102	0.00619	0.00131	0.00971	0.00494	0.00100	0.00214
$\Delta S = S_{comparable\ i} - S_{subject}$		(0.1176)	(0.2244)	0.0316	(0.1647)	(0.2409)	(0.2175)
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		(0.0040)	(0.0089)	(0.0005)	(0.0053)	(0.0092)	(0.0081)
ΔS + ΔVRM		(0.12156)	(0.23332)	0.03108	(0.16997)	(0.25013)	(0.22554)
ΔS + ΔVRM (%)		-12.16%	-23.33%	3.11%	-17.00%	-25.01%	-22.55%
Proposed terrain adjustment (to the nearest 5%)		**-10.00%**	**-25.00%**	**5.00%**	**-15.00%**	**-25.00%**	**-25.00%**

Table 4.8: Terrain element values and proposed adjustment for subject LD "B" generated from ASTER GDEM.

PROPERTY	Subject LD "B"	Comparable LD1	Comparable LD2	Comparable LD3	Comparable LD4	Comparable LD5	Comparable LD6
Property ID	Lot 1, Mkm Peretak	Lot 724(+3), Mkm Ampang Pechah & Rasa	Lot 35, Mkm Sg Tinggi	Lot 2566, Mkm Batang Kali	Lot 2418(+22), Mkm Serendah & Rasa	Lot 1899, Mkm Hulu Bernam	Lot 146(+28), Mkm Sg Gumut & Kerling
Min elevation (meter)	623	22	5	118	9	3	19
Max elevation (meter)	2,583	352	75	487	271	146	137
Range (meter)	1,960	330	70	369	262	143	118
Mean slope of property unit (degree)	24.00851	15.17448	8.93023	19.32143	13.54213	7.98425	11.29987
Mean slope-rise of property unit (%)	77.18009	27.83305	15.87916	36.28710	24.56620	14.19639	0.00808
Mean slope-rise (float), ΔS	0.7718	0.2783	0.1588	0.3629	0.2457	0.1420	0.0001
Surface roughness index, VRM	0.0213	0.00992	0.00664	0.00944	0.00494	0.00500	0.00899
$\Delta S = S_{Comparable\ i} - S_{Subject}$		(0.4935)	(0.6130)	(0.4089)	(0.5261)	(0.6298)	(0.7717)
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		(0.0114)	(0.0146)	(0.0118)	(0.0164)	(0.0163)	(0.0123)
$\Delta S + \Delta VRM$		(0.50484)	(0.62766)	(0.42078)	(0.54249)	(0.64613)	(0.78402)
$\Delta S + \Delta VRM$ (%)		-50.48%	-62.77%	-42.08%	-54.25%	-64.61%	-78.40%
Proposed terrain adjustment (to the nearest 5%)		**-50.00%**	**-65.00%**	**-40.00%**	**-55.00%**	**-65.00%**	**-80.00%**

Further discussion and analysis of the method's outputs can be found in the following chapter.

4.2 Analysis of Questionnaire Survey Feedback

The questionnaire survey consists of 22 multiple choice and two (2) open-ended questions aimed at gathering feedback from industry practitioners regarding the study subject. The survey was distributed via email to industry experts and published online in the Malaysian valuation community forums. At the end of the survey period, 120 responses were received with 28 respondents (23.33%) answering all questions.

In Section A of the survey, it was found that government valuers were an overwhelming majority of the respondents (Figure 4.1) compared to other sectors which were only represented by one out of five respondents. In terms of age, the respondent distribution appeared reasonable, with about two-third below 45 years old (Figure 4.2). Almost all respondents have at least a bachelor degree in property-related studies, with a quarter of respondents having advanced academic qualifications (Figure 4.3). In terms of work experience, about a quarter of respondents were from the junior-level (below 7 years work experience) group, while distribution is even between mid-level (7 to 15 years) and senior-level (above 50 years) real estate practitioners (Figure 4.4). However, licensed valuers made a minority group in the survey, as less than 30% of respondents had professionally qualified as registered valuers (Figure 4.5).

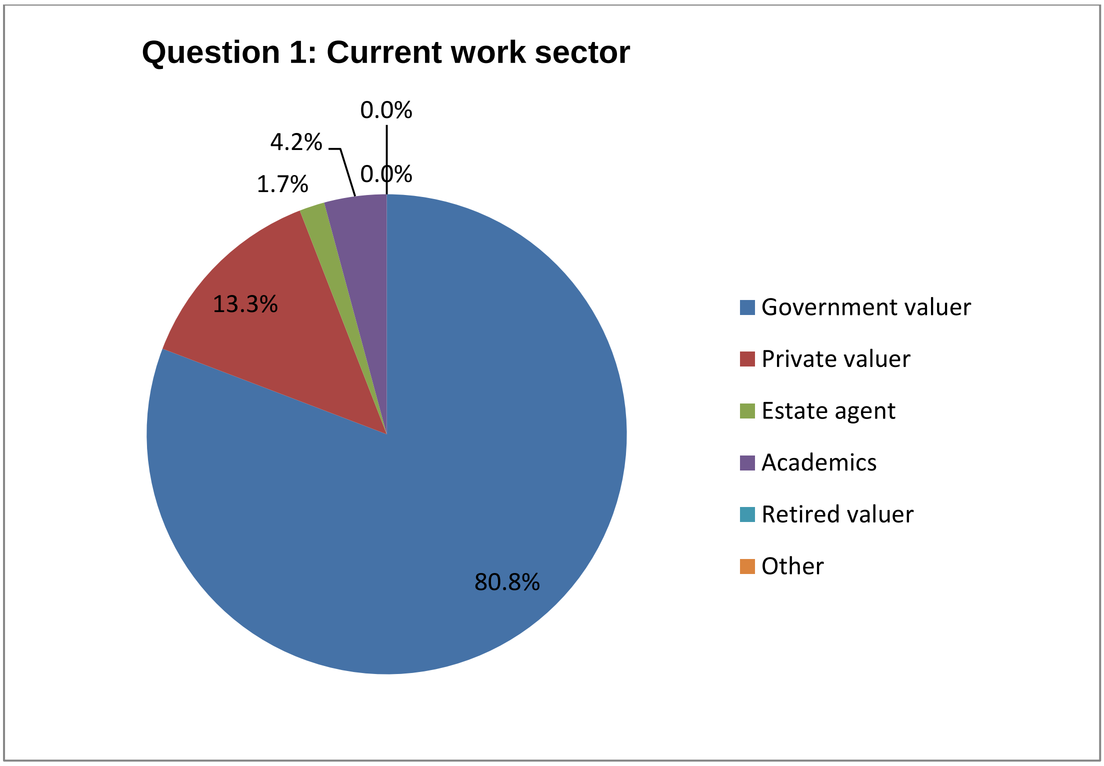

Figure 4.1: Distribution of respondent work sector.

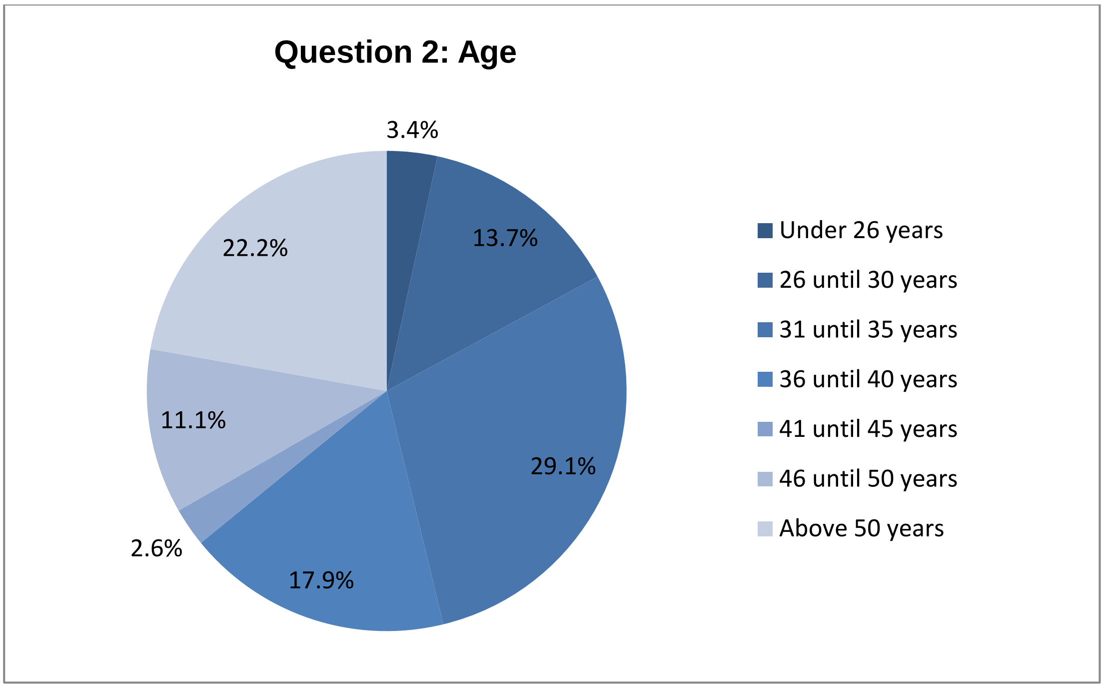

Figure 4.2: Respondent age distribution.

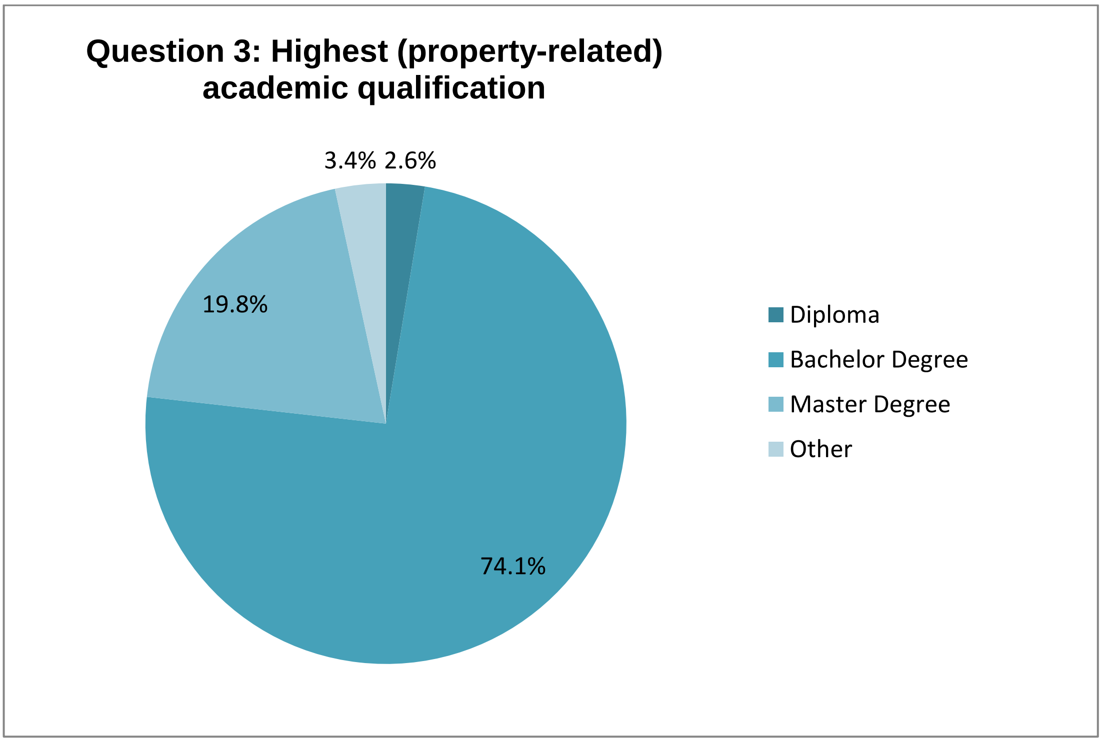

Figure 4.3: Respondent academic background.

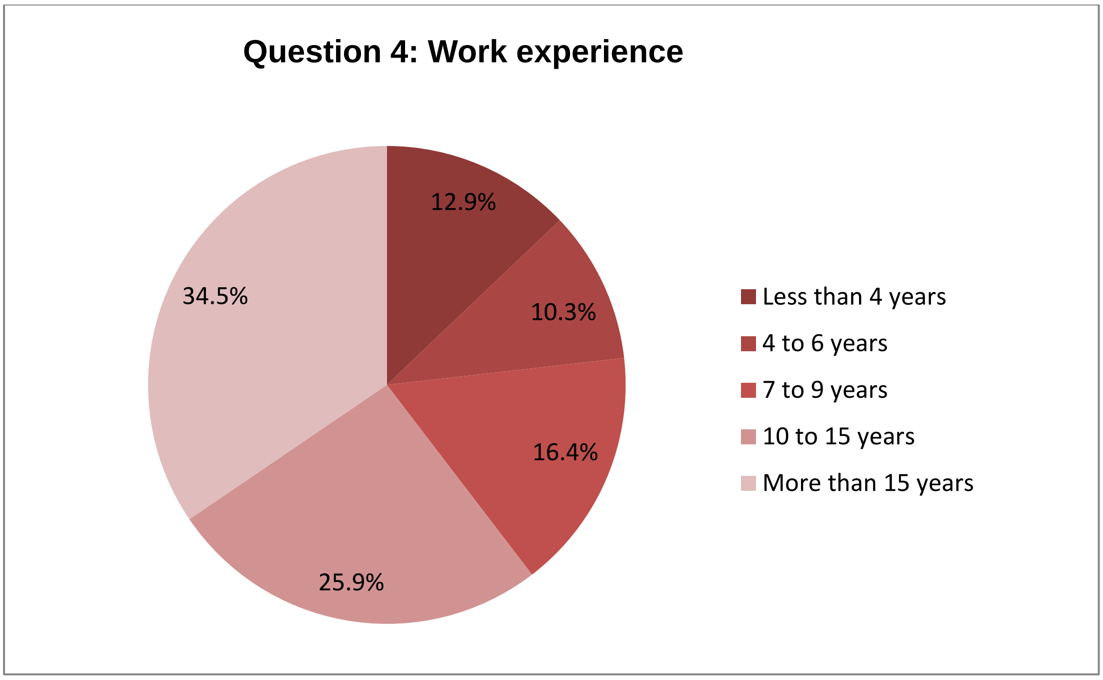

Figure 4.4: Respondent work experience.

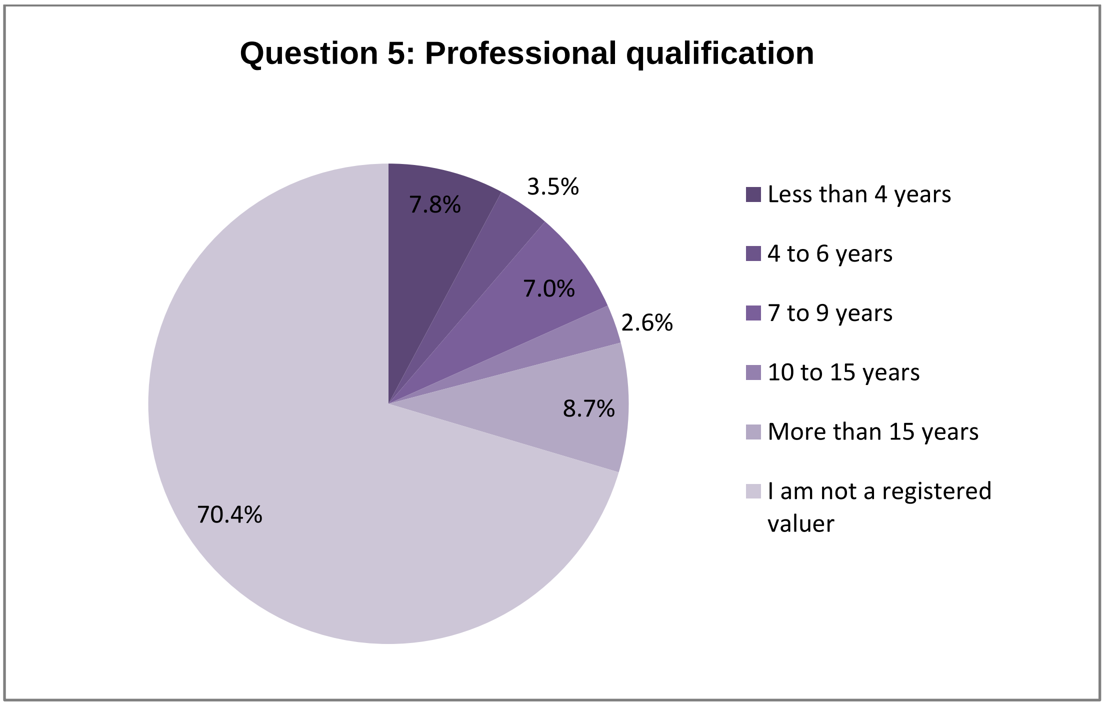

Figure 4.5: Respondent professional status.

Section B of the survey attempted to obtain information about how respondents individually rate a selection of factors affecting value. Question 6 required respondents to rank availability of legal road access, property layer, shape of property lot, size of property lot, and terrain condition factors on a scale of 1 (highest) to 5 (lowest) according to the factors' impact on value. The layer and accessibility factors scored best with six out of 10 respondents ranking those as either first or second (Figure 4.6). The layer factor, referring to the position of a property from the closest road, is extremely relevant when a property is located at an interior location without road access, due to the costs of applying for "rights of way" or compensation to pass through other private properties between the nearest road and the subject.

Terrain is perceived in the middle ground among the factors, with more than one-third of respondents ranking it as having the third highest impact on value.

These views are consistent with the feedback for Question 7, which asked respondents to rate the effects that the same set of factors have upon value (Figure 4.7). Once again, layer and accessibility were highly rated and both were the only factors that were perceived as having strong impact compared to the others.

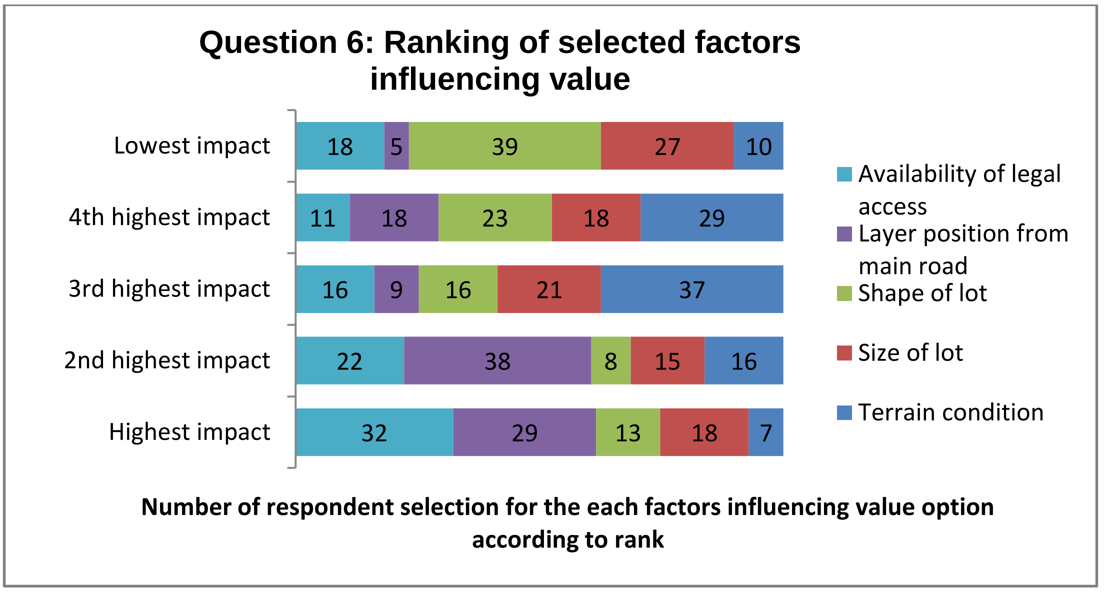

Figure 4.6: Respondent ranking of selected factors influencing value.

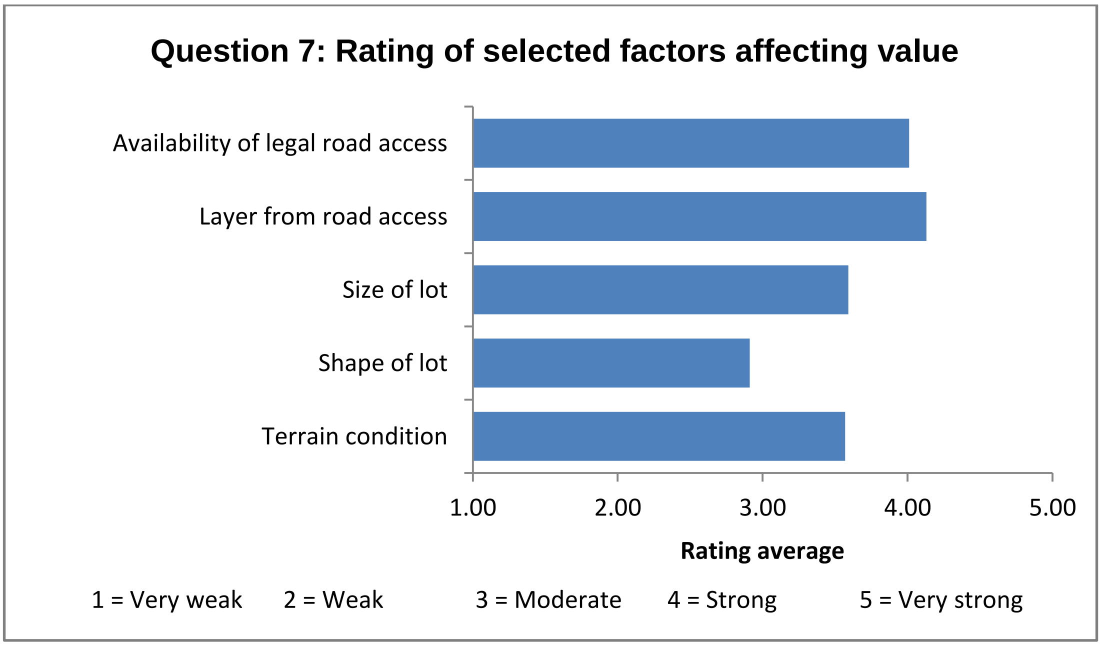

Figure 4.7: Respondent rating of selected factors influencing value.

The first question in Section C (Question 8) required respondents to associate selected adjectives with the terrain condition shown in a set of six photographs (Figure 4.8). It was interesting to note that with the exception of Photograph A5, the responses for the remaining five were very mixed in their character.

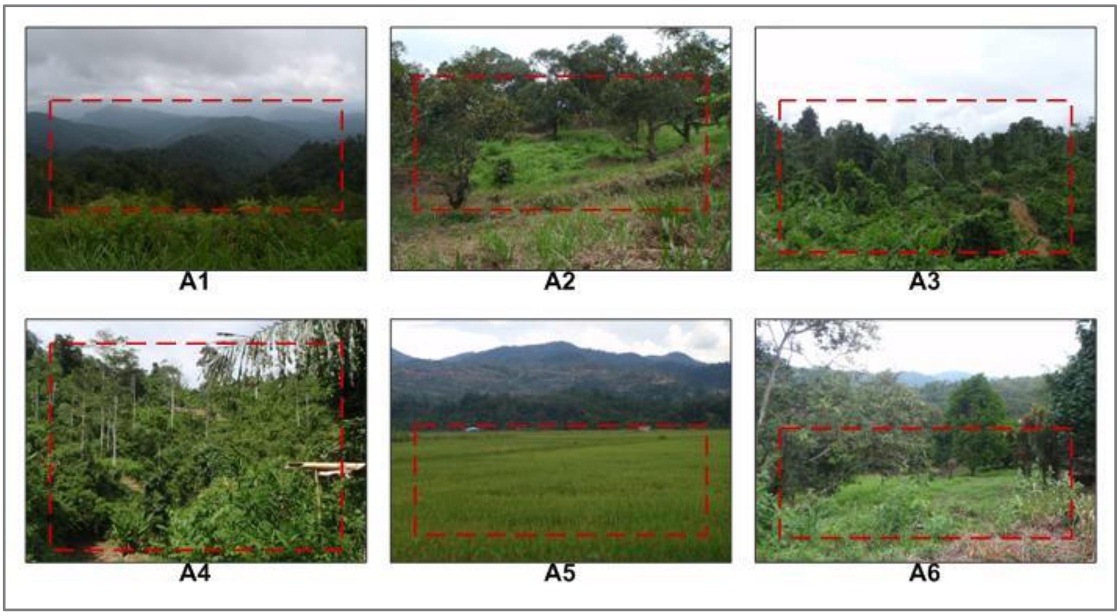

Figure 4.8: Selected terrain images for Question 8.

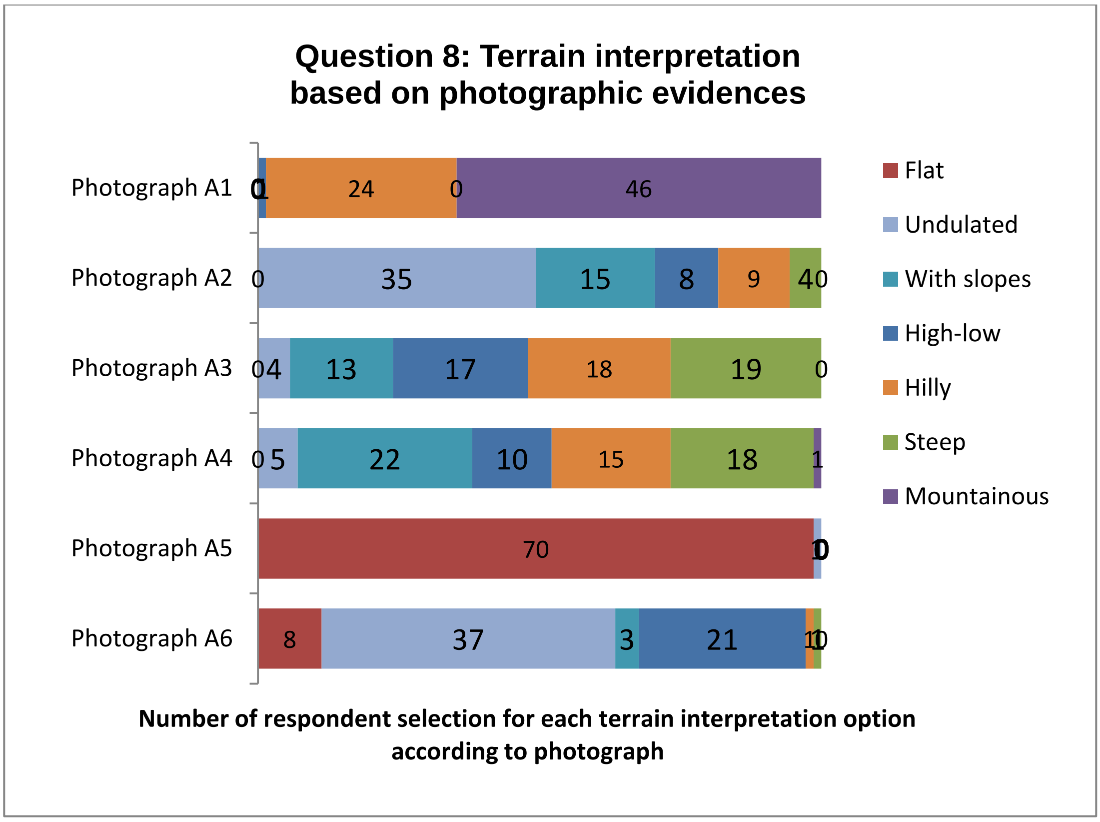

Figure 4.9: Respondent interpretation of photographic evidences in Question 8.

An open-ended question (Question 9) requested a brief description of how respondents would record the terrain in their inspection notes. Some consistency was detected in the description of Photograph A5, but the general vocabulary choices used in the descriptions, especially for uneven surfaces, showed a wide range of variation. It was noted that out of 71 respondents, less than 15 attempted to be thorough in their explanation by at least guessing the height or slope angle of the terrain shown. Only one respondent exercised great detail when explaining the terrain in the foreground, background, left and right side of the photo with a rough estimate of height and slope angle.

Question 10 required respondents to suggest reasonable adjustments for the terrain factor based on contour plans (Figure 4.10). For the purpose of this question, the labels B1, B2, B3 and B4 were used as property identifiers. Property B1 was selected as a provisional subject property to be compared with B2, B3 and B4. The average adjustments suggested for the three comparable against subject B1 ranges between -7.34% and -13.83% (Figure 4.11), which implied that respondents were consistent in viewing the comparable as moderately favoured (better) in terms of terrain conditions.

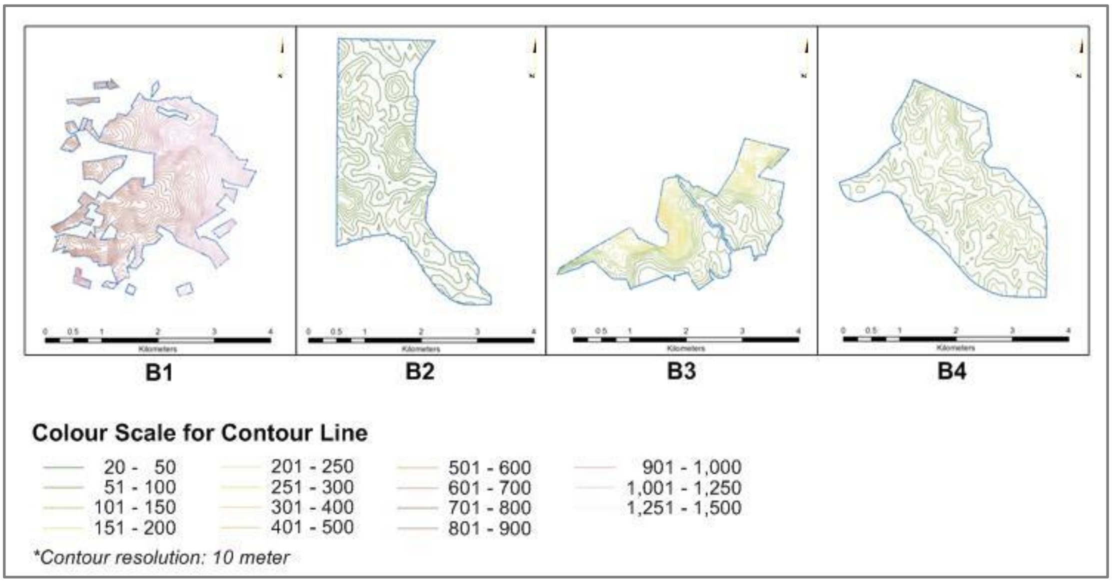

Figure 4.10: Scaled contour plan attached to Question 10.

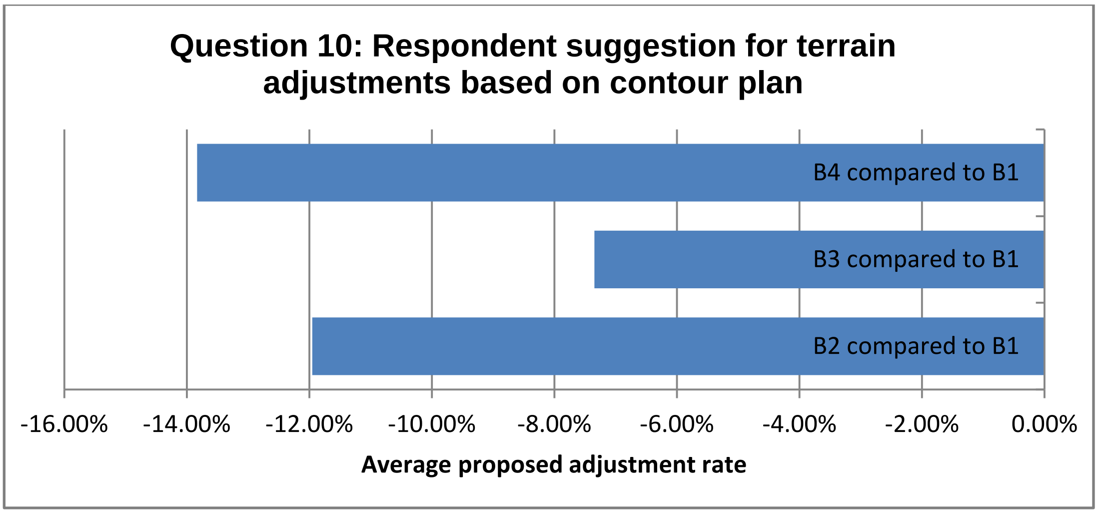

Figure 4.11: Respondent suggestion of terrain adjustment based on contour plan analysis.

Question 11 is similar to Question 10 and involved the same set of properties but rearranged to appoint a different subject property. This time, the property identifiers are referred to as C1, C2, C3 and C4. The images provided to aid respondents were 3D terrain renditions of the properties (Figure 4.12).

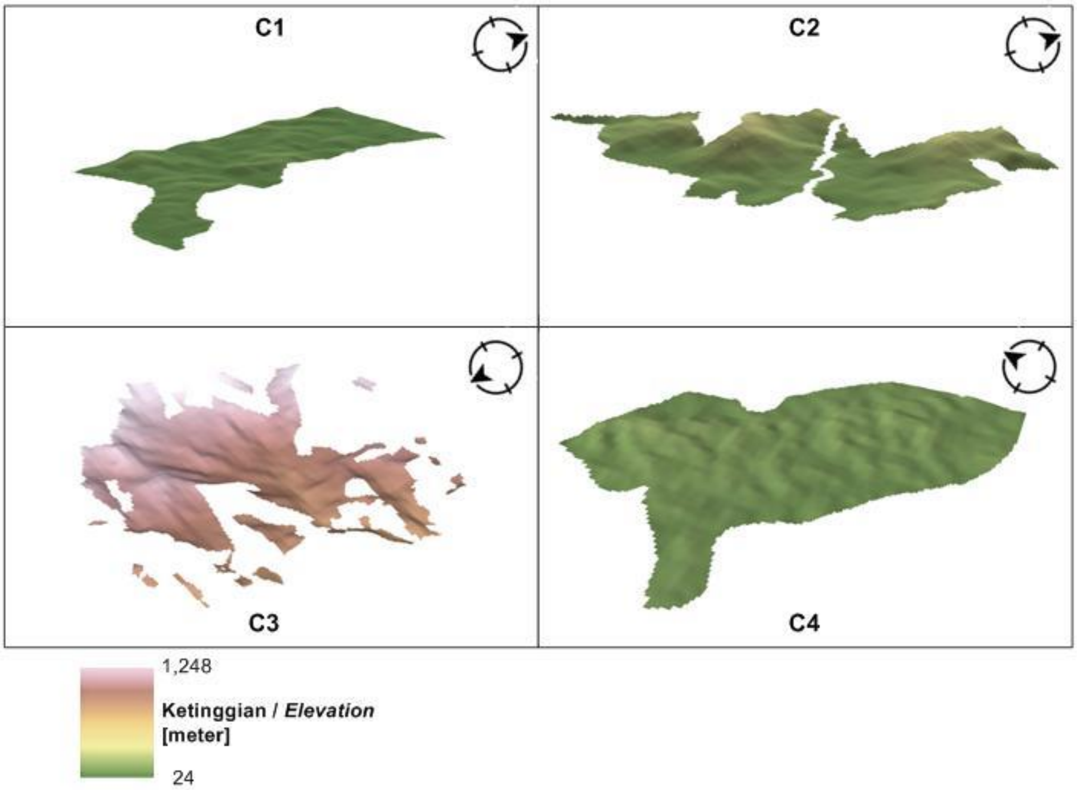

Figure 4.12: 3D-image renditions attached to Question 11.

Strangely, some inconsistencies were noted in the feedback as the proposed adjustments were widely distributed across the negative and positive ends of the adjustment range. In particular, when comparing comparable C3 to subject C1, almost equal number of respondents selected the maximum adjustment option at both ends (negative and positive) of the adjustment options (Figure 4.13). Reasons behind this result will be speculated in the following chapter.

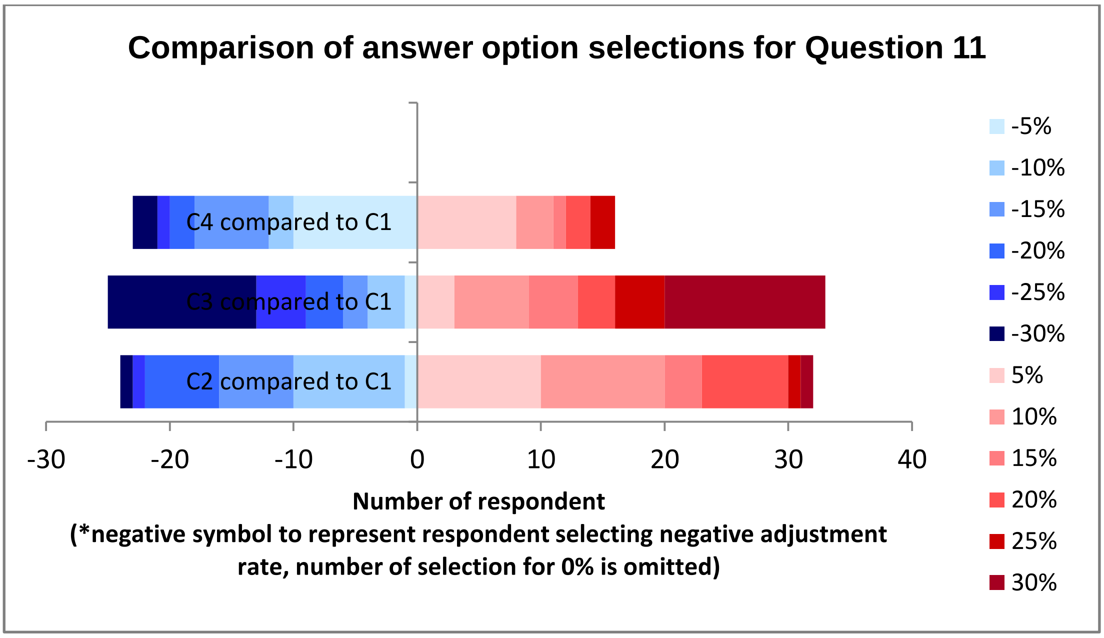

Figure 4.13: Comparison of answer option selection for Question 11.
Note that the trend showed almost even selection on both negative and positive sides.

Respondents were also asked how they will proceed with the valuation in the event that the property is inaccessible for inspection (Question 12). In the context of valuation, (in)accessibility refers to the ability to reach or arrive at a specific property. It is usually related to the existence (and/or absence) of road, path or trail. Sometimes, accessibility is prevented by natural factors such as rivers (without crossings), mountains or deep chasms. Sometimes it is caused by natural disasters (flood, landslide etc.), national policy (warzone, disease zone etc.) and many other factors. Of course, accessibility itself is one of the factors affecting value.

The majority replied that they would seek information from sources such as topographic maps or web applications such as Google Earth or request the client to provide a description of the property (Figure 4.14).

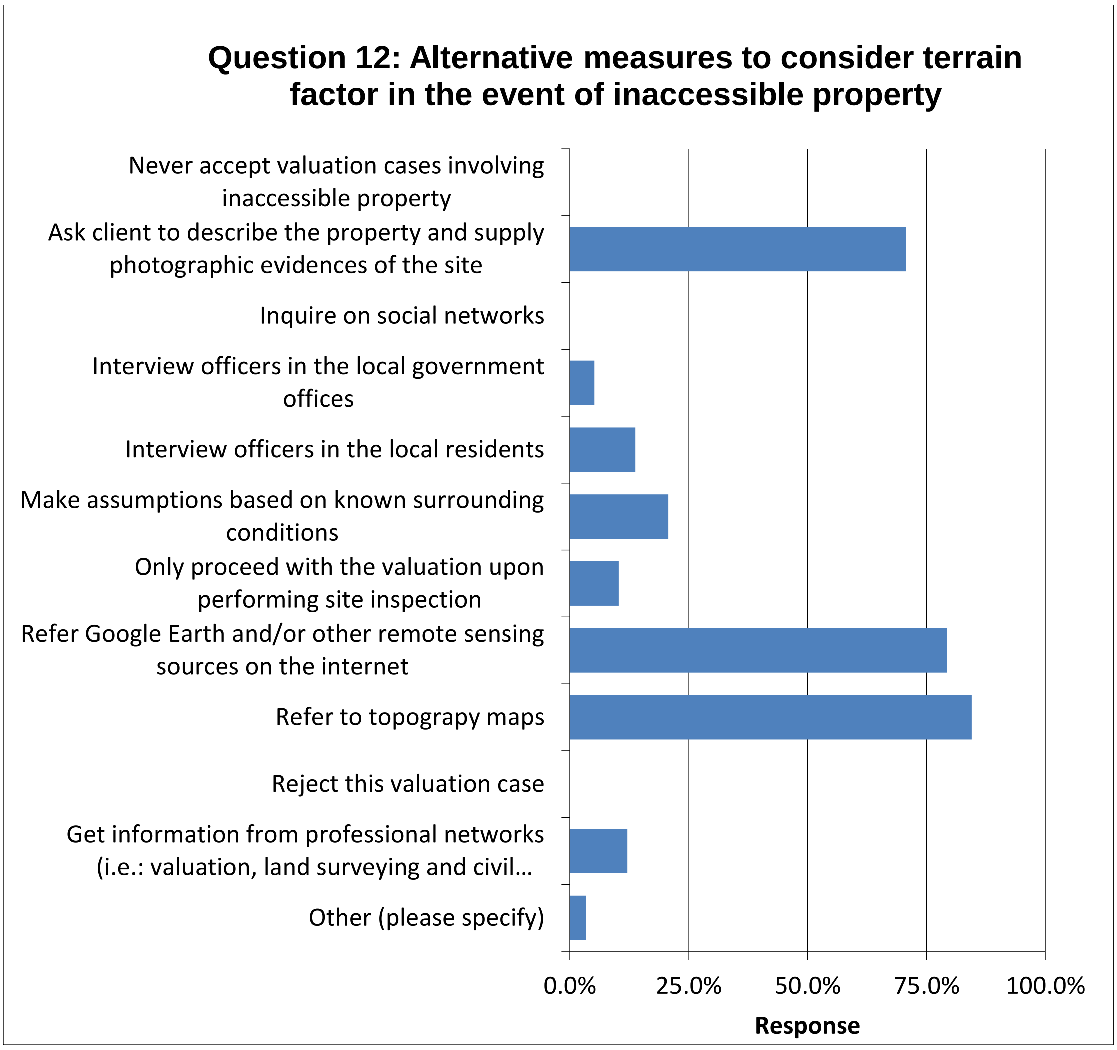

Figure 4.14: Respondent action in the event of inaccessible property.

Question 13 through 20 in Section D required respondents to evaluate the terrain adjustments proposed by the method. The questions involved four subject properties, in different size categories. The questions were in pairs, where the first question asked respondents to judge the method-output while the second asked for the respondent's opinion on how much adjustment they would allow if they were personally handling this case. Please refer to Section D of the survey questionnaire (Appendix C) for the complete instructions, questions and attached images.

For ease of reference, the feedback for Questions 13, 15, 17 and 19 are combined in Table 4.9 below to show the average rating given by respondents with regards to the adjustment rates proposed by the method. In the survey, respondents were requested to give judgement on a scale of 1 (too low) to 5 (too high).

Table 4.9: Respondent evaluation of adjustment rates provided by method-output.

Question	13	15	17	19
Comparable 1 vs subject property	3.25	3.10	3.14	2.59
Comparable 2 vs subject property	2.73	2.90	2.79	2.66
Comparable 3 vs subject property	2.67	2.93	3.31	2.86
Comparable 4 vs subject property	2.94	3.33	2.93	2.59
Comparable 5 vs subject property			2.93	2.86
Comparable 6 vs subject property			2.97	2.79
Average according to question	**2.8975**	**3.0650**	**3.0117**	**2.7250**
Overall average	**2.9135**			

The response conveyed a strong rating trend between 2.59 and 3.33 for all adjustment rates suggested by the method. The overall rating average is 2.9135 points, which demonstrated that respondents generally felt the proposed adjustments were sound and reasonable.

Meanwhile, for Question 14, 16, 18 and 20, comparison between method-proposed and industry proposed adjustments showed mixed results (Table 4.10).

In Question 14 and 16, low industry-proposed adjustment rates indicated that respondents view the subject and comparison as very similar as average opinions suggested that a mere ±5% adjustment is sufficient.

In Question 18 and 20, industry-proposed adjustments appeared to be on the conservative side compared to method-proposed adjustments that were more aggressive as some method-proposed adjustments were almost twice of industry-proposed figures.

An analysis of the differences showed RMSE values between 0.04 (4.81%) and 0.11 (11.44%) between the sets. A deeper outlook on the comparison will be further discussed in Chapter 5.

Table 4.10: Comparison between method-proposed adjustments and industry-proposed adjustments.

Question	Property	Method-proposed adjustments	Industry-proposed adjustments	Method-vs-industry difference	RMSE
14	Comparison HK1 vs Subject HK "A"	19.83%	1.67%	18.16%	11.44%
	Comparison HK2 vs Subject HK "A"	4.62%	-2.50%	7.12%	
	Comparison HK3 vs Subject HK "A"	3.34%	-0.52%	3.86%	
	Comparison HK4 vs Subject HK "A"	11.93%	0.63%	11.31%	
16	Comparison DA1 vs Subject DA "A"	-10.54%	-4.63%	-5.92%	4.81%
	Comparison DA2 vs Subject DA "A"	-8.09%	-5.75%	-2.34%	
	Comparison DA3 vs Subject DA "A"	-1.40%	1.38%	-2.77%	
	Comparison DA4 vs Subject DA "A"	9.41%	2.75%	6.66%	
18	Comparison LD1 vs Subject LD "A"	9.80%	3.62%	6.18%	6.98%
	Comparison LD2 vs Subject LD "A"	-1.38%	0.00%	-1.38%	
	Comparison LD3 vs Subject LD "A"	25.06%	10.17%	14.89%	
	Comparison LD4 vs Subject LD "A"	4.96%	2.24%	2.72%	
	Comparison LD5 vs Subject LD "A"	-3.06%	1.72%	-4.78%	
	Comparison LD6 vs Subject LD "A"	-0.60%	-0.17%	-0.43%	
20	Comparison LD1 vs Subject LD "B"	-12.16%	-8.45%	-3.71%	7.93%
	Comparison LD2 vs Subject LD "B"	-23.33%	-15.34%	-7.99%	
	Comparison LD3 vs Subject LD "B"	3.11%	-0.69%	3.80%	
	Comparison LD4 vs Subject LD "B"	-17.00%	-10.52%	-6.48%	
	Comparison LD5 vs Subject LD "B"	-25.01%	-13.62%	-11.39%	
	Comparison LD6 vs Subject LD "B"	-22.55%	-11.90%	-10.66%	

The final section of the survey was meant to observe the reaction of industry members on the inclusion of GIS application in valuation methods.

Question 21 asked respondents whether quantitative methods to analyse terrain should be encouraged in valuation. Interestingly, out of 28 respondents there was just a single response that disagreed with this. The respondent commented that computer-aided adjustments for the terrain factor are inaccurate due to the possibilities of changes in the surface terrain due to natural processes such as erosion, landslide and sinkholes.

Question 22 asked whether GIS education should be included in property valuation programmes, while Question 23 asked whether respondents are interested in undertaking GIS training if the opportunity were to arise. Both questions resulted in an overwhelming “Yes” response.

The final question was open-ended, asking respondent opinion on computer-aided valuation, in particular involving pre-determined algorithms to generate value. In general, most respondents were welcoming to such idea as it is presumed that valuation accuracy would be improved in some aspects and such methods offer better data management efficiency. However, there are some concerns that computer-aided valuation models may be too rigid or robotic in approaching value.

As a compromise, most respondents agree on using computer-generated valuation as a means for checking values derived from traditional methods, but ultimately it should still be up to professional judgement and consideration.

4.3 DEM Accuracy Analysis

DEM accuracy is determined by comparing DEM values with surveyed elevation data at sample points. As many as 523 Standard Benchmark (SBM) points are identified within the study area and to a greater extent, 2,129 SBM points are located within the Klang Valley area in the central region of Malaysia. The average root mean squared error (RMSE) of the study area, when comparing elevation from DEM sources to Standard Benchmark points, is shown in Table 4.11 below.

Table 4.11: RMSE values of DEM elevation

Location	No. of SBM points	RMSE (meter)	
		SRTM DEM	ASTER GDEM
Study area	523	52.2836	57.4871
Klang Valley region	2,129	28.1727	33.7544

Considering that the elevation values of the Standard Benchmark, SRTM DEM and ASTER GDEM are all in meters, the RMSE values are really high. Further discussion on this result will be done in Chapter 5.

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5. Accuracy Assessments and Discussion

As mentioned earlier in the introductory chapter, this study intends to find a way to address a quantifiable geographic factor that affects land value using spatial solutions provided by GIS applications. The terrain factor is selected as the study subject due to its independence from the influences of other factors affecting value. Values of terrain features are extracted from available DEM resources.

This study utilised the SRTM DEM and ASTER GDEM as the main sources of topography data. Elevation values were provided by the DEMs themselves while terrain values for the slope and surface roughness elements were derived using Spatial Analyst tools in the ArcGIS software environment.

Throughout the implementation of the technical workflow, several issues were faced that could possibly jeopardise the integrity of the results.

5.1 DEM Accuracy Assessment

The core data involved in this study is elevation data obtained from SRTM DEM and ASTER GDEM. The accuracy of the DEM is assessed by comparing DEM elevation values with surveyed elevation values at known point locations (SBM points). The DEMs, when compared to elevations from Standard Benchmarks, produced average RMSE values of 53.2836 and 57.4871 meters for the SRTM DEM and ASTER GDEM respectively. These values are almost double the average RMSE values found for the Klang Valley area (encompassing the study area and its surroundings) of 28.1727 meters (SRTM DEM) and 33.7544 meters (ASTER GDEM) (refer to Table 4.7 in Chapter 4). These values are significantly high considering each DEM had expected vertical accuracy of 16 meters (SRTM DEM) and 17 meters (ASTER GDEM).

Further analysis of the 523 sample points discovered 156 points (29.83%), from either the SRTM DEM or ASTER GDEM or both, that showed an elevation difference of more than ±30 meters. The distribution of errors for each DEM is noted in Table 5.1 below.

Table 5.1: Distribution of DEM errors.

Difference with SBM elevation	Frequency of points with errors of:			Total
	More than - 30 meters	Between ± 30 meters	More than + 30 meters	
SRTM DEM	29	430	64	523
ASTER GDEM	46	380	97	523

To investigate the potential causes for the huge differences found, the SBM points were overlaid on a satellite image of the study area to identify which area produced the largest differences. It was noted that both the SRTM DEM and ASTER GDEM showed some consistency in the location of points with the greatest differences. For instance, in both DEMs, points that were 30 meters lower than the SBM elevation were clustered in the north-east and south-west quadrants of the study area.

The SBM points in the north-east quadrant are located along Fraser's Hill Road that ascends west to east (Figure 5.1). This road is located beside a ravine with a river flowing through. Considering that the measurements of known SBM points are along road networks, it highly possible that the SBM points are located on road plateaus. On the other hand, elevation data of DEMs are subject to the cell value according to its resolution. For example, the value of a single SRTM raster cell is representative of a 90 meter-by-90 meter are, while the SBM point elevation may not be located at the centre of the cell. In other words, the SBM point could be located on a high road plateau while the DEM elevation is showing the elevation value of the cell centre which could be a ravine. Similarly, sample points at the south-west quadrant of the study area are also located along rivers, which could provide a speculative, but logical reason for the discrepancies.

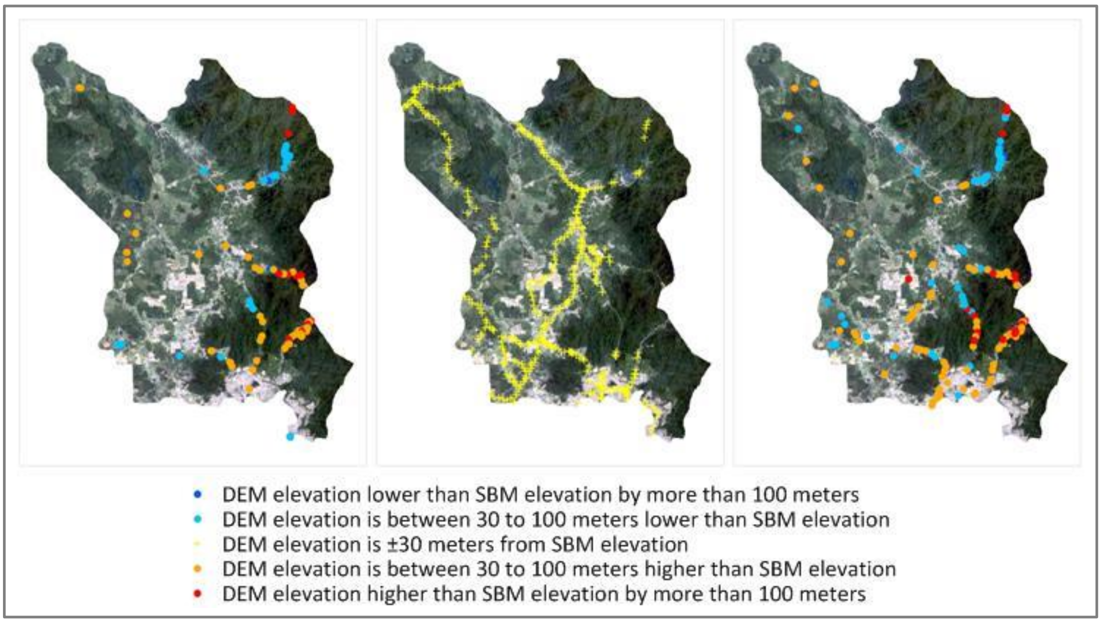

Figure 5.1: An analysis of DEM error distribution in the study area.

Points that recorded higher elevation values (by more than 30 meters) compared to the SBM measurements were evident in the south-east quadrant of the study area. These points are located along major trunk roads that pass through areas of dense tropical vegetation.

According to Bhang et al. (2007) and Carabajal and Harding (2006) as cited by LaLonde et al. (2010), vegetation cover is regarded as a significant cause of DEM error due to signal reflection from tree canopies. This view is supported by Castel and Oettli (2008), also cited by LaLonde et al. (2010) ,who stated that regional studies in France noted that coniferous forests showed a stronger upward bias than deciduous forests, while non-forested areas had lower errors. However, the SRTM sensor is designed to penetrate vegetation, so errors due to tree canopies should be minimal and not so prominent. Therefore, it could be speculated that the SRTM DEM accuracy is affected due to its optical resolution. This matter will be further discussed in paragraph 5.3 below.

In the case of ASTER GDEM, there are some concerns that errors in the south-west quadrant of the study area are due to manmade structures as the area is a heavy-industry zone.

Initially, the study intended to use the SBM points to perform an interpolation of the surface as an alternative source of elevation data apart from the two (2) to DEMs. However, because the SBM points were measured along road networks instead of scattered across the study area (please refer Figure 2.4 in Chapter 2), the interpolated result exhibited bias elevation trends along the roads and was deemed unsuitable for this study, as it did not reasonably resemble the terrain of the study area.

5.2 Method Accuracy

Leaving aside issues with DEM input data, the methods adopted in this study are very simple to execute. It interprets terrain by considering terrain subsets such as elevation, slope and surface roughness.

One of the earliest concerns during the conceptualization of the study was to address the magnitude of the terrain impact. To put the issue into perspective, if 5% is a reasonable adjustment for a 5° slope factor, would the adjustment for a 10° slope factor simply be twice of the 5%? This question arises because the magnitude of the effect of slope with respect to the difficulty it poses for development is amplified as slope angle increases.

The tangent of slope (tan θ) is a function of the opposite and adjacent catheters in a right angle triangle (Figure 5.2). Therefore, in the geographical context, slope is a function of height and distance (rise over run).

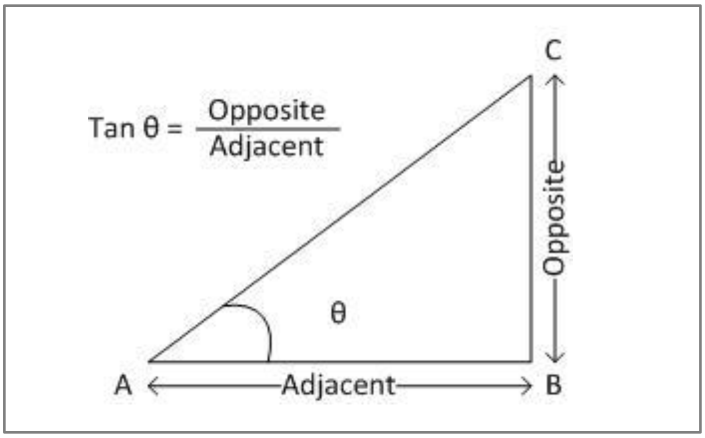

Figure 5.2: Trigonometric function

However, this means that if distance is constant, the increase in slope becomes smaller as elevation rises (Figure 5.3) which does not have the amplification factor that is needed.

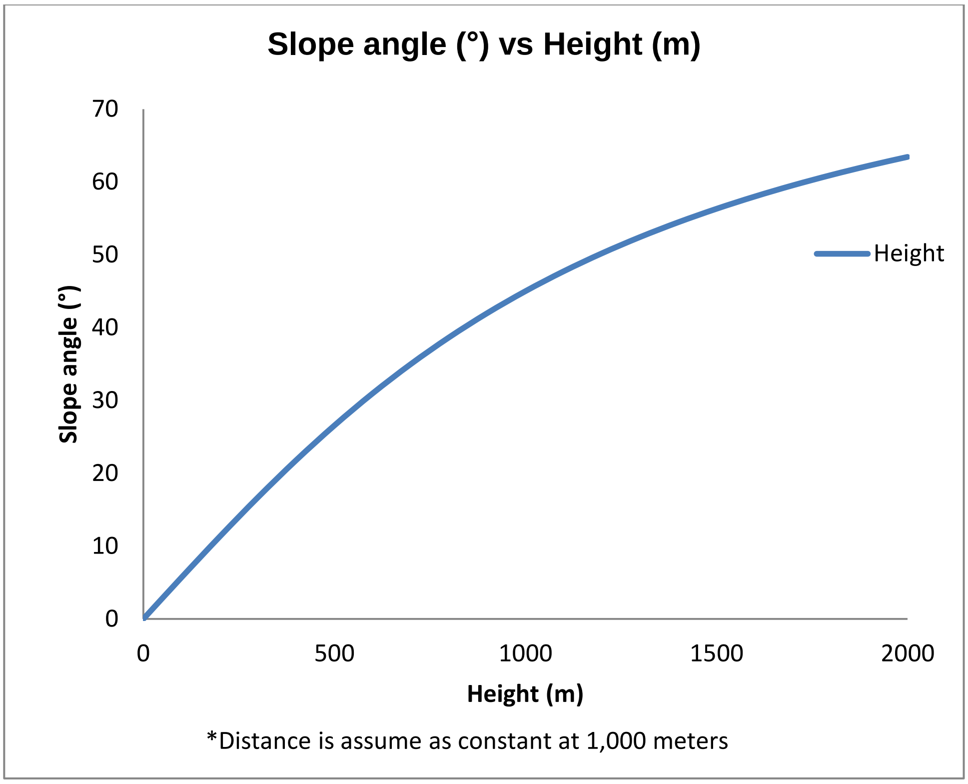

Figure 5.3: The relationship between slope angle and height (elevation) over constant distance.

To address this problem, slope adjustments are instead calculated from slope rise. Slope rise is based on the principles of trigonometry. It is a function of height over distance (Equation 5.1).

$$Slope\ rise = \frac{Height}{Distance} \qquad \text{(Equation 5.1)}$$

This approach is suitable for the purposes of this study as slope rise value is magnified when slope angle increases (Figure 5.4).

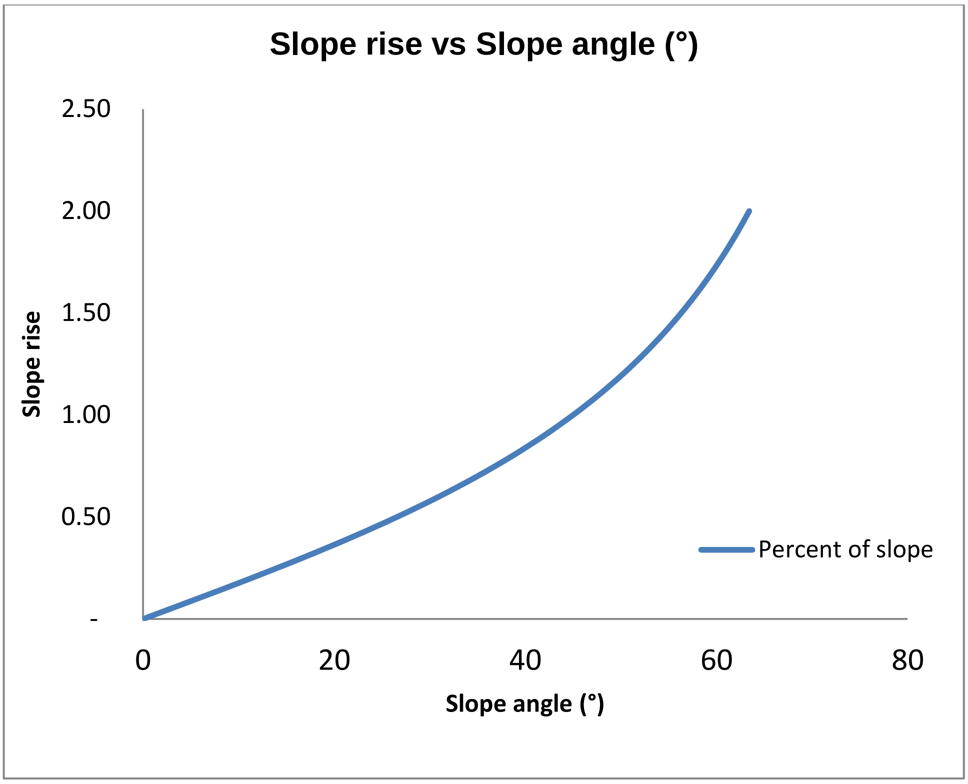

Figure 5.4: The relationship between slope angle and slope rise

Therefore, the magnitude of slope effect is effectively addressed in the method-output. Thus, with regards to the terrain adjustments in valuation, the amount of adjustment is amplified as slope angle increases.

Since the magnitude of slope has already been considered by referring to the slope rise values, the next concern is to ensure the independence of surface roughness to avoid the issue of "double-counting" the slope element. The Vector Ruggedness Measurement (VRM) developed by Sappington et al. (2007) was adopted to calculate surface roughness as it is able to measure the heterogeneity of terrain more independently of slope than other existing terrain indices such as the land surface ruggedness index (LSRI) developed by Beasom et al. (1983) and the terrain ruggedness index (TRI) developed by Riley et al. (1999 (Figure 5.5) .

In his analysis of the LSRI and TRI, (Sappington et al., 2007) noted that there is slight dependency of the indices towards slope angle values (refer top and middle row of Figure 5.5). On the other hand, the VRM displays a more "normalised" distribution against slope (bottom row of Figure 5.5).

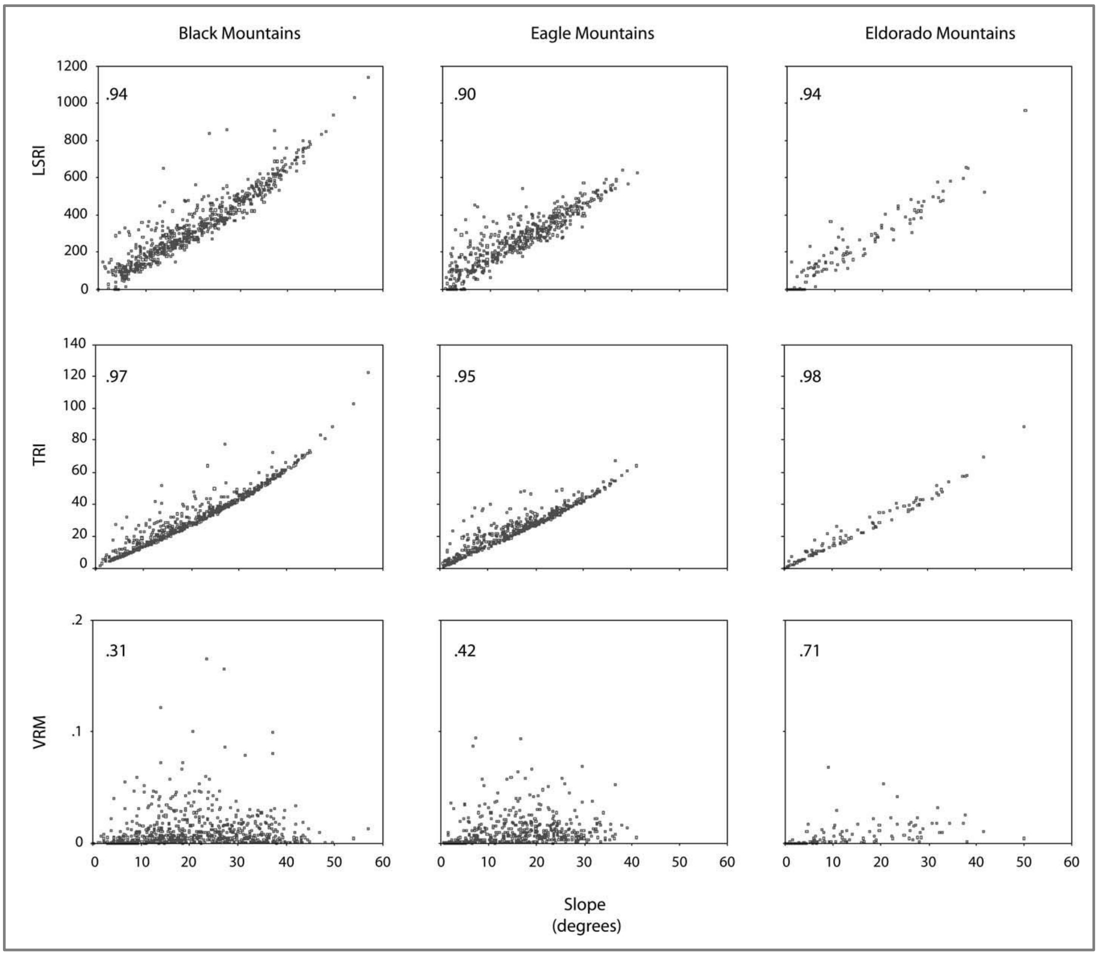

Figure 5.5: Spearman non-parametric correlation coefficients among random point measurements of LSRI, TRI and VRM in southern Nevada (Sappington et al., 2007).

By considering these two issues, it is thus objective to say that the selected study method is able to produce a fair representation of the terrain factor in value adjustments.

5.3 The Effects of DEM Resolution Over Method-Outputs

A comparison between SRTM-derived and ASTER-derived method-outputs showed little resemblance for small properties (set HK "A" and DA "A" in the questionnaire survey). Both sets of output were too varied to establish any similar trends. Neither set demonstrates a resemblance to industry-proposed adjustments. In addition, SRTM-derived adjustment could not be produced for Comparable HK1 versus HK "A" due to the size of the property being smaller than the size of a single SRTM cell (8,100 square meters).

However, for the purposes of this study, it is too soon to conclude that DEM resolution has no effect on small-sized properties. Rather, the sample size for this analysis should be increased and further investigated should be made to confirm the existence or lack of relationship between resolution and property size.

For large properties (set LD "A" and LD "B" in the questionnaire survey), the consistency between both adjustment sets showed improvement for set LD "A" but SRTM-derived adjustments were closer to industry-proposed adjustments.

The industry-SRTM consistency is also evident in set LD "B". However, ASTER-derived adjustments showed extreme outputs exceeding -50% for almost all comparable.

Further investigation of the matter found that ASTER-derived data produced extreme elevation values in some areas, notably for subject LD "B", where its maximum elevation value is recorded as 2,583 meters. This is a huge elevation error considering that the highest point in Peninsula Malaysia - Mount Tahan - only measures 2,187 meters.

Due to these developments, for the purposes of this study, evaluation of method-output in the questionnaire survey adopted the ASTER-derived adjustments for small properties and SRTM-derived adjustments for large properties.

It was initially thought that by having finer spatial resolution, the ASTER-derived data would provide outputs that are closer to industry-outputs. However, the result of this study has shown otherwise. The SRTM-derived data - despite having coarser resolution - proved to provide better consistency to industry estimates.

The outputs are insufficient to draw conclusions regarding the effects of DEM resolution on method-outputs due to the varying result. After all, the ASTER error was a data error and not a resolution issue. Nevertheless, it is fair to say that the SRTM DEM should not be overlooked due to its coarser resolution although it is disadvantageous to use with extremely small properties.

Table 5.2: Comparison of industry-proposed and DEM-derived adjustments.

Property	Industry-proposed adjustments	SRTM-derived-proposed adjustment	SRTM-vs-industry difference	STRM-vs-industry RMSE	ASTER-derived-proposed adjustment	ASTER-vs-industry difference	ASTER-vs-industry RMSE
Comparison HK1 vs Subject HK "A"	1.67%			8.28%	19.83%	18.16%	11.44%
Comparison HK2 vs Subject HK "A"	-2.50%	-0.39%	2.11%		4.62%	7.12%	
Comparison HK3 vs Subject HK "A"	-0.52%	9.27%	9.79%		3.34%	3.86%	
Comparison HK4 vs Subject HK "A"	0.63%	10.90%	10.27%		11.93%	11.31%	
Comparison DA1 vs Subject DA "A"	-4.63%	-1.17%	3.45%	11.72%	-10.54%	-5.92%	4.81%
Comparison DA2 vs Subject DA "A"	-5.75%	-7.91%	-2.16%		-8.09%	-2.34%	
Comparison DA3 vs Subject DA "A"	1.38%	23.58%	22.21%		-1.40%	-2.77%	
Comparison DA4 vs Subject DA "A"	2.75%	-3.57%	-6.32%		9.41%	6.66%	
Comparison LD1 vs Subject LD "A"	3.62%	9.80%	6.18%	6.98%	7.87%	4.25%	9.49%
Comparison LD2 vs Subject LD "A"	0.00%	-1.38%	-1.38%		-4.41%	-4.41%	
Comparison LD3 vs Subject LD "A"	10.17%	25.06%	14.89%		16.37%	6.20%	
Comparison LD4 vs Subject LD "A"	2.24%	4.96%	2.72%		4.56%	2.32%	
Comparison LD5 vs Subject LD "A"	1.72%	-3.06%	-4.78%		-6.25%	-7.98%	
Comparison LD6 vs Subject LD "A"	-0.17%	-0.60%	-0.43%		-20.04%	-19.87%	
Comparison LD1 vs Subject LD "B"	-8.45%	-12.16%	-3.71%	7.93%	-50.48%	-42.04%	49.44%
Comparison LD2 vs Subject LD "B"	-15.34%	-23.33%	-7.99%		-62.77%	-47.42%	
Comparison LD3 vs Subject LD "B"	-0.69%	3.11%	3.80%		-42.08%	-41.39%	
Comparison LD4 vs Subject LD "B"	-10.52%	-17.00%	-6.48%		-54.25%	-43.73%	
Comparison LD5 vs Subject LD "B"	-13.62%	-25.01%	-11.39%		-64.61%	-50.99%	
Comparison LD6 vs Subject LD "B"	-11.90%	-22.55%	-10.66%		-78.40%	-66.51%	

5.4 Evaluation of Method-Output by Industry Experts

As shown in Table 4.9 in the previous chapter, industry experts generally view the adjustments proposed by this method as reasonable. However, a comparison with industry-proposed adjustments (averaged) showed a significant difference in the adjustment rates that valuers would *actually* adopt in their analysis.

In situations involving small properties (set HK "A" and DA "A" in the questionnaire survey), no consistency is shown between method-proposed and industry-proposed adjustments, as industry-proposed adjustments are found within a ±5% range. On the other hand, method-proposed adjustments were more aggressive with suggestions up to 20%, which can be regarded as a large amount.

Meanwhile, analysis of industry-proposed adjustments for large properties (set LD "A" and LD "B" in the questionnaire survey) showed some consistency with method-proposed adjustments where they both proposed large adjustments for the same comparable. However, industry-proposed adjustments were more conservative as they tend to be smaller than method-proposed adjustments.

The motive behind the conservative view (from industry experts) may be speculated, but it is likely because valuers view the whole set of comparable as a unit before forming their opinions. That is to say valuers not only pay attention to one-by-one comparison (as done by the study method), but they also look at how all properties in the adjustment sets would impact the property market together.

5.5 Other Findings from the Study

One of the most general statements made often made by senior work colleagues as one enters the workforce is “As you work longer and gain more experience, you will build up your aptitude and skills in the job”. However, within the context of this study, is there a relationship between work experience and how terrain is perceived?

A closer look at the survey results found insufficient evidence to link terrain perception with work experience as feedback from all segments according work experience showed similar trends in the survey responses. This also applies to status of professional qualification.

Questions 10 and 11 of the survey were provided to simulate a situation that forces valuers to rely on secondary data (instead of seeing the site on their own) to form a judgement on the terrain condition. This is a situation that is sometimes faced during practice in the event that the property in question is inaccessible for site inspection.

In Question 10, contour plans (scaled with colour) were provided as aids. References to contour maps are practiced by valuers in reality. Therefore, it is expected that the survey results would show some consistency in the responses on this issue.

The average industry-proposed adjustments for this question are quite close to method-proposed adjustments (Table 5.3).

Table 5.3: Comparison between industry-proposed and DEM-derived adjustments for Question 10 of the questionnaire survey

Question	Property	Respondent-proposed average adjustment	SRTM-derived-proposed adjustment	SRTM-Respondent RMSE	ASTER-derived-proposed adjustment	ASTER-Respondent RMSE
10	Comparison B2 vs Subject B1	-11.95%	-14.77%	2.84%	-16.59%	3.23%
	Comparison B3 vs Subject B1	-7.34%	-3.47%		-4.54%	
	Comparison B4 vs Subject B1	-13.83%	-14.95%		-15.24%	

In Question 11, 3D-terrain renditions were provided as aids. This is to simulate the 3D-functions attached to programs such as Google Earth that is often referred to in the event of inaccessible property.

Industry-proposed adjustments for this question are surprising as almost no adjustment is given to any of the comparable property (Table 5.4). Zero-adjustments imply that the subject and comparable are of similar characteristic.

Table 5.4: Comparison between industry-proposed and DEM-derived adjustments for Question 11 of the questionnaire survey

Question	Property	Respondent-proposed average adjustment	SRTM-derived-proposed adjustment	SRTM-Respondent RMSE	ASTER-derived-proposed adjustment	ASTER-Respondent RMSE
11	Comparison C2 vs Subject C1	0.52%	11.31%	9.83%	12.04%	11.02%
	Comparison C3 vs Subject C1	1.72%	14.77%		16.59%	
	Comparison C4 vs Subject C1	-1.90%	-0.18%		1.35%	

This finding occurs because respondent selection included the maximum adjustment allocation at both ends (positive/negative) of the adjustment options (refer to Figure 4.13 to see the distributions).

The 3D-terrain rendition attached to the question is scaled using the same colour scale for all properties in the question. Therefore, it is difficult to speculate what were the driving factors that caused such decision.

In addition, the properties in Questions 10 and 11 are the same, with some reshuffling where:

- B1 is identical to C3
- B2 is identical to C1
- B3 is identical to C2
- B4 is identical to C4

Therefore, Comparable B2 versus Subject B1 is actually the inversion of Comparable C3 vs Subject C1.

Nevertheless, survey results showed that while respondents suggested -11.95% adjustment for comparable B2 against subject B1, they only awarded 1.72% for comparable C3 against subject C1, which when inverted as comparable C1 against subject C3 would be -1.72%.

Giving consideration that the method-proposed adjustments were reasonably close to industry-proposed adjustments in Question 10, upon revisiting the 3D-terrain rendition used for Question 11 (refer Figure 4.11 in Chapter 4), it could be speculated that respondents were not quite certain of the images that they are seeing. Since the comparable properties used in this question were large estates measuring more than 100 hectares each, the "dumps" on the terrain surface did not properly register as "hills" as seen in actual reality, but were viewed as slight mounds on an uneven surface. In addition to that, the use of colours to represent elevation was also disregarded as the impact of a 3D-image is larger.

Although the inconsistency of the result of Question 11 could not be explained, it could at least be said for certain that respondents have a better comprehension of the information displayed in a contour plan (refer Figure 4.10) than a 3D-image rendition of terrain surface.

5.6 Applicability

The DEM accuracy assessment may show that the DEM data is inaccurate due to the large average errors, however, that does not mean that the study method is inapplicable. Considering that the method managed to address the concerns discussed in paragraph 5.2 and there was favourable feedback from industry experts, this method should be given some thought.

One of the limitations of this study is the absence of good quality sampled elevation measurements within the study area. The availability of such data would allow interpolation of a DEM for the study area based on local data. The SBM data provided by JUPEM were unfortunately located along major road networks where the data is collected. This disadvantage produced biased interpolation results that do not resemble the general terrain of the study area at any significant distance from roads.

Should a good set of elevation data becomes available, this method will be extremely valuable as a quantitative-based support for individual opinion of terrain. From another perspective, it may also be said that the study method can be immediately applied wherever high quality elevation data is available.

The need for such a (quantitative-based) method is proven by the survey where although respondents were most consistent in their interpretation of flat surfaces, variation of interpretation gained prominence when terrain features are more diverse. When respondents were presented with an open-ended question requiring them to describe a set of photographs containing terrain images (Question 9), it is interesting to observe what features that were evident in the photograph were given the greatest emphasis in their descriptions. A majority of respondents used simple descriptions such as “hilly” or “mountainous” or “steep” to describe rough, uneven surfaces with high relief, but what do they mean? What are the differences?

On the other hand, by having a numerical representation of the feature, the scale of interpretation may be significantly reduced.

In addition, the valuation community is generally receptive and welcoming to methods that would make their work simpler and contribute to production efficiency. If training and service support is provided, the industry is more than willing to invest in GIS solutions for the purposes of their work. However, survey feedback noted that respondents urged to exercise some caution when using automated methods to approach valuation, as the property market is very dynamic and difficult to explain by means of mathematical algorithms.

6. Conclusion and Recommendations

In Malaysia, the property valuation profession exercises limited use of GIS applications in their line of work. This is driven by the lack of knowledge regarding GIS technology especially regarding the analytical functions provided by GIS applications. This study was conducted in an effort to expand local use of the GIS solutions beyond map making and spatial data management.

The terrain factor was selected as the study subject due to its independence from the influences of other factors affecting value.

The ultimate objective of this study is to propose terrain factor adjustments based on slope and surface roughness values derived from DEMs, to be used in the comparative method of valuation. This was successfully achieved by implementing the methods described within this study report.

The outputs of this study, that are the terrain adjustments, were distributed for industry expert evaluations via online questionnaire survey instrument. Feedback received showed that the study methods were successful in producing terrain adjustments that are considered as reasonable within industry standards. However, this study also noted that method-outputs are extremely dependent on the quality of the input data - in this case, the DEM elevation - to convey reasonable adjustment rates.

The study also noted generally positive reactions from industry members regarding the inclusion of a GIS application to evaluate the terrain factor in approaching value. However, some concerns were also raised regarding the use of automatic methods in value estimates.

In conclusion, this study finds that using GIS applications to determine terrain factor adjustments in property valuation is extremely relevant and useful to the industry and is well worth being given some consideration.

Some areas that could be improved upon for similar future studies include:

- Using finer-scaled DEM data such as high resolution Light Detection and Ranging (LiDAR) data instead of coarse-scaled DEMs;
- Collection of high quality elevation data at sample points across the study area to produce a DEM using interpolation methods as an alternative to satellite-sourced DEM datasets;
- Inclusion of other independent factors affecting value to be analysed along with the terrain factor;
- .Studying a way to deal with redundant or dependent data;

- Some consideration needs to be given to efficiently managing contiguous property transactions
    - Sometimes, more than one property is transferred in a single transaction. In this study, contiguous transaction was attended to manually by dissolving the multiple lots into one single property for extraction of terrain data by property unit. While this is doable for the small scale of this study, it is very tedious to take this approach in actual valuation practice, as one usually need to attend to multiple valuation cases at once.

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U. S. National Aeronautics and Space Administration. 2015. ASTER | Terra. Retrieved, from. http://terra.nasa.gov/about/terra-instruments/aster
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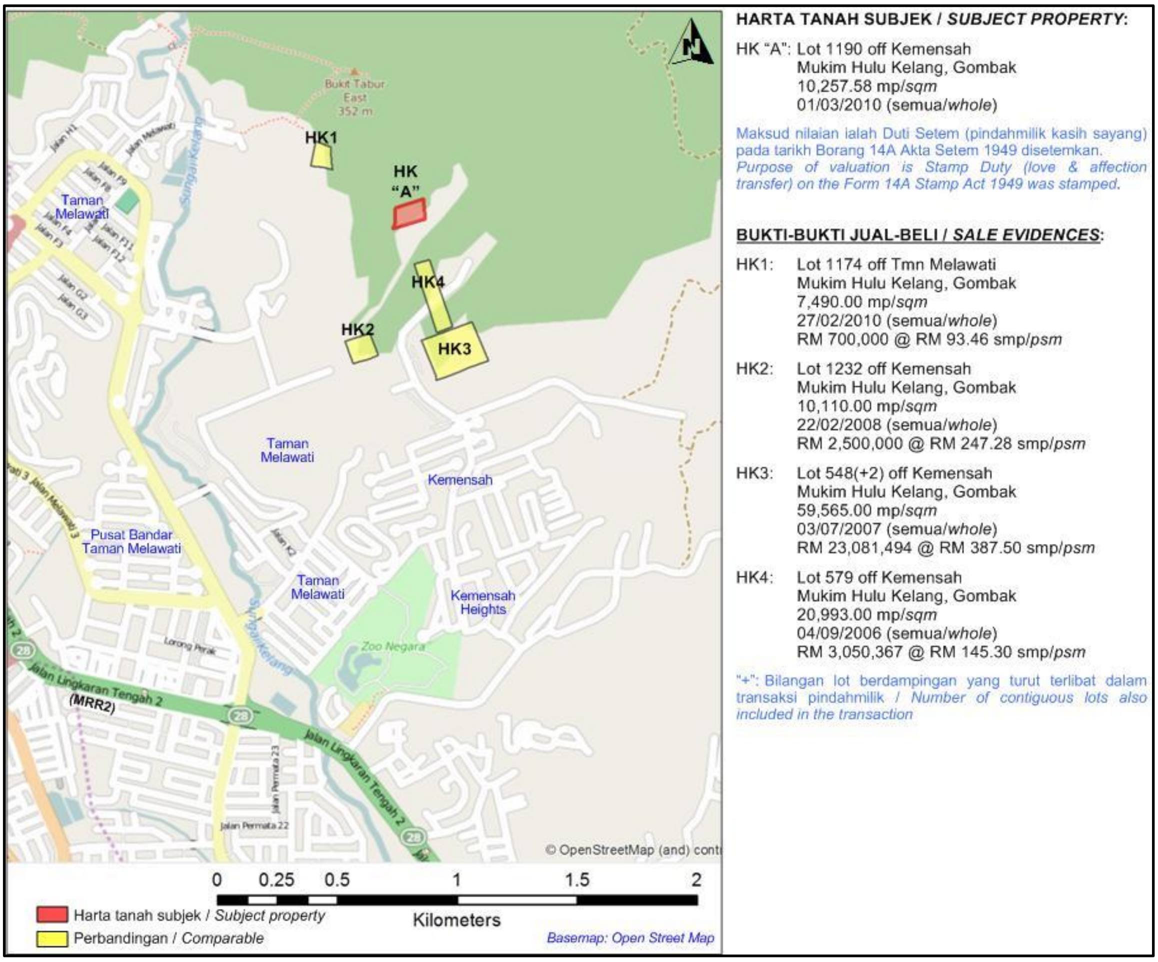
Appendix A(i): Property Sales Evidences for HK "A" (simplified into comparison maps)



Appendix A(ii): Property Sales Evidences for DA "A" and LD "A" & "B" (simplified into comparison maps)

HARTA TANAH SUBJEK / *SUBJECT PROPERTY*:

DA "A": PT 9582, Kg Desa Aman
Mukim Bdr Sg Buloh, Gombak
18,219.49 mp/*sqm*
31/12/2010 (semua/*whole*)

Maksud nilaian ialah Duti Setem (pindahmilik kasih sayang) pada tarikh Borang 14A Akta Setem 1949 disetemkan.
Purpose of valuation is Stamp Duty (love & affection transfer) on the Form 14A Stamp Act 1949 was stamped.

BUKTI-BUKTI JUAL-BELI / *SALE EVIDENCES*:

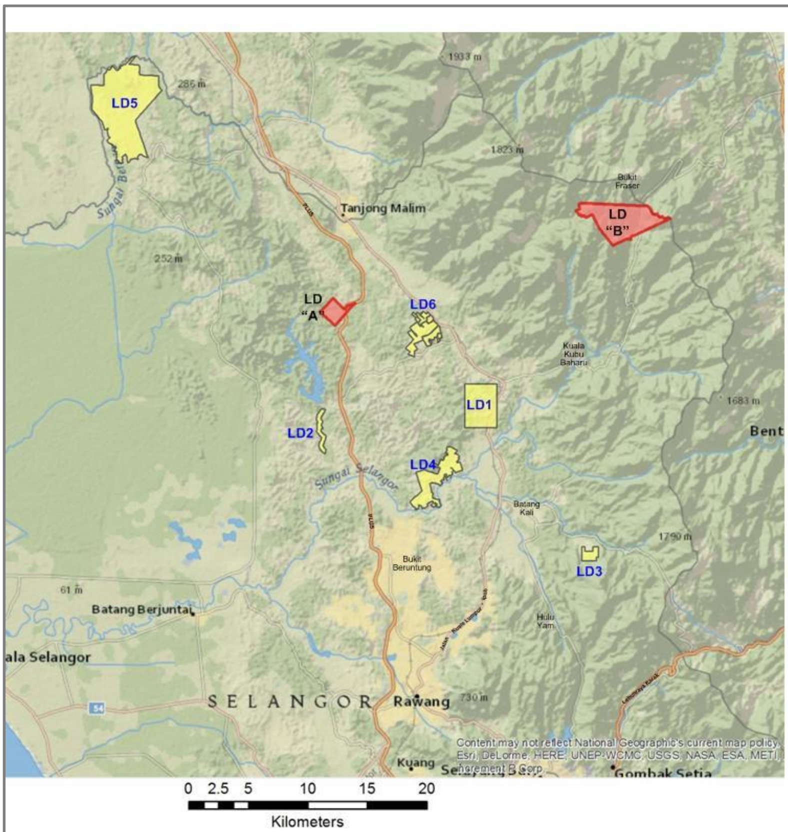
DA1: PT 9671, Kg Desa Aman
Mukim Bdr Sg Buloh, Gombak
16,490.63 mp/*sqm*
02/12/2010 (semua/*whole*)
RM 3,893,175 @ RM 263.08 smp/*psm*

DA2: PT 9600, Kg Desa Aman
Mukim Bdr Sg Buloh, Gombak
18,004.29 mp/*sqm*
09/09/2008 (semua/*whole*)
RM 6,500,000 @ RM 361.03 smp/*psm*

DA3: PT 9605, Kg Desa Aman
Mukim Bdr Sg Buloh, Gombak
18,270.81 mp/*sqm*
30/11/2007 (semua/*whole*)
RM 8,820,900 @ RM 482.79 smp/*psm*

DA4: PT 9588, Kg Desa Aman
Mukim Bdr Sg Buloh, Gombak
14,840.97 mp/*sqm*
31/10/2007 (semua/*whole*)
RM 5,892,572 @ RM 397.05 smp/*psm*

DA5: PT 9555, Kg Desa Aman
Mukim Bdr Sg Buloh, Gombak
12,618.69 mp/*sqm*
09/01/2007 (semua/*whole*)
RM 2,000,000 @ RM 158.50 smp/*psm*



HARTA TANAH SUBJEK / *SUBJECT PROPERTY*:

LD "A": Lot XXX off off Lembah Beringin
Mukim XXX, Hulu Selangor
ha
01/10/2008 (semua/*whole*)

LD "B": Lot XXX off Bukit Fraser
Mukim XXX, Hulu Selangor
ha
01/10/2008 (semua/*whole*)

Maksud nilaian ialah Duti Setem (pindahmilik kasih sayang) pada tarikh Borang 14A Akta Setem 1949 disetemkan.
Purpose of valuation is Stamp Duty (love & affection transfer) on the Form 14A Stamp Act 1949 was stamped.

BUKTI-BUKTI JUAL-BELI / *SALE EVIDENCES*:

LD1: Lot 724(+3) off persimpangan Jln Ipoh-KKB
Mukim Ampang Pechah, Hulu Selangor
531.00 ha
02/05/2008 (semua/*whole*)
RM 41,466.535 @ RM 79,091 pha

LD2: Lot 35 off Jalan Bukit Tagar
Mukim Sg Tinggi, Hulu Selangor
150.49 ha
02/08/2007 (semua/*whole*)
RM 29,200,000 @ RM 194,030 pha

LD3: Lot 2566 off Jln Batang Kali-Genting Highlands
Mukim Batang Kali, Hulu Selangor
132.23 ha
25/10/2007 (semua/*whole*)
RM 12,500,000 @ RM 94,532 pha

LD4: Lot 2418(+22) off Kaw Perindustrian Rasa
Mukim Rasa, Hulu Selangor
838.80 ha
12/06/2007 (semua/*whole*)
RM 56,000,000 @ RM 66,762 pha

LD5: Lot 1899 off FELDA Gedangsa
Mukim Hulu Bernam, Hulu Selangor
2,891.89 ha
26/12/2003 (semua/*whole*)
RM 117,770,000 @ RM 40,727 pha

LD6: Lot 146(+28) off Kg Jawa Kerling
Mukim Kerling & Sg Gumut, Hulu Selangor
619.07 ha
22/07/2002 (semua/*whole*)
RM 45,893,800 @ RM 74,133 pha

"+": Bilangan lot berdampingan yang turut terlibat dalam transaksi pindahmilik / *Number of contiguous lots also included in the transaction*

Appendix B: Terrain Tools_92 Python Script (Sappington et al., 2007)

```
# Ruggedness.py
# Description: This tool measures terrain ruggedness by
     calculating the vector ruggedness measure
# described in Sappington, J.M., K.M. Longshore, and D.B.
     Thomson. 2007. Quantifiying
# Landscape Ruggedness for Animal Habitat Anaysis: A case
     Study Using Bighorn Sheep in
# the Mojave Desert. Journal of Wildlife Management. 71(5):
     1419 -1426.
# Requirements: Spatial Analyst
# Author: Mark Sappington
# Date: 2/1/2008

# Import system modules
import sys, string, os, arcgisscripting

# Create the geoprocessor object
gp = arcgisscripting.create()

# Check out any necessary licenses
gp.CheckOutExtension("spatial")

# Load required toolboxes
gp.AddToolbox("C:/Program
     Files/ArcGIS/ArcToolbox/Toolboxes/Spatial      Analyst
     Tools.tbx")

# Script arguments
InRaster = sys.argv[1]
Neighborhood_Size = sys.argv[2]
OutWorkspace = sys.argv[3]
OutRaster = sys.argv[4]

# Local variables
AspectRaster = OutWorkspace + "\\aspect"
SlopeRaster = OutWorkspace + "\\slope"
SlopeRasterRad = OutWorkspace + "\\sloperad"
AspectRasterRad = OutWorkspace + "\\aspectrad"
xRaster = OutWorkspace + "\\x"
yRaster = OutWorkspace + "\\y"
zRaster = OutWorkspace + "\\z"
xyRaster = OutWorkspace + "\\xy"
xSumRaster = OutWorkspace + "\\xsum"
ySumRaster = OutWorkspace + "\\ysum"
zSumRaster = OutWorkspace + "\\zsum"
ResultRaster = OutWorkspace + "\\result"

try:
 # Create Slope and Aspect rasters
 gp.AddMessage("Calculating aspect...")
 gp.Aspect_sa(InRaster, AspectRaster)
 gp.AddMessage("Calculating slope...")
```

```
gp.Slope_sa(InRaster, SlopeRaster, "DEGREE")

# Convert Slope and Aspect rasters to radians
gp.AddMessage("Converting slope and aspect to radians...")
gp.times_sa(SlopeRaster,(3.14/180), SlopeRasterRad)
gp.times_sa(AspectRaster,(3.14/180), AspectRasterRad)
# Calculate x, y, and z rasters
gp.AddMessage("Calculating x, y, and z rasters...")
gp.sin_sa(SlopeRasterRad, xyRaster)
gp.cos_sa(SlopeRasterRad, zRaster)
gp.SingleOutputMapAlgebra_sa("con(" + AspectRaster + " ==
    -1, 0, sin(" + AspectRasterRad + ") * " + xyRaster +
    ")", xRaster)
gp.SingleOutputMapAlgebra_sa("con(" + AspectRaster + " ==
    -1, 0, cos(" + AspectRasterRad + ") * " + xyRaster +
    ")", yRaster)

# Calculate sums of x, y, and z rasters for selected
    neighborhood size
gp.AddMessage("Calculating sums of x, y, and z rasters in
    selected neighborhood...")
gp.FocalStatistics_sa(xRaster, xSumRaster, "Rectangle " +
    str(Neighborhood_Size) + " " + str(Neighborhood_Size)
    + " CELL", "SUM", "NODATA")
gp.FocalStatistics_sa(yRaster, ySumRaster, "Rectangle " +
    str(Neighborhood_Size) + " " + str(Neighborhood_Size)
    + " CELL", "SUM", "NODATA")
gp.FocalStatistics_sa(zRaster, zSumRaster, "Rectangle " +
    str(Neighborhood_Size) + " " + str(Neighborhood_Size)
    + " CELL", "SUM", "NODATA")

# Calculate the resultant vector
gp.AddMessage("Calculating the resultant vector...")
gp.SingleOutputMapAlgebra_sa("sqrt(sqr(" + xSumRaster + ")
    + sqr(" + ySumRaster + ") + sqr(" + zSumRaster + "))",
    ResultRaster)

# Calculate the Ruggedness raster
gp.AddMessage("Calculating the final ruggedness
    raster...")
maxValue = int(Neighborhood_Size) * int(Neighborhood_Size)
gp.SingleOutputMapAlgebra_sa("1 - (" + ResultRaster + " /
    " + str(maxValue) + ")", OutRaster)

# Delete all intermediate raster data sets
gp.AddMessage("Deleting intermediate data...")
gp.Delete(AspectRaster)
gp.Delete(SlopeRaster)
gp.Delete(SlopeRasterRad)
gp.Delete(AspectRasterRad)
gp.Delete(xRaster)
gp.Delete(yRaster)
gp.Delete(zRaster)
gp.Delete(xyRaster)
gp.Delete(xSumRaster)
gp.Delete(ySumRaster)
```

```
 gp.Delete(zSumRaster)
 gp.Delete(ResultRaster)

except:
# Print error message if an error occurs
 gp.GetMessages()
```

Appendix C: Online Survey Questionnaire

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

Selamat Datang / *Welcome*

Assalamualaikum dan salam sejahtera.

Rakan-rakan penilai sekalian,

Soal-selidik ini adalah sebahagian daripada kajian tahun akhir pengajian *Master Programme in Geomatics*, Lund University, Sweden. Kajian bertajuk "Penggunaan Aplikasi GIS untuk Menentukan Kadar Pelarasan Faktor Rupabumi dalam Penilaian Harta Tanah" ini bertujuan menggunakan kaedah-kaedah teknologi spatial bagi mengkuantifikasi faktor rupabumi tapak. Ini kerana dalam amalan sedia ada, faktor rupabumi sering dilihat sebagai faktor kualitatif dan terjemahannya berbeza dari seorang penilai kepada penilai yang lain.

Dalam kajian ini, *Digital Elevation Model* (DEM) dari sumber percuma telah digunakan untuk mengekstrak data aras ketinggian, diikuti penggunaan aplikasi GIS bagi menjana kecerunan dan kekasaran rupabumi. Seterusnya, kombinasi aplikasi GIS dan kaedah statistik digunakan dalam penentuan kadar pelarasan bersesuaian bagi harta tanah perbandingan.

Sehubungan itu, soal-selidik ini bertujuan mendapatkan pandangan rakan penilai berkaitan faktor rupabumi serta pandangan pakar tuan/puan berkaitan kesesuaian kadar pelarasan yang disyorkan oleh kaedah ini. Sumbangan tuan/puan dalam menjayakan kajian ini amatlah saya hargai.

Sekian, terima kasih.

Fellow valuers,

This survey is part of the final year research for the Master Programme in Geomatics, Lund University, Sweden. The study titled "Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation" is aimed at using spatial technology methods to quantify the surface terrain factor. This is because terrain factor is often viewed qualitatively in current practice and its interpretation may differ from one valuer to another.

In this study, open-sourced Digital Elevation Models (DEMs) are used to extract elevation values and GIS Application is used to generate slope gradient and surface roughness. A combinations of GIS application and spatial statistics is then performed generate suitable adjustment rates for the comparables.

In relation to that, this survey hopes to gather views from fellow valuers as well as your expert evaluation on the suitability of the adjustment rates proposed by this method. Your contribution towards the success of this study is greatly appreciated.

Thank you.

1

Dahlia Mudzaffar Ali
Lund University, 2015

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

A: Latar belakang responden / *Respondent background*

Soalan-soalan di bawah seksyen ini adalah bagi mengklasifikasi responden berdasarkan pembabitan mereka dalam bidang penilaian harta tanah.
The questions under this section is to classify respondents based on their involvement in the property valuation field.

* 1. Status pekerjaan semasa / *Current work status*

- Penilai kerajaan / *Government valuer*
- Penilai swasta / *Private valuer*
- Ejen harta tanah / *Estate agent*
- Akademik / *Academics*
- Pesara penilaian / *Retired valuer*
- Lain-lain (sila nyatakan) / Other (please specify):

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

A: Latar belakang responden (smbg) / *Respondent background (con't)*

* 2. Umur / *Age*

- Bawah 26 tahun / *Under 26 years*
- 26 hingga 30 tahun / *26 until 30 years*
- 31 hingga 35 tahun / *31 until 35 years*
- 36 hingga 40 tahun / *36 until 40 years*
- 41 hingga 45 tahun / *41 until 45 years*
- 46 hingga 50 tahun / *46 until 50 years*
- Atas 50 tahun / *Above 50 years*

2

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

A: Latar belakang responden (smbg) / *Respondent background (con't)*

* 3. Kelayakan akademik tertinggi berkaitan bidang harta tanah /*Highest academic qualification involving the property field*

- ○ Diploma / *Diploma*
- ○ Ijazah Sarjana Muda / *Bachelor Degree*
- ○ Ijazah Sarjana / *Master Degree*
- ○ Lain-lain (sila nyatakan) / Other (please specify):

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

A: Latar belakang responden (smbg) / *Respondent background (con't)*

* 4. Pengalaman kerja dalam bidang penilaian / *Work experience in property valuation*

- ○ Kurang daripada 4 tahun / *Less than 4 years*
- ○ 4 hingga 6 tahun / *4 to 6 years*
- ○ 7 hingga 9 tahun / *7 to 9 years*
- ○ 10 hingga 15 tahun / *10 to 15 years*
- ○ Lebih daripada 15 tahun / *More than 15 years*

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

A: Latar belakang responden (smbg) / *Respondent background (con't)*

3

* 5. Pengalaman sebagai penilai berdaftar / *Experience as registered valuer*

- Kurang daripada 4 tahun / *Less than 4 years*
- 4 hingga 6 tahun / *4 to 6 years*
- 7 hingga 9 tahun / *7 to 9 years*
- 10 hingga 15 tahun / *10 to 15 years*
- Lebih daripada 15 tahun / *More than 15 years*
- Saya bukan penilai berdaftar / *I am not a registered valuer*

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

B: Faktor-faktor pelarasan nilai / *Factors for value adjustment*

Masa, lokasi dan syarat-syarat hakmilik adalah faktor-faktor yang diberi penekanan dalam hampir semua kes penilaian harta tanah. Seksyen ini mengkaji pandangan responden terhadap faktor-faktor lain yang sering dipertimbangkan dalam pelarasan nilai. Sila berikan maklum balas berdasarkan pandangan pakar anda.
Time, location and title conditions are factors that are emphasized in almost all property valuation cases. This section studies respondent's view on other factors that are often considered in value adjustments. Please provide feedback based on your expert opinion.

* 6. Berikut adalah beberapa faktor yang dipertimbangkan dalam pelarasan nilai. Susunkan faktor-faktor tersebut berdasarkan kesannya ke atas nilai dari 1 (kesan paling kuat) hingga 5 (kesan paling lemah).
Nota: Soalan ini adalah soalan 'FORCED-RANKING'. Setiap 'rank' hanya boleh diperuntukkan kepada 1 faktor sahaja.

The following are several factors that are considered in value adjustments. Rank the factors according to their impact on value from 1 (highest impact) to 5 (lowest impact).
Note: This is a FORCED-RANKING question. Each rank may be allocated with 1 factor only

	1	2	3	4	5
Bentuk lot / *Shape of lot*	○	○	○	○	○
Keadaan rupabumi / *Terrain condition*	○	○	○	○	○
Kewujudan jalan masuk sah / *Availability of legal road access*	○	○	○	○	○
Lapisan dari jalan masuk / *Layer from road access*	○	○	○	○	○
Saiz lot / *Size of lot*	○	○	○	○	○

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

B: Faktor-faktor pelarasan nilai (smbg) / *Factors for value adjustment (con't)*

* 7. Pilih kesan faktor-faktor berikut ke atas nilai dalam kebanyakan kes penilaian /
Select the effects of the following factors on value in most valuation cases

	Sangat lemah *Very weak*	Lemah *Weak*	Sederhana *Moderate*	Kuat *Strong*	Sangat kuat *Very strong*
Bentuk lot *Shape of lot*	○	○	○	○	○
Keadaan rupabumi *Terrain condition*	○	○	○	○	○
Kewujudan jalan masuk sah *Availability of legal road access*	○	○	○	○	○
Lapisan dari jalan masuk *Layer from road access*	○	○	○	○	○
Saiz lot *Size of lot*	○	○	○	○	○

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

C: Persepsi visual terhadap faktor rupabumi / *Visual perception of terrain factor*

Jumlah pelarasan bagi faktor rupabumi dianggarkan berdasarkan pemerhatian semasa lawat periksa tapak tetapi amat dipengaruhi oleh pengetahuan dan pengalaman kerja penilai. Seksyen ini bertujuan mengkaji interpretasi visual responden terhadap faktor rupabumi berdasarkan latar belakang di Seksyen A dalam menentukan kadar pelarasan sewajarnya.

Adjustment for the terrain factor is estimated based on observation during site inspection but is highly influenced by the valuer's knowledge and work experience. This section aims at studying respondent's visual interpretation of the terrain factor in relation to the background in Section A in determining the reasonable adjustment rate.

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

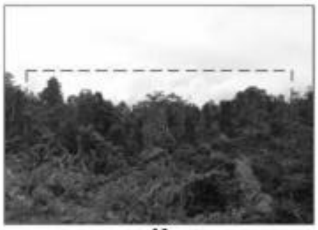
Terjemahan rupabumi berdasarkan pemerhatian / *Terrain interpretation based on observation*

Soalan 8 hingga 9 adalah berdasarkan Gambarfoto Tapak berikut /
Questions 8 until 9 are based on the following Site Photographs

Gambarfoto Tapak / *Site Photographs*

A1

A2



A3

A4

A5

A6

* 8. Perhatikan **Gambarfoto Tapak** di atas dan pilih adjektif terbaik untuk menerangkan rupabumi yang anda lihat /
*Observe**Site Photographs** above and select the adjective that best describe the terrain that you see*

	Beralun / *Undulated*	Berbukit / *Hilly*	Bercerun / *With slopes*	Bergunung / *Mountainous*	Curam / *Steep*	Rata / *Flat*	Tinggi-rendah / *High-low*
Gambarfoto A1 / *Photograph A1*	○	○	○	○	○	○	○
Gambarfoto A2 / *Photograph A2*	○	○	○	○	○	○	○
Gambarfoto A3 / *Photograph A3*	○	○	○	○	○	○	○
Gambarfoto A4 / *Photograph A4*	○	○	○	○	○	○	○
Gambarfoto A5 / *Photograph A5*	○	○	○	○	○	○	○
Gambarfoto A6 / *Photograph A6*	○	○	○	○	○	○	○

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* 9. Sila ulas ciri-ciri rupabumi Gambarfoto A1 hingga A6 dengan lebih lanjut untuk menggambarkan apa yang anda lihat /

Please further describe the terrain conditions of Photograph A1 until A6 to describe what you see

Gambarfoto A1 / *Photograph A1*

Gambarfoto A2 / *Photograph A2*

Gambarfoto A3 / *Photograph A3*

Gambarfoto A4 / *Photograph A4*

Gambarfoto A5 / *Photograph A5*

Gambarfoto A6 / *Photograph A6*

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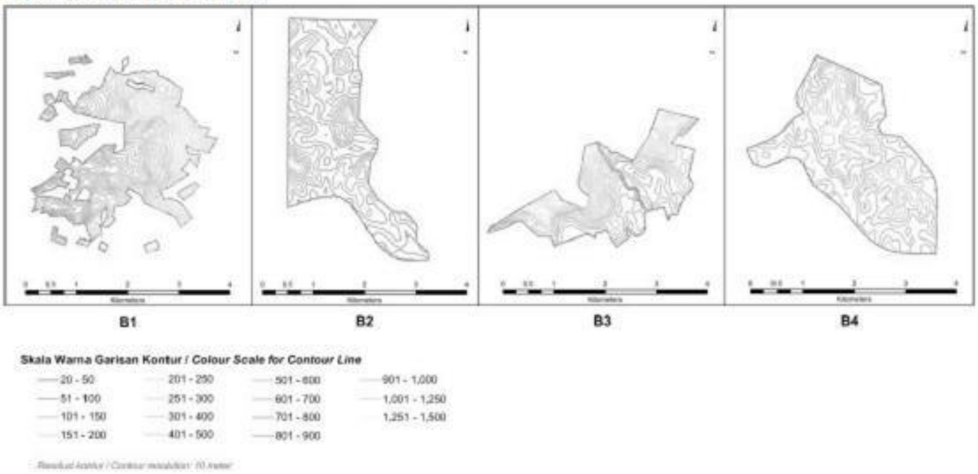
Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

Terjemahan rupabumi berdasarkan pelan kontur / *Terrain interpretation based on contour plan*

Soalan 10 adalah berdasarkan Pelan Kontur berikut /
Question 10 is based on the following Contour Plan

7

Pelan Kontur / *Contour Plan*



* 10. Katakan B1 ialah harta tanah subjek dan B2 hingga B4 ialah harta tanah perbandingan, sila syorkan kadar pelarasan yang munasabah atas <u>faktor rupabumi</u> bagi Perbandingan B2, B3 dan B4.

Say B1 is the subject property and B2 until B4 are the comparables, please suggest the adjustment rate for <u>terrain factor</u> for Comparison B2, B3 and B4.

	≥ -30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	≥ 30%
B2 berbanding B1 / *B2 compared to B1*	○	○	○	○	○	○	○	○	○	○	○	○	○
B3 berbanding B1 / *B3 compared to B1*	○	○	○	○	○	○	○	○	○	○	○	○	○
B4 berbanding B1 / *B4 compared to B1*	○	○	○	○	○	○	○	○	○	○	○	○	○

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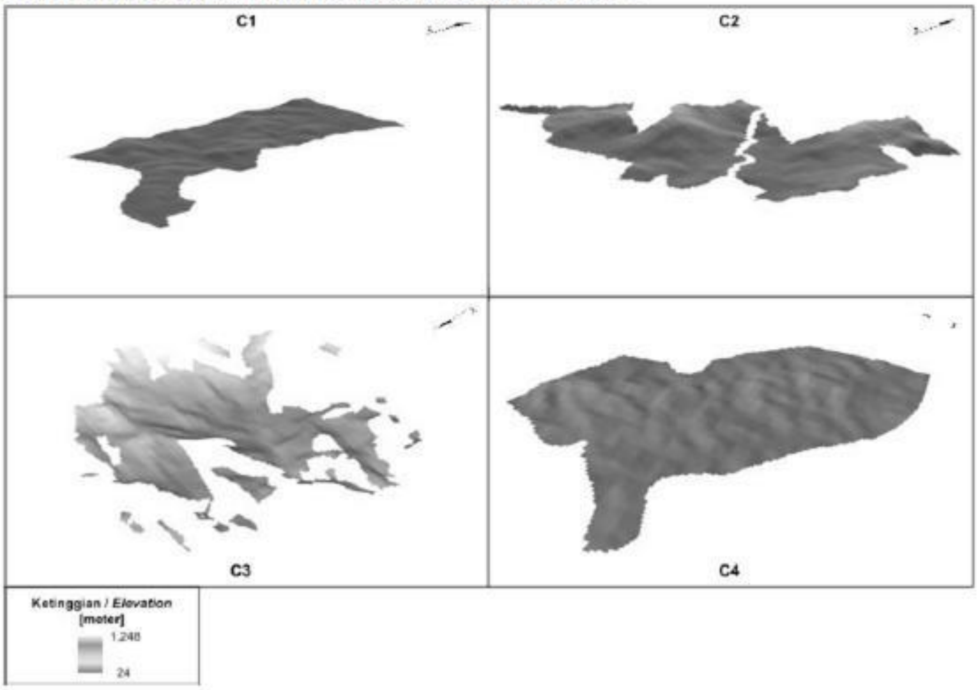
Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

Terjemahan rupabumi dibantu grafik-3D / *Terrain interpretation based on 3D-graphics*

Soalan 11 adalah berdasarkan Janaan Imej-3D berikut /
Question 11 is based on the following 3D-Image Renditions

8

Janaan Imej-3D Rupabumi Tapak /*3D-Image Rendition of Site Terrain*



* 11. Katakan C1 ialah harta tanah subjek dan C2 hingga C4 ialah harta tanah perbandingan, sila syorkan kadar pelarasan yang munasabah atas faktor rupabumi bagi Perbandingan C2, C3 dan C4.

Say C1 is the subject property and C2 until C4 are the comparables, please suggest the adjustment rate for terrain factor for Comparison C2, C3 and C4.

	≥ -30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	≥ 30%
C2 berbanding C1 / *C2 compared to C1*	○	○	○	○	○	○	○	○	○	○	○	○	○
C3 berbanding C1 / *C3 compared to C1*	○	○	○	○	○	○	○	○	○	○	○	○	○
C4 berbanding C1 / *C4 compared to C1*	○	○	○	○	○	○	○	○	○	○	○	○	○

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

Harta tanah tidak dapat dilawatperiksa / Inaccessible property

* 12. Sekiranya harta tanah subjek terletak di lokasi yang tidak dapat diakses untuk lawat periksa tapak, bagaimanakah anda mempertimbangkan faktor rupabumi? Sila pilih tiga (3) daripada pilihan yang disenaraikan di bawah /

If the subject property is situated in an inaccessible location for site inspection, how would you consider the terrain factor? Please choose three (3) out of the selections listed below

- [ ] Saya hanya akan meneruskan penilaian apabila lawat periksa dapat dijalankan / *I will only proceed with the valuation upon performing site inspection*
- [ ] Saya akan merujuk kepada pelan topografi / *I will refer to topograpy maps*
- [ ] Saya akan merujuk 'Google Earth' dan/atau sumber 'remote sensing' lain di internet / *I will refer Google Earth and/or other remote sensing sources on the internet*
- [ ] Saya akan meminta klien untuk menerangkan keadaan harta tanah dan membekalkan gambarfoto tapak / *I will ask the client to describe the property and supply photographic evidences of the site*
- [ ] Saya akan membuat andaian berdasarkan keadaan sekitar yang diketahui keadaannya / *I will make assumptions based on known surrounding conditions*
- [ ] Saya akan cuba mendapatkan maklumat dari jaringan profesional (cth: komuniti/forum penilai, juruukur tanah dan jurutera awam) / *I will try to get information from professional networks (i.e.: valuation, land surveying and civil engineering communities/forums)*
- [ ] Saya akan bertanya di laman sosial / *I will inquire on social networks*
- [ ] Saya akan menolak kes penilaian ini / *I will reject this valuation case*
- [ ] Saya tidak akan menerima kes penilaian membabitkan harta tanah yang tidak dapat diakses / *I never accept valuation cases involving inaccessible property*
- [ ] Saya akan menemubual pegawai di pejabat kerajaan tempatan / *I will interview officers in the local government offices*
- [ ] Saya akan menemubual penduduk tempatan / *I will interview officers in the local residents*
- [ ] Lain-lain (sila nyatakan) / Other (please specify)

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

D: Penilaian ke atas cadangan kadar pelarasan / *Evaluation of proposed adjustments rates*

Kajian ini telah menggunakan sumber 'remote sensing' dan aplikasi GIS bagi mengkuantifikasikan faktor rupabumi untuk pelarasan nilai. Maklum balas anda diperlukan untuk menguji ketepatan dan keberkesanan pendekatan ini. Soalan-soalan di bawah seksyen ini bertujuan menilai kadar

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pelarasan rupabumi yang disyorkan oleh kaedah ini.

This study uses remote sensing sources and GIS applications to quantify terrain factor for value adjustment. Your feedback is needed to test the accuracy and efficiency of this approach. The questions in this section is aimed at evaluating the terrain adjustment rates suggested by this method.

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

Harta tanah kecil I / Small property I

Soalan ini bagi mengkaji kesesuaian kaedah yang digunakan bagi harta tanah bersaiz kecil berikutan resolusi kasar (minimum 30 meter) sumber 'remote sensing' yang digunakan /
This question is to study the suitability of this method for small sized property due to the coarse resolution (minimum 30 meters) of the remote sensing source used

Subjek HK "A" dan Perbandingan HK1 hingga HK4 adalah tanah kosong di Mukim Hulu Kelang, Gombak. Kaedah yang digunakan dalam kajian ini telah mengesyorkan kadar pelarasan bagi faktor rupabumi seperti di Jadual HK di bawah. Soalan 13 hingga 14 adalah berkaitan kadar pelarasan yang disyorkan. Untuk membantu anda membuat pertimbangan, turut disertakan Pelan Perbandingan, Pelan Kontur dan janaan imej-3D tapak sebagai rujukan.

Subject HK "A" and Comparison HK1 until HK4 are vacant land in Mukim Hulu Kelang, Gombak. The methods in this study proposed terrain adjustment rates as in Table HK below. Question 13 until 14 are regarding the proposed adjustment rates. To assist your judgement, attached are the Comparison Plan, Contour Plan and 3D-image rendition of the site for your references.

Jadual HK: Syor kadar pelarasan rupabumi /
Table HK: Proposed adjustment rates for terrain

PROPERTY	Subject HK "A"	Comparable HK1	Comparable HK2	Comparable HK3	Comparable HK4
Property ID	Lot 1190, Mkm Hulu Kelang	Lot 1174, Mkm Hulu Kelang	Lot 1232, Mkm Hulu Kelang	Lot 584(+2), Mkm Hulu Kelang	Lot 579, Mkm Hulu Kelang
Min elevation (meter)	181	108	89	83	114
Max elevation (meter)	199	128	113	121	175
Range (meter)	18	20	24	38	61
Mean slope of property unit (degree)	10.0909	20.9035	12.5603	12.3098	16.3494
Mean slope-rise of property unit (%)	17.8281	38.3107	22.4936	21.9118	29.8051
Mean slope-rise (float), ΔS	0.1783	0.3831	0.2249	0.2191	0.2981
Surface roughness index, VRM	0.0132	0.0066	0.0127	0.0057	0.0127
$\Delta S = S_{comparable\,i} - S_{subject}$		0.2048	0.0467	0.0408	0.1198
$\Delta VRM = VRM_{comparable\,i} - VRM_{subject}$		(0.0065)	(0.0005)	(0.0074)	(0.0005)
ΔS + ΔVRM		0.1983	0.0462	0.0334	0.1193
ΔS + ΔVRM (%)		0.1983	4.62%	3.34%	11.93%
Proposed terrain adjustment (to the nearest 5%)		20.00%	5.00%	5.00%	10.00%

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Pelan Perbandingan / *Comparison Plan*

HARTA TANAH SUBJEK / *SUBJECT PROPERTY*:

HK "A": Lot 1190 off Kemensah
Mukim Hulu Kelang, Gombak
10,257.58 mp/sqm
01/03/2010 (semua/*whole*)

Maksud nilaian ialah Duti Setem (pindahmilik kasih sayang) pada tarikh Borang 14A Akta Setem 1949 disetemkan. *Purpose of valuation is Stamp Duty (love & affection transfer) on the Form 14A Stamp Act 1949 was stamped.*

BUKTI-BUKTI JUAL-BELI / *SALE EVIDENCES*:

HK1: Lot 1174 off Tmn Melawati
Mukim Hulu Kelang, Gombak
7,490.00 mp/sqm
27/02/2010 (semua/*whole*)
RM 700,000 @ RM 93.46 smp/*psm*

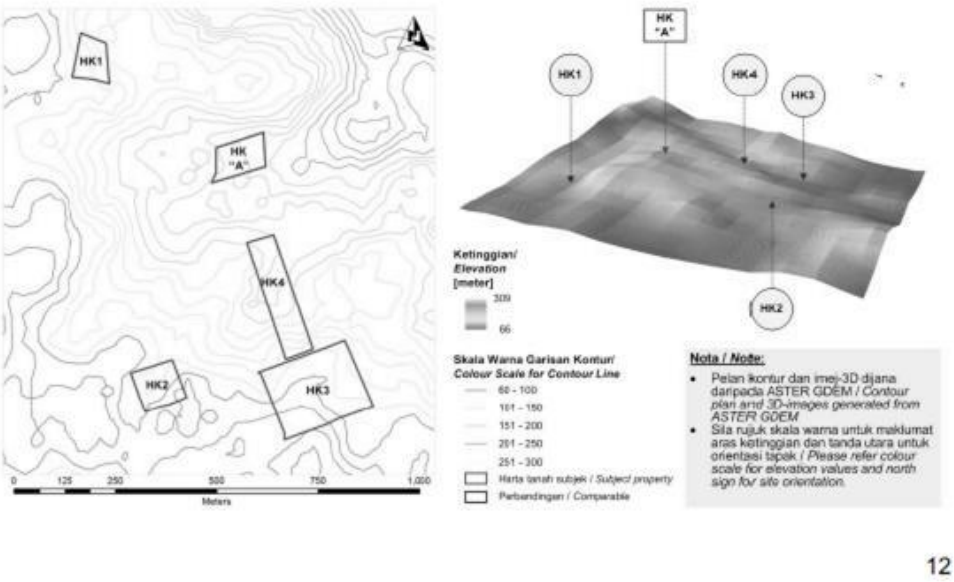
HK2: Lot 1232 off Kemensah
Mukim Hulu Kelang, Gombak
10,110.00 mp/sqm
22/02/2008 (semua/*whole*)
RM 2,500,000 @ RM 247.28 smp/*psm*

HK3: Lot 548(+2) off Kemensah
Mukim Hulu Kelang, Gombak
59,565.00 mp/sqm
03/07/2007 (semua/*whole*)
RM 23,081,494 @ RM 387.50 smp/*psm*

HK4: Lot 579 off Kemensah
Mukim Hulu Kelang, Gombak
20,993.00 mp/sqm
04/09/2006 (semua/*whole*)
RM 3,050,367 @ RM 145.30 smp/*psm*

"+": Bilangan lot berdampingan yang turut terlibat dalam transaksi pindahmilik / *Number of contiguous lots also included in the transaction*

Pelan Kontur & Janaan Imej-3D / *Contour Plan & 3D-Image Generation*



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* 13. Sila pertimbangkan kadar pelarasan yang dicadangkan oleh pendekatan ini (tulisan merah dalam Jadual HK di atas) /

Please evaluate the adjustment rates suggested by this approach (red font in Table HK above)

	Terlalu rendah / *Too low*	Agak rendah / *Slightly low*	Munasabah / *Reasonable*	Agak tinggi / *Slightly high*	Terlalu tinggi / *Too high*
HK1 berbanding HK "A" / *HK1 compared to HK "A"*	○	○	○	○	○
HK2 berbanding HK "A" / *HK2 compared to HK "A"*	○	○	○	○	○
HK3 berbanding HK "A" / *HK3 compared to HK "A"*	○	○	○	○	○
HK4 berbanding HK "A" / *HK4 compared to HK "A"*	○	○	○	○	○

Komen / Comments

* 14. Anda adalah penilai bagi Subjek HK "A". Sila cadangkan kadar pelarasan faktor rupabumi bagi perbandingan di atas mengikut pertimbangan anda.

You are the valuer for the Subject HK "A". Please suggest the terrain adjustment rates for the comparisons according to your judgement.

	≥ -30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	≥ 30%
HK1 berbanding HK "A" / *HK1 compared to HK "A"*	○	○	○	○	○	○	○	○	○	○	○	○	○
HK2 berbanding HK "A" / *HK2 compared to HK "A"*	○	○	○	○	○	○	○	○	○	○	○	○	○
HK3 berbanding HK "A" / *HK3 compared to HK "A"*	○	○	○	○	○	○	○	○	○	○	○	○	○
HK4 berbanding HK "A" / *HK4 compared to HK "A"*	○	○	○	○	○	○	○	○	○	○	○	○	○

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Harta tanah kecil II / *Small property II*

Soalan ini bagi mengkaji kesesuaian kaedah yang digunakan bagi harta tanah bersaiz kecil berikutan resolusi kasar (minimum 30 meter) sumber 'remote sensing' yang digunakan /
This question is to study the suitability of this method for small sized property due to the coarse resolution (minimum 30 meters) of the remote sensing source used

Subjek DA "A" dan Perbandingan DA1 hingga DA4 adalah tanah kosong di Bandar Sungai Buloh, Gombak. Kaedah yang digunakan dalam kajian ini telah mengesyorkan kadar pelarasan bagi faktor rupabumi seperti di Jadual DA di bawah. Soalan 15 hingga 16 adalah berkaitan kadar pelarasan yang disyorkan. Untuk membantu anda membuat pertimbangan, turut disertakan Pelan Perbandingan, Pelan Kontur dan janaan imej-3D tapak sebagai rujukan.

Subject DA "A" and Comparison DA1 until DA4 are vacant land in Bandar Sungai Buloh, Gombak. The methods in this study proposed terrain adjustment rates as in Table DA below. Question 15 until 16 are regarding the proposed adjustment rates. To assist your judgement, attached are the Comparison Plan, Contour Plan and 3D-image rendition of the site for your references.

Jadual DA: Syor kadar pelarasan rupabumi /
Table DA: Proposed adjustment rates for terrain

PROPERTY	Subject DA "A"	Comparable DA1	Comparable DA2	Comparable DA3	Comparable DA4
Property ID	Lot 9582, Bdr Sg Buloh	PT 9671, Bdr Sg Buloh	PT 9600, Bdr Sg Buloh	PT 9605, Bdr Sg Buloh	Lot 9588, Bdr Sg Buloh
Min elevation (meter)	53	52	54	103	45
Max elevation (meter)	111	88	81	154	99
Range (meter)	58	36	27	51	54
Mean slope of property unit (degree)	16.4406	11.6643	12.7726	16.6172	20.8384
Mean slope-rise of property unit (%)	30.3220	20.8298	22.9684	29.9728	38.9737
Mean slope-rise (float), ΔS	0.3032	0.2083	0.2297	0.2997	0.3897
Surface roughness index, VRM	0.0165	0.0059	0.0091	0.0060	0.0240
$\Delta S = S_{comparable\ i} - S_{subject}$		(0.0949)	(0.0735)	(0.0035)	0.0865
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		(0.0105)	(0.0073)	(0.0105)	0.0076
ΔS + ΔVRM		(0.1054)	(0.0809)	(0.0140)	0.0941
ΔS + ΔVRM (%)		-10.54%	-8.09%	-1.40%	9.41%
Proposed terrain adjustment (to the nearest 5%)		-10.00%	-10.00%	0.00%	10.00%

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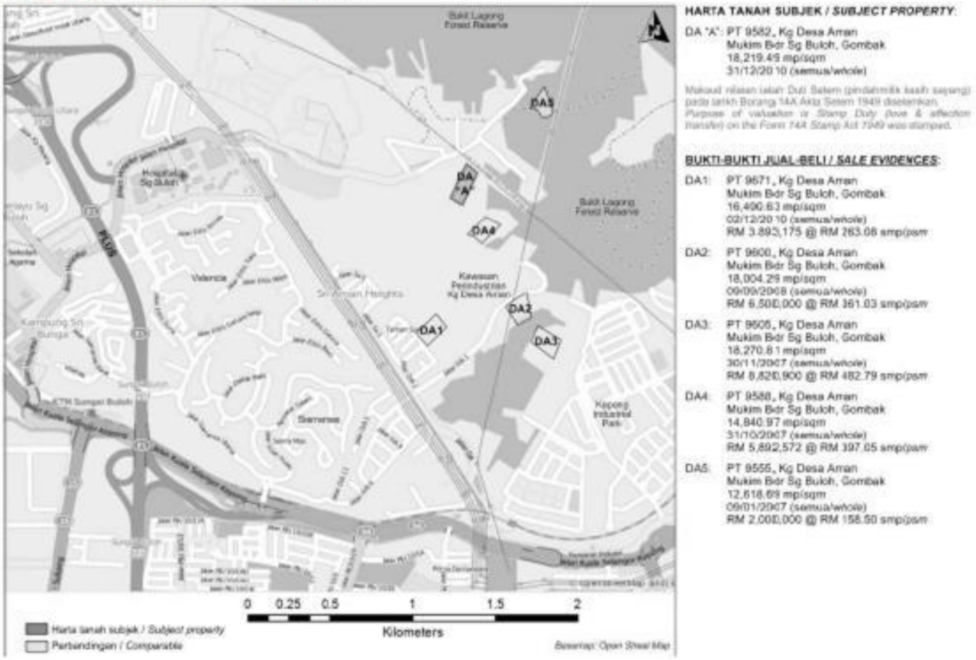
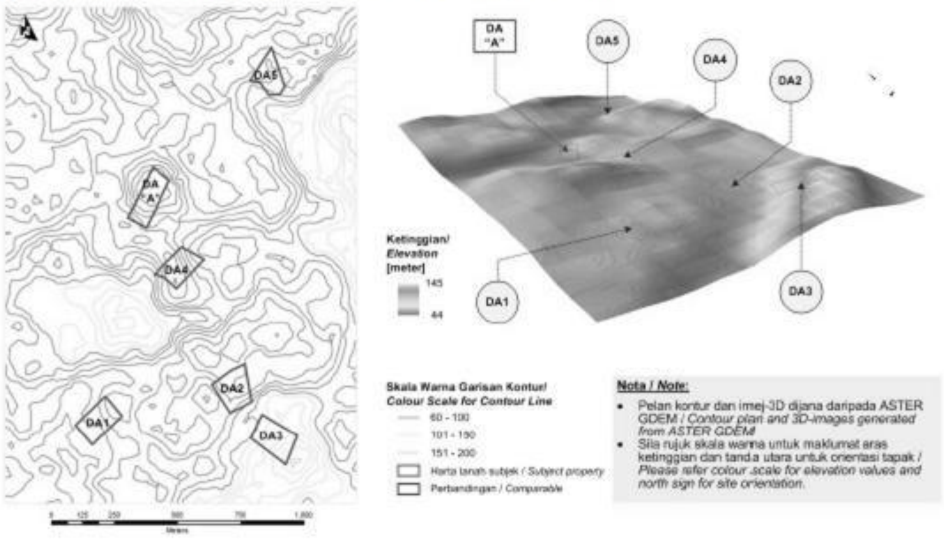
Pelan Perbandingan / *Comparison Plan*



Pelan Kontur & Janaan Imej-3D / *Contour Plan & 3D-Image Generation*



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* 15. Sila pertimbangkan kadar pelarasan yang dicadangkan oleh pendekatan ini (tulisan merah dalam Jadual DA di atas) /

Please evaluate the adjustment rates suggested by this approach (red font in Table DA above)

	Terlalu rendah / *Too low*	Agak rendah / *Slightly low*	Munasabah / *Reasonable*	Agak tinggi / *Slightly high*	Terlalu tinggi / *Too high*
DA1 berbanding DA "A" / *DA1 compared to DA "A"*					
DA2 berbanding DA "A" / *DA2 compared to DA "A"*					
DA3 berbanding DA "A" / *DA3 compared to DA "A"*					
DA4 berbanding DA "A" / *DA4 compared to DA "A"*					

Komen / Comments

* 16. Anda adalah penilai bagi Subjek DA "A". Sila cadangkan kadar pelarasan faktor rupabumi bagi perbandingan di atas mengikut pertimbangan anda.

You are the valuer for the Subject DA "A". Please suggest the terrain adjustment rates for the comparisons according to your judgement.

	≥ -30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	≥ 30%
DA1 berbanding DA "A" / *DA1 compared to DA "A"*													
DA2 berbanding DA "A" / *DA2 compared to DA "A"*													
DA3 berbanding DA "A" / *DA3 compared to DA "A"*													
DA4 berbanding DA "A" / DA4 compared to DA "A"													

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Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

Harta tanah besar (ladang) / *Large property (estate)*

Subjek LD "A" dan LD "B" serta Perbandingan LD1 hingga LD6 adalah tanah ladang di Daerah Hulu Selangor. Kaedah yang digunakan dalam kajian ini telah mengesyorkan kadar pelarasan bagi faktor rupabumi seperti di Jadual LD "A" dan LD "B" di bawah. Untuk membantu anda membuat pertimbangan, turut disertakan Pelan Perbandingan, Pelan Kontur dan janaan imej-3D tapak sebagai rujukan.

Subject LD "A" and LD "B" as well as Comparison LD1 until LD6 are estate land in District of Hulu Selangor. The methods in this study proposed terrain adjustment rates as in Table LD "A" and LD "B" below. To assist your judgement, attached are the Comparison Plan, Contour Plan and 3D-image rendition of the site for your references.

Pelan Perbandingan / *Comparison Plan*

HARTA TANAH SUBJEK / *SUBJECT PROPERTY*:

LD "A": Lot 31 off off Lembah Beringin
Mukim Kuala Kalumpang, Hulu Selangor
262.32 ha
01/10/2008 (semua/whole)

LD "B": Lot XXX off Bukit Fraser
Mukim Peretak, Hulu Selangor
1,466.59 ha
01/10/2008 (semua/whole)

Maksud nilaian ialah Duti Setem (pindahmilik kasih sayang) pada tarikh Borang 14A Akta Setem 1949 ditandakan. *Purpose of valuation is Stamp Duty (love & affection transfer) on the Form 14A Stamp Act 1949 was stamped.*

BUKTI-BUKTI JUAL-BELI / *SALE EVIDENCES*:

LD1: Lot 724(+3) off persimpangan Jln Ipoh-KKB
Mukim Ampang Pechah & Rasa, Hulu Selangor
531.00 ha
02/05/2008 (semua/whole)
RM 41,466,535 @ RM 79,091 pha

LD2: Lot 35 off Jalan Bukit Tagar
Mukim Sg Tinggi, Hulu Selangor
150.49 ha
02/08/2007 (semua/whole)
RM 29,200,000 @ RM 194,030 pha

LD3: Lot 2566 off Jln Batang Kali-Genting Highlands
Mukim Batang Kali, Hulu Selangor
132.23 ha
25/10/2007 (semua/whole)
RM 12,500,000 @ RM 94,532 pha

LD4: Lot 2418(+22) off Kaw Perindustrian Rasa
Mukim Serendah & Rasa, Hulu Selangor
838.80 ha
12/06/2007 (semua/whole)
RM 56,000,000 @ RM 66,762 pha

LD5: Lot 1899 off FELDA Gedangsa
Mukim Hulu Bernam, Hulu Selangor
2,891.89 ha
26/12/2003 (semua/whole)
RM 117,770,000 @ RM 40,727 pha

LD6: Lot 146(+26) off Kg Jawa Kerling
Mukim Sg Gumut & Kerling, Hulu Selangor
619.07 ha
22/07/2002 (semua/whole)
RM 45,893,800 @ RM 74,133 pha

"+": Bilangan lot berdampingan yang turut terlibat dalam transaksi pindahmilik / *Number of contiguous lots also included in the transaction*

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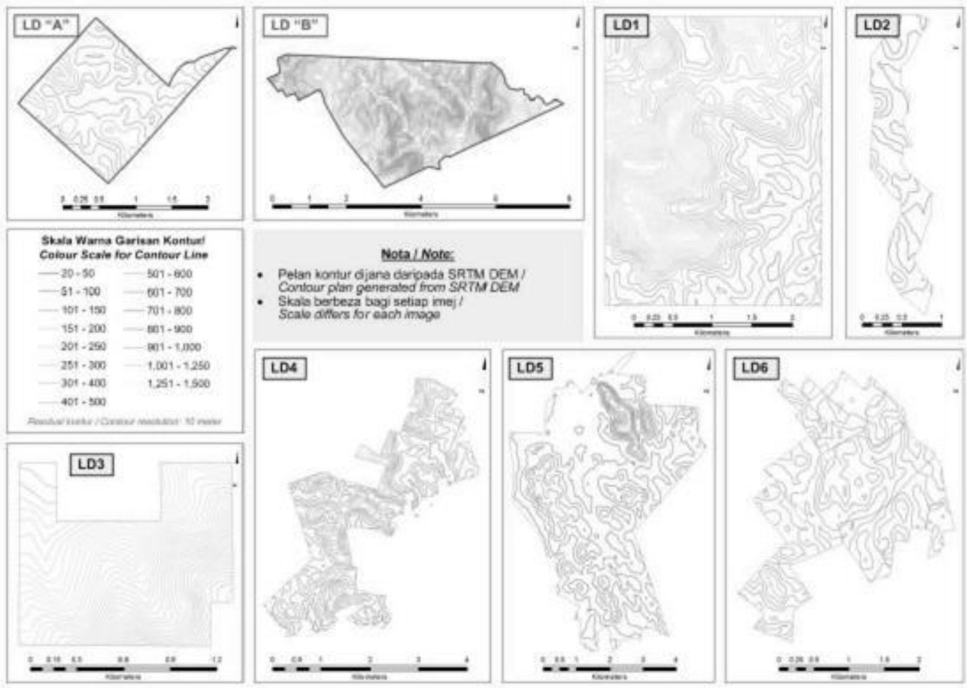
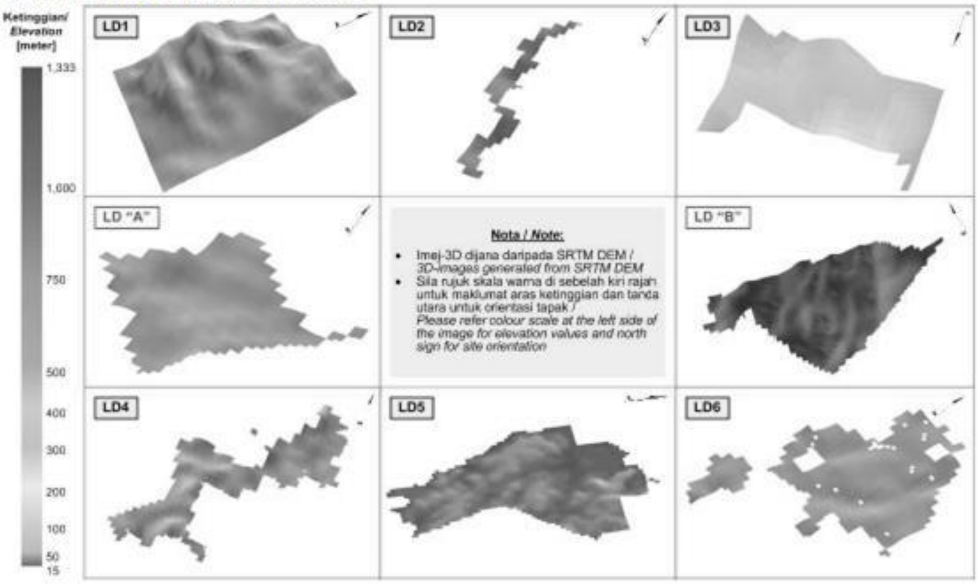
Pelan Kontur / *Contour Plan*



Janaan Imej-3D / *3D-Image Generation*



18

Soalan 17 hingga 18 adalah berkaitan kadar pelarasan yang disyorkan di Jadual LD "A" berikut. Anda boleh merujuk kepada Pelan Perbandingan, Pelan Kontur dan janaan imej-3D yang disertakan di atas untuk mendapatkan gambaran rupabumi subjek dan perbandingan /

Question 17 to 18 are related to the proposed adjustment rates in Table LD "A". You can refer to the Comparison Plan, Contour Plan and 3D-image rendition attached above for an overview of the subject's and comparisons' terrain condition

Jadual LD "A": Syor kadar pelarasan rupabumi /

Table LD "A": Proposed adjustment rates for terrain

PROPERTY	Subject LD "A"	Comparable LD1	Comparable LD2	Comparable LD3	Comparable LD4	Comparable LD5	Comparable LD6
Property ID	Lot 31, Mkm Kuala Kalumpang	Lot 724(+3), Mkm Ampang Pechah & Rasa	Lot 35, Mkm Sg Tinggi	Lot 2566, Mkm Batang Kali	Lot 2418(+22), Mkm Serendah & Rasa	Lot 1899, Mkm Hulu Bernam	Lot 146(+28), Mkm Sg Gumut & Kerling
Min elevation (meter)	52	44	22	132	26	13	52
Max elevation (meter)	146	347	80	511	254	133	135
Range (meter)	94	303	58	379	228	120	83
Mean slope of property unit (degree)	4.79384	9.94562	4.06387	17.88796	7.41632	3.11739	4.45893
Mean slope-rise of property unit (%)	8.40139	17.80320	7.11539	32.71541	13.08753	5.46537	7.81062
Mean slope-rise (float), ΔS	0.0840	0.1780	0.0712	0.3272	0.1309	0.0547	0.0781
Surface roughness index, VRM	0.00223	0.00619	0.00131	0.00971	0.00494	0.00100	0.00214
$\Delta S = S_{comparable\,i} - S_{subject}$		0.0940	(0.0129)	0.2431	0.0469	(0.0294)	(0.0059)
$\Delta VRM = VRM_{Comparable\,i} - VRM_{Subject}$		0.0040	(0.0009)	0.0075	0.0027	(0.0012)	(0.0001)
ΔS + ΔVRM		0.09798	(0.01378)	0.25062	0.04957	(0.03059)	(0.00600)
ΔS + ΔVRM (%)		9.80%	-1.38%	25.06%	4.96%	-3.06%	-0.60%
Proposed terrain adjustment (to the nearest 5%)		10.00%	0.00%	25.00%	5.00%	-5.00%	0.00%

19

* 17. Sila pertimbangkan kadar pelarasan yang dicadangkan oleh pendekatan ini (tulisan merah dalam Jadual LD "A" di atas) /

Please evaluate the adjustment rates suggested by this approach (red font in Table LD "A" above)

	Terlalu rendah / *Too low*	Agak rendah / *Slightly low*	Munasabah / *Reasonable*	Agak tinggi / *Slightly high*	Terlalu tinggi / *Too high*
LD1 berbanding LD "A" / *LD1 compared to LD "A"*	○	○	○	○	○
LD2 berbanding LD "A" / *LD2 compared to LD "A"*	○	○	○	○	○
LD3 berbanding LD "A" / *LD3 compared to LD "A"*	○	○	○	○	○
LD4 berbanding LD "A" / *LD4 compared to LD "A"*	○	○	○	○	○
LD5 berbanding LD "A" / *LD5 compared to LD "A"*	○	○	○	○	○
LD6 berbanding LD "A" / *LD6 compared to LD "A"*	○	○	○	○	○

Komen / Comments

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* 18. Anda adalah penilai bagi Subjek LD "A". Sila cadangkan kadar pelarasan faktor rupabumi bagi perbandingan di atas mengikut pertimbangan anda.

You are the valuer for the Subject LD "A". Please suggest the terrain adjustment rates for the comparisons according to your judgement.

	≥ -30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	≥ 30%
LD1 berbanding LD "A" / *LD1 compared to LD "A"*	○	○	○	○	○	○	○	○	○	○	○	○	○
LD2 berbanding LD "A" / *LD2 compared to LD "A"*	○	○	○	○	○	○	○	○	○	○	○	○	○
LD3 berbanding LD "A" / *LD3 compared to LD "A"*	○	○	○	○	○	○	○	○	○	○	○	○	○
LD4 berbanding LD "A" / LD4 compared to LD "A"	○	○	○	○	○	○	○	○	○	○	○	○	○
LD5 berbanding LD "A" / LD5 compared to LD "A"	○	○	○	○	○	○	○	○	○	○	○	○	○
LD6 berbanding LD "A" / LD6 compared to LD "A"	○	○	○	○	○	○	○	○	○	○	○	○	○

Soalan 19 hingga 20 adalah berkaitan kadar pelarasan yang disyorkan di Jadual LD "B" berikut. Anda boleh merujuk kepada Pelan Perbandingan, Pelan Kontur dan janaan imej-3D yang disertakan di atas untuk mendapatkan gambaran rupabumi subjek dan perbandingan /

Question 19 to 20 are related to the proposed adjustment rates in Table LD "B". You can refer to the Comparison Plan, Contour Plan and 3D-image rendition attached above for an overview of the subject's and comparisons' terrain condition

Jadual LD "B": Syor kadar pelarasan rupabumi /

Table LD "B": Proposed adjustment rates for terrain

PROPERTY	Subject LD "B"	Comparable LD1	Comparable LD2	Comparable LD3	Comparable LD4	Comparable LD5	Comparable LD6
Property ID	Lot 1, Mkm Peretak	Lot 724(+3), Mkm Ampang Pechah & Rasa	Lot 35, Mkm Sg Tinggi	Lot 2566, Mkm Batang Kali	Lot 2418(+22), Mkm Serendah & Rasa	Lot 1899, Mkm Hulu Bernam	Lot 146(+28), Mkm Sg Gumut & Kerling
Min elevation (meter)	637	44	22	132	26	13	52
Max elevation (meter)	1,335	347	80	511	254	133	135
Range (meter)	698	303	58	379	228	120	83
Mean slope of property unit (degree)	16.2369	9.94562	4.06387	17.88796	7.41632	3.11739	4.45893
Mean slope-rise of property unit (%)	29.5588	17.80320	7.11539	32.71541	13.08753	5.46537	7.81062
Mean slope-rise (float), ΔS	0.2956	0.1780	0.0712	0.3272	0.1309	0.0547	0.0781
Surface roughness index, VRM	0.0102	0.00619	0.00131	0.00971	0.00494	0.00100	0.00214
$\Delta S = S_{Comparable\ i} - S_{Subject}$		(0.1176)	(0.2244)	0.0316	(0.1647)	(0.2409)	(0.2175)
$\Delta VRM = VRM_{Comparable\ i} - VRM_{Subject}$		(0.0040)	(0.0089)	(0.0005)	(0.0053)	(0.0092)	(0.0081)
ΔS + ΔVRM		(0.12156)	(0.23332)	0.03108	(0.16997)	(0.25013)	(0.22554)
ΔS + ΔVRM (%)		-12.16%	-23.33%	3.11%	-17.00%	-25.01%	-22.55%
Proposed terrain adjustment (to the nearest 5%)		-10.00%	-25.00%	5.00%	-15.00%	-25.00%	-25.00%

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* 19. Sila pertimbangkan kadar pelarasan yang dicadangkan oleh pendekatan ini (tulisan merah dalam jadual LD "B" di atas) /

Please evaluate the adjustment rates suggested by this approach (red font in Table LD "B" above)

	Terlalu rendah / *Too low*	Agak rendah / *Slightly low*	Munasabah / *Reasonable*	Agak tinggi / *Slightly high*	Terlalu tinggi / *Too high*
LD1 berbanding LD "B" / *LD1 compared to LD "B"*	○	○	○	○	○
LD2 berbanding LD "B" / *LD2 compared to LD "B"*	○	○	○	○	○
LD3 berbanding LD "B" / *LD3 compared to LD "B"*	○	○	○	○	○
LD4 berbanding LD "B" / *LD4 compared to LD "B"*	○	○	○	○	○
LD5 berbanding LD "B" / *LD5 compared to LD "B"*	○	○	○	○	○
LD6 berbanding LD "B" / *LD6 compared to LD "B"*	○	○	○	○	○

Komen / Comments

22

* 20. Anda adalah penilai bagi Subjek LD "B". Sila cadangkan kadar pelarasan faktor rupabumi bagi perbandingan di atas mengikut pertimbangan anda.

You are the valuer for the Subject LD "B". Please suggest the terrain adjustment rates for the comparisons according to your judgement.

	≥ -30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	≥ 30%
LD1 berbanding LD "B" / *LD1 compared to LD "B"*	○	○	○	○	○	○	○	○	○	○	○	○	○
LD2 berbanding LD "B" / *LD2 compared to LD "B"*	○	○	○	○	○	○	○	○	○	○	○	○	○
LD3 berbanding LD "B" / *LD3 compared to LD "B"*	○	○	○	○	○	○	○	○	○	○	○	○	○
LD4 berbanding LD "B" / *LD4 compared to LD "B"*	○	○	○	○	○	○	○	○	○	○	○	○	○
LD5 berbanding LD "B" / *LD5 compared to LD "B"*	○	○	○	○	○	○	○	○	○	○	○	○	○
LD6 berbanding LD "B" / *LD6 compared to LD "B"*	○	○	○	○	○	○	○	○	○	○	○	○	○

LUNDS UNIVERSITET

Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

E: Aplikasi GIS dalam penilaian harta tanah / *GIS application in property valuation*

Kajian ini menggunakan aplikasi GIS untuk mengesyorkan kadar pelarasan bagi faktor rupabumi. Walau bagaimanapun, terdapat banyak lagi ruang dan peluang untuk menggunakan aplikasi GIS dalam kerja-kerja penilaian. Seksyen ini bertujuan memahami pandangan, kerisauan dan jangkaan anda terhadap pendekatan sedemikian dalam penilaian harta tanah.
This study uses GIS applications to suggest adjustment rates for terrain factors. In reality, there is a lot more space and opportunity to include GIS Application in valuation works. This section attempts to understand your views concerns and expectation of such approaches in property valuation.

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* 21. Penilaian selalu digambarkan sebagai kombinasi di antara seni dan sains. Kajian ini menggunakan kaedah kuantitatif untuk menentukan pelarasan rupabumi. Adakah kaedah/pendekatan sebegini patut digalakkan dalam amalan penilaian semasa? /

Valuation is always described as a combination of art and science. This study uses quantitative methods to determine terrain adjustments. Should this method/approach be encouraged in current valuation practice?

- Ya / Yes
- Tidak / No

* 22. Adakah program penilaian patut memperkenalkan GIS sebagai salah satu subjek pengajian? /

Should valuation programmes introduce GIS subjects as part of the course?

- Ya / Yes
- Tidak / No
- Tiada pandangan / No opinion

* 23. Adakah anda berminat untuk turut serta dalam latihan GIS sekiranya diberi peluang? /

Would you be interested in GIS training if given the opportunity?

- Ya / Yes
- Tidak / No

* 24. Apakah pandangan anda terhadap penilaian yang dibantu oleh kaedah berkomputer, khasnya apabila melibatkan algorithm statistik untuk menjana nilai?

What is your opinion on computer-aided valuation, in particular when involving pre-determined statistical algorithms to generate value?

25. Terima kasih kerana turut serta dalam soal selidik ini. Sekiranya terdapat sebarang komen berkaitan soal-selidik atau kajian ini, sila ulas dalam ruang komen yang disertakan. Anda juga boleh meninggalkan emel anda di sini sekiranya anda inginkan maklum balas peribadi berkaitan komen tersebut. /

Thank you for participating in this study. If you have any comment regarding the survey or the study, please leave your comment in the following text box. You may also leave your email here if you wish a for a personal response regarding your comment.

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END OF QUESTIONNAIRE

Appendix D: Online Survey Questionnaire Results

Using GIS Applications to Determine Terrain Factor Adjustments in Property Valuation

1. Current work sector		
Answer Options	Response Percent	Response Count
Government valuer	80.8%	97
Private valuer	13.3%	16
Estate agent	1.7%	2
Academics	4.2%	5
Retired valuer	0.0%	0
Other (please specify):	0.0%	0
	answered question	120
	skipped question	1

2. Age		
Answer Options	Response Percent	Response Count
Under 26 years	3.4%	4
26 until 30 years	13.7%	16
31 until 35 years	29.1%	34
36 until 40 years	17.9%	21
41 until 45 years	2.6%	3
46 until 50 years	11.1%	13
Above 50 years	22.2%	26
	answered question	117
	skipped question	4

3. Highest academic qualification related to property		
Answer Options	Response Percent	Response Count
Diploma	2.6%	3
Bachelor Degree	74.1%	86
Master Degree	19.8%	23
Other (please specify):	3.4%	4
	answered question	116
	skipped question	5

4. Work experience in property valuation		
Answer Options	Response Percent	Response Count
Less than 4 years	12.9%	15
4 to 6 years	10.3%	12
7 to 9 years	16.4%	19
10 to 15 years	25.9%	30
More than 15 years	34.5%	40
	answered question	116
	skipped question	5

5. Professional status (license registration)		
Answer Options	Response Percent	Response Count
Less than 4 years	7.8%	9
4 to 6 years	3.5%	4
7 to 9 years	7.0%	8
10 to 15 years	2.6%	3
More than 15 years	8.7%	10
I am not a registered valuer	70.4%	81
	answered question	11
	skipped question	

6. The following are several factors that are considered in value adjustme :s. Rank the factors according to their impact on value from 1 (highest impact) to 5 (lowest impact).Note: Each rank may be allocated ith 1 factor only							
Answer Options	1	2	3	4	5	Rating Average	Response Count
Shape of lot	13	8	16	23	39	3.68	99
Terrain condition	7	16	37	29	10	3.19	99
Availability of legal road access	32	22	16	11	18	2.61	99
Layer from road access	29	38	9	18	5	2.31	99
Size of lot	18	15	21	18	27	3.21	99
					answered question		99
					skipped question		22

7. Rate the effects of the following factors on value in most valuation case							
Answer Options	Very weak	Weak	Moderate	Strong	Very strong	Rating Average	Response Count
Shape of lot	17	16	34	17	12	2.91	96
Terrain condition	2	10	31	37	16	3.57	96
Availability of legal road access	5	5	16	28	42	4.01	96
Layer from road access	6	4	5	38	43	4.13	96
Size of lot	7	11	25	24	29	3.59	96
					answered question		96
					skipped question		25

8. Observe the following property site photographs above and select the ljective that best describe the terrain that you see								
Answer Options	Undulated	Hilly	With slopes	Mountain ous	Steep	Flat	High-low	Response Count
Photograph A1	0	24	0	46	0	0	1	71
Photograph A2	35	9	15	0	4	0	8	71
Photograph A3	4	18	13	0	19	0	17	71
Photograph A4	5	15	22	1	18	0	10	71
Photograph A5	1	0	0	0	0	70	0	71
Photograph A6	37	1	3	0	1	8	21	71
						answered question		71
						skipped question		50

9. Please further describe the terrain conditions of Photograph A1 until A6 based on what you see (assume you are taking inspection notes)		
Answer Options	Response Percent	Response Count
Photograph A1	100.0%	71
Photograph A2	100.0%	71
Photograph A3	100.0%	71
Photograph A4	100.0%	71
Photograph A5	100.0%	71
Photograph A6	100.0%	71
	answered question	71
	skipped question	50

10. Say B1 is the subject property and B2 until B4 are the comparables, please suggest the adjustment rate for terrain factor for Comparison B2, B3 and B4.

Answer Options	≥ -30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	≥ 30%	Percent Average	Response Count
B2 compared to B1	8	5	16	6	14	4	3	0	1	1	3	1	2	-4.45%	64
B3 compared to B1	2	5	10	6	13	12	2	3	4	3	2	1	1	-5.47%	64
B4 compared to B1	13	5	12	15	6	3	1	3	0	0	2	1	3	-1.64%	64
														answered question	64
														skipped question	57

11. Say C1 is the subject property and C2 until C4 are the comparables, please suggest the adjustment rate for terrain factor for Comparison C2, C3 and C4.

Answer Options	≥ -30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	≥ 30%	Percent Average	Response Count
C2 compared to C1	1	1	6	6	9	1	2	10	10	3	7	1	1	0.52%	58
C3 compared to C1	12	4	3	2	3	1	0	3	6	4	3	4	13	1.72%	58
C4 compared to C1	2	1	2	6	2	10	19	8	3	1	2	2	0	-1.90%	58
														answered question	58
														skipped question	63

12. If the subject property is situated in an inaccessible location for site inspection, how would you consider the terrain factor? Please choose three (3) out of the selections listed below

Answer Options	Response Percent	Response Count
I will only proceed with the valuation upon	10.3%	6
I will refer to topograpy maps	84.5%	49
I will refer Google Earth and/or other remote	79.3%	46
I will ask the client to describe the property and	70.7%	41
I will make assumptions based on known	20.7%	12
I will try to get information from professional	12.1%	7
I will inquire on social networks	0.0%	0
I will reject this valuation case	0.0%	0
I never accept valuation cases involving inaccessible	0.0%	0
I will interview officers in the local government	5.2%	3
I will interview officers in the local residents	13.8%	8
Other (please specify)	3.4%	2
answered question		58
skipped question		63

13. Please evaluate the adjustment rates suggested by this approach (red font in Table HK above)

Answer Options	Too low	Slightly low	Reasonable	Slightly high	Too high	Rating Average	Response Count
HK1 compared to HK "A"	1	9	17	19	2	3.25	48
HK2 compared to HK "A"	2	11	34	0	1	2.73	48
HK3 compared to HK "A"	4	12	29	2	1	2.67	48
HK4 compared to HK "A"	1	9	31	6	1	2.94	48
Comments							3
						answered question	48
						skipped question	73

14. You are the valuer for the Subject HK "A". Please suggest the terrain adjustment rates for the comparisons according to your judgement.

Answer Options	-30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	30%	Rating Average	Response Count
HK1 compared to HK "A"	1	1	4	2	3	12	3	2	6	5	7	2	0	0.33	48
HK2 compared to HK "A"	0	1	5	1	9	6	2	20	4	0	0	0	0	-0.50	48
HK3 compared to HK "A"	1	1	2	1	7	8	2	18	5	2	0	1	0	-0.10	48
HK4 compared to HK "A"	0	1	1	2	6	11	3	7	14	3	0	0	0	0.13	48
														answered question	48
														skipped question	73
	-30%	-25%	-80%	-30%	-30%	-60%	0%	10%	60%	75%	140%	50%	0%	1.67%	
	0%	-25%	-100%	-15%	-90%	-30%	0%	100%	40%	0%	0%	0%	0%	-2.50%	
	-30%	-25%	-40%	-15%	-70%	-40%	0%	90%	50%	30%	0%	25%	0%	-0.52%	
	0%	-25%	-20%	-30%	-60%	-55%	0%	35%	140%	45%	0%	0%	0%	0.63%	

15. Please evaluate the adjustment rates suggested by this approach (red font in Table DA above)

Answer Options	Too low	Slightly low	Reasonable	Slightly high	Too high	Rating Average	Response Count
DA1 compared to DA "A"	0	5	26	9	0	3.10	40
DA2 compared to DA "A"	0	10	24	6	0	2.90	40
DA3 compared to DA "A"	2	3	33	0	2	2.93	40
DA4 compared to DA "A"	0	2	25	11	2	3.33	40
Comments							4
						answered question	40
						skipped question	81

16. You are the valuer for the Subject DA "A". Please suggest the terrain adjustment rates for the comparisons according to your judgement.

Answer Options	-30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	30%	Rating Average	Response Count
DA1 compared to DA "A"	0	0	0	1	15	12	8	2	1	0	1	0	0	-0.93	40
DA2 compared to DA "A"	0	0	0	4	17	9	5	3	1	0	1	0	0	-1.15	40
DA3 compared to DA "A"	0	0	1	0	2	6	21	3	3	1	2	1	0	0.28	40
DA4 compared to DA "A"	0	0	0	0	3	7	10	8	10	1	1	0	0	0.55	40
														answered question	40
														skipped question	81
	0%	0%	0%	-15%	-150%	-60%	0%	10%	10%	0%	20%	0%	0%	-4.63%	
	0%	0%	0%	-60%	-170%	-45%	0%	15%	10%	0%	20%	0%	0%	-5.75%	
	0%	0%	-20%	0%	-20%	-30%	0%	15%	30%	15%	40%	25%	0%	1.38%	
	0%	0%	0%	0%	-30%	-35%	0%	40%	100%	15%	20%	0%	0%	2.75%	

17. Please evaluate the adjustment rates suggested by this approach (red font in Table LD "A" above)

Answer Options	Too low	Slightly low	Reasonable	Slightly high	Too high	Rating Average	Response Count
LD1 compared to LD "A"	0	3	19	7	0	3.14	29
LD2 compared to LD "A"	0	6	23	0	0	2.79	29
LD3 compared to LD "A"	0	2	19	5	3	3.31	29
LD4 compared to LD "A"	0	3	25	1	0	2.93	29
LD5 compared to LD "A"	0	3	25	1	0	2.93	29
LD6 compared to LD "A"	0	1	28	0	0	2.97	29
Comments							1
						answered question	29
						skipped question	92

18. You are the valuer for the Subject LD "A". Please suggest the terrain adjustment rates for the comparisons according to your judgement.

Answer Options	-30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	30%	Rating Average	Response Count
LD1 compared to LD "A"	0	0	0	1	2	3	5	5	13	0	0	0	0	0.72	29
LD2 compared to LD "A"	0	0	0	1	2	2	19	4	0	0	0	1	0	0.00	29
LD3 compared to LD "A"	0	2	0	1	0	1	7	2	2	1	2	10	1	2.03	29
LD4 compared to LD "A"	0	0	0	1	0	3	7	17	1	0	0	0	0	0.45	29
LD5 compared to LD "A"	0	0	0	1	0	5	6	16	1	0	0	0	0	0.34	29
LD6 compared to LD "A"	0	0	0	0	1	2	23	3	0	0	0	0	0	-0.03	29
														answered question	29
														skipped question	92
	0%	0%	0%	-15%	-20%	-15%	0%	25%	130%	0%	0%	0%	0%	3.62%	
	0%	0%	0%	-15%	-20%	-10%	0%	20%	0%	0%	0%	25%	0%	0.00%	
	0%	-50%	0%	-15%	0%	-5%	0%	10%	20%	15%	40%	250%	30%	10.17%	
	0%	0%	0%	-15%	0%	-15%	0%	85%	10%	0%	0%	0%	0%	2.24%	
	0%	0%	0%	-15%	0%	-25%	0%	80%	10%	0%	0%	0%	0%	1.72%	
	0%	0%	0%	0%	-10%	-10%	0%	15%	0%	0%	0%	0%	0%	-0.17%	

19. Please evaluate the adjustment rates suggested by this approach (red font in Table LD "B" above)

Answer Options	Too low	Slightly low	Reasonable	Slightly high	Too high	Rating Average	Response Count
LD1 compared to LD "B"	4	4	21	0	0	2.59	29
LD2 compared to LD "B"	3	5	20	1	0	2.66	29
LD3 compared to LD "B"	3	1	22	3	0	2.86	29
LD4 compared to LD "B"	3	7	18	1	0	2.59	29
LD5 compared to LD "B"	1	5	20	3	0	2.86	29
LD6 compared to LD "B"	2	4	21	2	0	2.79	29
Komen / Comments							0
						answered question	29
						skipped question	92

20. You are the valuer for the Subject LD "B". Please suggest the terrain adjustment rates for the comparisons according to your judgement.

Answer Options	-30%	-25%	-20%	-15%	-10%	-5%	0%	5%	10%	15%	20%	25%	30%	Rating Average	Response Count
LD1 compared to LD "B"	0	1	1	2	18	2	3	1	0	1	0	0	0	-1.69	29
LD2 compared to LD "B"	3	1	14	1	2	4	3	1	0	0	0	0	0	-3.07	29
LD3 compared to LD "B"	0	0	2	1	1	5	7	12	1	0	0	0	0	-0.14	29
LD4 compared to LD "B"	0	2	1	13	6	2	3	0	1	0	1	0	0	-2.10	29
LD5 compared to LD "B"	3	10	4	1	1	2	3	3	0	0	1	1	0	-2.72	29
LD6 compared to LD "B"	3	1	12	1	2	2	3	3	0	0	2	0	0	-2.38	29
														answered question	29
														skipped question	92
	0%	-25%	-20%	-30%	-180%	-10%	0%	5%	0%	15%	0%	0%	0%	-8.45%	
	-90%	-25%	-280%	-15%	-20%	-20%	0%	5%	0%	0%	0%	0%	0%	-15.34%	
	0%	0%	-40%	-15%	-10%	-25%	0%	60%	10%	0%	0%	0%	0%	-0.69%	
	0%	-50%	-20%	-195%	-60%	-10%	0%	0%	10%	0%	20%	0%	0%	-10.52%	
	-90%	-250%	-80%	-15%	-10%	-10%	0%	15%	0%	0%	20%	25%	0%	-13.62%	
	-90%	-25%	-240%	-15%	-20%	-10%	0%	15%	0%	0%	40%	0%	0%	-11.90%	

21. Valuation is always described as a combination of art and science. This study uses quantitative methods to determine terrain adjustments. Should this method/approach be encouraged in current valuation practice?

Answer Options	Response Percent	Response Count
Yes	96.4%	27
No	3.6%	1
	answered question	28
	skipped question	93

22. Should valuation programmes introduce GIS subjects as part of the course?

Answer Options	Response Percent	Response Count
Yes	92.9%	26
No	3.6%	1
No opinion	3.6%	1
	answered question	28
	skipped question	93

23. Would you be interested in GIS training if given the opportunity?		
Answer Options	Response Percent	Response Count
Yes	89.3%	25
No	10.7%	3
	answered question	28
	skipped question	93

24. What is your opinion on computer-aided valuation, in particular when involving pre-determined statistical algorithms to generate value?	
Answer Options	Response Count
	28
answered question	28
skipped question	93

25. Thank you for participating in this study. If you have any comment regarding the survey or the study, please leave your comment in the following text box. You may also leave your email here if you wish a for a personal response regarding your comment.	
Answer Options	Response Count
	9
answered question	9
skipped question	112

Institutionen för naturgeografi och ekosystemvetenskap, Lunds Universitet.

Student examensarbete (Seminarieuppsatser). Uppsatserna finns tillgängliga på institutionens geobibliotek, Sölvegatan 12, 223 62 LUND. Serien startade 1985. Hela listan och själva uppsatserna är även tillgängliga på LUP student papers (https://lup.lub.lu.se/student-papers/search/) och via Geobiblioteket (www.geobib.lu.se)

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