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DEPARTMENT OF GEOMATIC ENGINEERING

A RESEARCH REPORT ENTITLED

GEOSPATIAL TECHNIQUES FOR SUSTAINABLE HUMAN SETTLEMENT DESIGN: A CASE STUDY

BY

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SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN GEOMATIC ENGINEERING

THESIS SUPERVISORS

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MAY, 2020

DECLARATION

I declare that this research work is my own work and its being submitted in partial fulfilment for the degree of Master of Science in Geomatic Engineering in the University of Mines and Technology (UMaT), Tarkwa. It has not been submitted for any degree or examination in any other University.

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ABSTRACT

In recent decades, the landscape of cities changed significantly because of rapid urban population growth, which has resulted in the struggle for space. This has been accompanied by many serious problems including inefficient use of land, encroachment of water bodies and forest, landuse specialisation, among others. It is therefore necessary to adopt strategies to address these problems through the designing communities. This study investigates the existing planning scheme of Mfuom community within the Upper Denkyira East Municipality in the central region of Ghana and proposed a sustainable planning scheme using geospatial techniques for the undeveloped portions to absorb the future population growth. The methods used include evaluation of existing planning scheme, household questionnaire administration, determination of proposed land area and plot sizes, proposal of community goals and objectives, the Analytical Hierarchy Process (AHP) and the Grey Relational Analysis (GRA). The evaluation of the existing planning scheme showed that, the current design was unsustainable since it was not exhibiting the component and principles of sustainable design. The total land area of the proposed settlement was calculated to be 303000m^2 and plot sizes to be 450m^2 using the medium residential density of the Ghana's Planning and Zoning standards. The AHP was used in the selection of suitable urban design model for the study area by allocating weights to the various design models in order of suitability. A pairwise matrix was formed and then normalised. A consistency check was carried out and the consistency ratio was found to be 0.019 which is less than 0.1. Hence, the weights obtained for the types of the design models i.e., "Neighborhood Design model", "Multi Nuclei Model", "Sector Model" and "Concentric Model" were 0.51 (or 51%), 0.28 (or 28%), 0.13 (or 13%) and 0.08 (or 8%) respectively. Therefore, the neighbourhood design model was selected for the research. The GRA was then used in the selection of optimal site for some prominent landuses. Zone A, B, C, and D was selected for shopping area, Active recreational area and Health Centre, Police Post and Education respectively with their corresponding Grey Relational Grade (GRG) as 0.58, 0.54 and 0.81, 0.78 and 0.66. The final result of a settlement model designed proved that the design was sustainable and when implemented could absorb the future population growth and be free from current city spatial problems.

DEDICATION

This research is dedicated to my husband, Mr Edmund Dawson-Ahmoah for his support throughout this degree programme. I also dedicate this project work to my project supervisors, Dr Saviour Mantey and Dr Michael S. Aduah for their time and coaching given me to come out with this research work. Finally, I dedicate this research work to my parents and siblings.

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CHAPTER 1

INTRODUCTION

1.1 Statement of the Problem

The recent increasing competition for space among human activities as a result of population growth has been the motivating factor for the practice of land use planning in the world (Pacione, 2009). Settlement design is one of the mostly used tools to manage land usage and other resources on land. This is because, land is significant to socio-economic development of people and nations, since most human activities occur on it. Significance of land has to do with its key characteristics, such as its finite nature, provision of direct sustainable livelihood for people, support of ecosystem services and its socio-political-religious functions relating to identity of people (Fuseini and Kemp, 2015). The emergence of the concept of sustainable development has added another dimension to the need for judicious planning as it seeks to integrate economic development with environmental and social equity. According to the United Nations Agenda 21, sustainable development is aimed to balance the effects of overall development in terms of three dimensions, *i.e*. environment, economic and social. The initial focus of this three-pillar concept was only on the national level. But most of the challenges of sustainable development are experienced at the local level such as the cities and towns (Zhang *et al*., 2018). Planning and development decisions at local level play significant role on enhancing the local sustainability (Thabrew *et al*., 2009). Therefore, in order to achieve this, most countries have adopted the chapter 28 of the "Local Agenda 21," which deals specifically with actions at the local stages (Anon., 1992).

According to Jacobs (1996), a sustainable way of living should effortlessly drive the way we design our neighborhoods, as they are beneficial to the community, individual, and the environment as a whole. Therefore, settlement planning and design is very important when facilitating sustainable development. However, unlike many developed countries where sustainable development has been implemented at neighborhood, communities or grassroots stages, sustainable planning and design research has been concentrated at the national level and a little has focus on the neighborhood or community level in most developing countries (Zhang *et al*., 2018) including Ghana.

This is because settlement planning and designing has faced challenges in complying with the sustainability design criteria in many African countries. These challenges have been attributed to rapid urbanisation, poor link between planning, budgeting and Implementation as well as poor city management (Anon., 2013a).

It has been estimated that about 60% of the world's population will be living in urban areas by 2050 (Anon., 2014a). Urbanisation combined with overall growth of the world's population could add another 2.5 billion people to urban populations and close to 90% of the increase concentrated in Asia and Africa (Anon., 2014a). This indicates that if settlements and cities are not well planned, they may grow to face serious challenges than before (Anon, 2013a).

Moreover, the case in Ghana is not different, the challenges of settlement or city planning and design has been attributed to inadequate number of qualified physical planning professionals, political interferences, complex land tenure system, lack of data for the design and lack of effective collaboration between agencies mandated to design and execute plans (Fuseini and Kemp, 2015). Additionally, commitment of planning agencies, stragedies and poor law enforcement in Ghana has impeded the success of sustainable design and implementation of settlement plans (Appiah, 2016).

This research therefore seeks to investigate the existing local planning scheme of the Mfuom community in the Upper Denkyira East Municipal Assembly in the Central Region of Ghana and to design a sustainable planning scheme to address any identified challenges.

1.2 Research Objectives

The objectives of this research are:

i. To investigate the existing planning scheme of the study area
ii. To design a sustainable planning scheme for the undeveloped portions of the study area.

1.3 Expected Outcomes

At the end of this research:

i. Mfuom community planning scheme and facilities will be investigated and
ii. Sustainable local planning scheme would be designed to promote sustainable development.

1.4 Methods Used

The methods used for the research include:

i. Reconnaissance survey of the study area,
ii. Drone image acquisition,
iii. Georeferencing of aerial photos and planning scheme,
iv. Setting out and plotting of Data for validation,
v. Analysis of administered Household questionnaire,
vi. Analytical Hierarchy Process in selecting suitable design model,
vii. Grey Relational Analysis in siting various landuse,
viii. Using Date to Generate various maps.

1.5 Materials Used

The facilities and materials used for this research include:

i. Internet and library facility at the University of Mines and Technology,
ii. South Static GNSS Receiver,
iii. Orthophotos of the study area,
iv. Administered household questionnaires.

1.6 Organisation of Thesis

The thesis is made up of six chapters. Chapter 1 gives an introductory view of the Research. Relevant information about the study area is given in chapter 2. Relevant literature about the project topic is reviewed in chapter 3. Chapter 4 addresses both the materials and methods used to achieve the objectives of the Research. The results were analysed and discussed in chapter 5. Chapter 6 gives the conclusions with outlined recommendations.

CHAPTER 2

THE STUDY AREA

2.1 Relevant Information about the Study Area

Mfuom is one of the oldest and fastest growing communities in the Upper Denkyira East Municipal Assembly with population of 6160 and annual growth rate of 3.7 % which is higher than the municipal annual growth rate of 3.1%. Mfuom is ranked as a second order settlement in the municipality. About 50.4% (3104) of the population are males whiles 49.6% (3074) are females. The working population (i.e. age 18-60) is 78 % (4804) whiles 22% are in the dependency group (i.e. 0-17 and above 70 years).

The natives of the community are Denkyiras. However, the community exhibits heterogeneous characteristics with some tribes such as the Fantes, Asantes, Dagombas and Nzemas.

Mfuom is predominantly a Christian community with the total population of 62%, whiles 27% are Muslims and 11 percent fall within the other religions (traditional believers, Hindus, etc.). The total economic active group or workforce (ages between 18-70 years) are 56% and are employed in various types of employment whiles 44% are unemployed. Among the employment group, 38% have their jobs within the community whiles 62% are outside the community. This implies that, the community is somehow being used as a dormitory town within the Municipality where people go to work at places outside the community and comes to the community to sleep after work closes.

36% of the employment group are into service, 48% in commerce, 12% in Agriculture and 4% are into various types of industrial jobs (Mining, quarrying, wood processing, block work production, *etc.* (Field survey, 2019).

2.2 Location and Size

Mfuom can be found between the latitudes 5º 56.07' N and 5º 57.73' N and longitudes 1º 46.98'W and 1º 48.62' West of the Greenwich Meridian. It can be located at the northern part of the Municipality. It is bounded with the communities to the north by Atechem, East by Aboabo, West by Babianiha and South by Mbradan. The community has a total land area of 4.16sqkm. The community is physically divided into two section i.e. south and north by the main road which runs through to Asikuma and Twifo Praso. Showing in the figure 2.1 is the location of the study area.

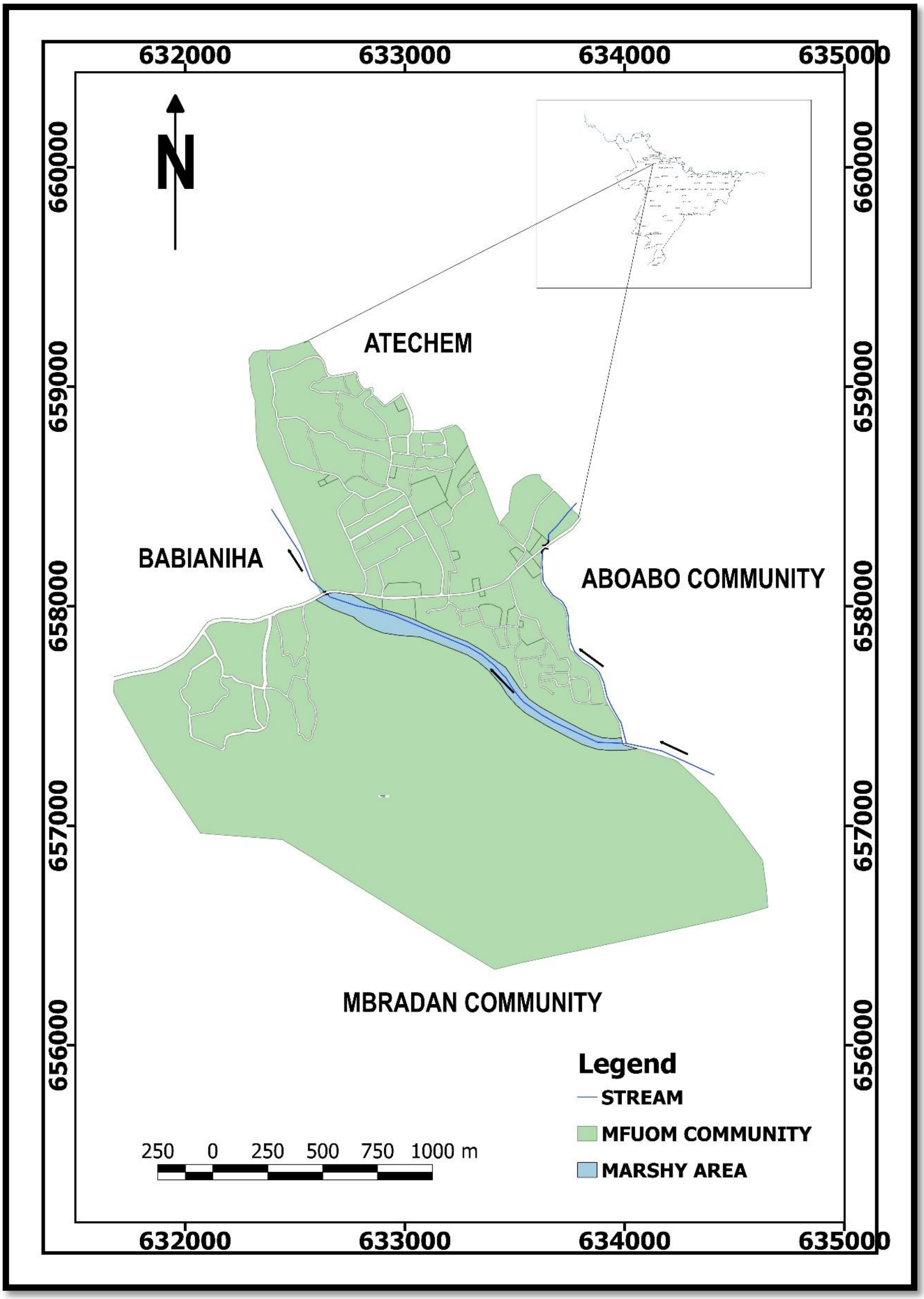

Figure 2.1 Location of Mfuom in Municipal context

2.3 Topography and Drainage

The community is characterised by hills at the south-eastern part with the highest height of 260 m above sea level and the lowest point of 120 m above sea level. The built up of the study area is fairly flat with height ranging between 120 m and 160 m above sea level. The community is drained by three streams namely Aboabo, Adjukusu and Sia stream. The streams have their source from the high lands in the south-eastern part and flows down northwards towards the low lands of the community (Anon., 2018). The figure 2.2 and 2.3 show the cross-section of the community.

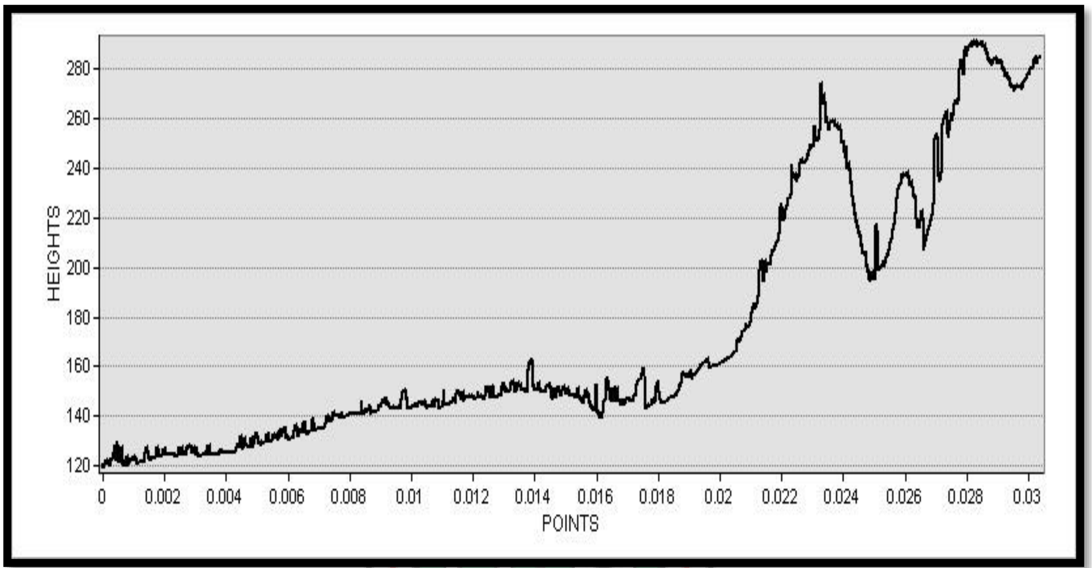

Figure 2.2 Cross-Section from NNW to SSE of Mfuom

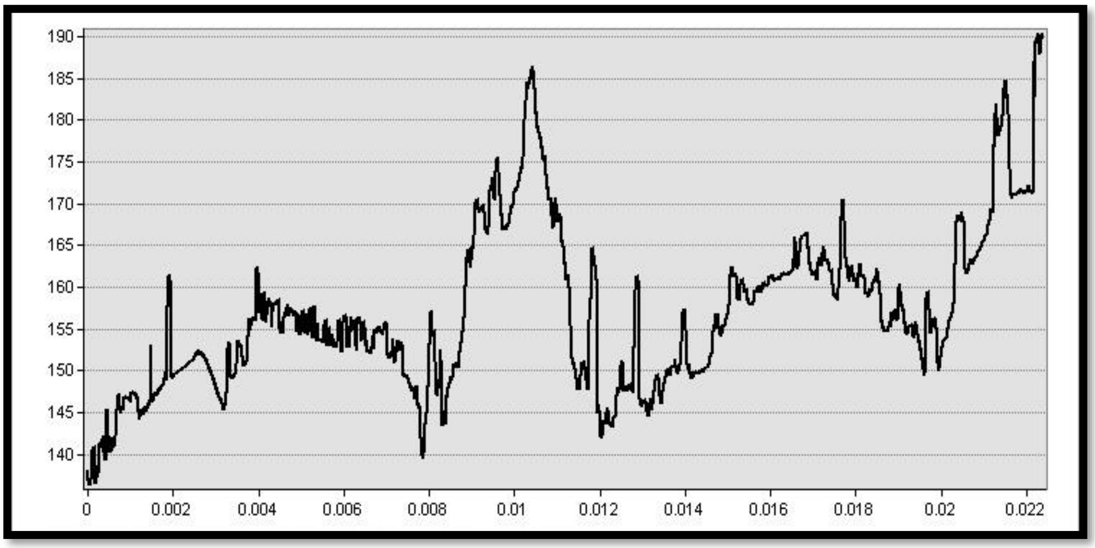

Figure 2.3 Cross-Section from NNE to SSW of Mfuom

2.4 Vegetation

The community has some similar vegetation characteristics as the Municipality. Community falls under the semi-deciduous forest zone which has similar characteristics as the Tropical rain forest in the country. Here, trees found are of different species and do not shed all leaves during the dry season. However, the vegetation is depleting due to farming and construction activities in the area (Anon., 2014b).

CHAPTER 3

LITERATURE REVIEW

3.1 Evolution of Human Settlements

A human settlement is defined as a place occupied more or less permanently by people (Anon., 2017b). It includes structures in which they live or use and the routes over which they travel. It may also include temporary camps of the hunters and herders. It may consist of a few dwelling units called hamlets or big cluster of buildings called urban cities. In many respects, settlements are important in all facets of life, because it is through their development that man can explore the environment for his needs (Akinrogunde, 2016).

Settlements are the most visible sign that human culture has imposed on the natural world and its forms, patterns, distributions, types and sizes and their tendency towards change with time have fascinated geographers (Ahmed, 2009).

In about 8000 BC, which was the end of the last ice age, the world's population consisted of small groups of hunters and gatherers living mainly in subtropical lands. At this time, two major technological changes, known as the Neolithic revolution turned the hunters and gatherers into sedentary farmers (the domestication of animals such as sheep, goats and cattle and the cultivation of cereals like wheat, rice and maize). Here, people did not have to migrate any more in search for food. Over thousand and more years later, villages grew to sizes much larger than before. Humankind therefore developed further intellectually, militarily and spiritually. Over time, villages fought each other and spread their control over a large area and developed into more advanced civilisations. Improvements in early farming gradually led to food surpluses and some were traded for other goods. This enabled humankind to specialize in non-farming activities (Anon., 2018d).

By 1500 BC, larger towns and urban areas had developed with an increasingly large range of functions such as administration, engineering and craftsmanship functions. Administrators were needed to organize the collection of crops and the distribution of food supplies and also exchange surplus goods with other urban centers and early engineers introduced irrigation systems. Craftsmen were needed to make farming equipment and articles. The oldest known pottery, woven textiles were found in Yuchanyan Cave found in Hunan, China. As towns continued to grow it became necessary to have a legal system and an army for defense and other arms of governance (Anon., 2018d).

The evolution of human settlements has been classified into five main phases namely; the primitive non-organised, the primitive organised, static urban settlements and dynamic urban settlements as well as universal human settlement (Ecumenopolis).

3.1.1 The primitive Non-Organised

Here, man first settled in natural shelters such as hollows in the ground, hollow trees or shallow caves, before he began to build his own primitive and unorganised place. After man had exploited the natural environment, he then transformed them into dwellings by alterating the existing ones. Additional dwellings were added and boundaries were within certain confinement. There were no communication or transportation connecting them to the others. Their closeness of putting up dwelling was attributed to security reasons. This type of settlement on a large scale consisted of the centre which is the built up area of the settlement and several parts which leads out into the open, thinning out until there are no dwellings. The people here are mostly hunters and gatherers and later went into agriculture and animal husbandry (Birrell *et al.*, 2011; Lakshmanan, 2011).

3.1.2 The Primitive Organised

This is where man began to enter the era of organised agriculture and so his settlements also began to show some characteristics of organisation. This happened from ten thousand to twelve thousand years ago. Previously, man had one-room dwelling in circular form, to organise the relationship of his community with other communities he expanded his dwelling by placing more round forms of dwellings side by side taking the shape of an ellipse and rectangle. The evolution reached the stage at which a rectilinear pattern develops into a regular grid - iron pattern. This period was called the period of villages. During this era, the development of human settlements patterns or distribution of settlements differ depending on the phase of evolution and the prevailing conditions of safety, the population still remains small and villages were mostly found in the plains, near the rivers and near the sea.

When the population increased and became larger, new patterns developed, and the villages came over to cover the entire plain, hill or mountain in a small hexagonal pattern. Here, the people were still farmers (Birrell *et al.*, 2011; Lakshmanan, 2011).

3.1.3 Static Urban Settlements

This type of settlements happened around 5,000 to 6,000 years ago. The first urban settlement developed as small cities in a plain or as fortresses on hills and mountains. As settlements grew in size, expansion of settlements was no longer at the centre or the nucleus type. It was no longer limited to the settlement's centre of gravity. Expansion occurred either in a linear form along the main streets or cluster at the centre of the settlement or around great buildings such as the temples. An example is the small settlement of Priene in ancient Greece. In larger cities, additional nodal points and central places gradually came into being within the shells of the settlements (Birrell *et al.*, 2011; Lakshmanan, 2011).

3.1.4 Dynamic Urban Settlement

This era of the dynamic urban settlement started in the 17th century as a result of the multiplying forms of industrial technological revolution and may probably last for the next 100 to 200 years until we reach the next phase of settlement. With this phase of settlement, it is characterised by continuous growth so therefore, its problems are also continuously created. The problems experienced in them are those of yesterday which are being multiplied today in a very dangerous manner (Birrell *et al.*, 2011). This makes the dynamic settlement completely different from any other category of settlements and a real threat to humanity itself. An example is China where about 17 percent of total deaths in the country is caused by air pollution and is killing 1.2 to 2 million deaths annually (Rohde and Muller, 2015). The dynamic urban settlement includes Dynapolis, Metropolis/dynametropolis and megapolis/ Dynamegapolis which are described below.

Dynapolis

This is the phase when small independent human settlements with independent administrative units are beginning to grow beyond their initial boundaries. This period was the time railway transportation was invented to facilitate the movement of people from distant places to the other. The settlements expand in all directions, instead of spreading only along the railway lines, they expanded creating new islands of dependent settlements around railway stations. The city is breaking its walls and spreading into the countryside in a disorganised manner. Here microorganisms in the soil no longer exist, the original animal habitat such as ants have largely been banished, rivers are foul and the atmosphere is polluted, climate and microclimate have retrogressed.

Metropolis / Dynametropolis

The next phase of dynamic settlement is of metropolis, which incorporates several other urban and rural settlements of the surrounding area. The few metropolises from the past became static, then declined and died out because of its increasing problems in the urban centres.
This was then followed by a period of dynamic growth, thereby adapting dynametropolis.

Megalopolis / Dynamegalopolis

Settlement expansion occur on a large scale merging more than one metropolis and many other urban settlements.
A megalopolis has the same external characteristics as the metropolis, the only difference is that every actions and phenomenon appears on a larger scale.

3.1.5 Universal Human Settlement: Ecumenopolis

This is where two or more megapolis grows and merge to form one big composite city. This is also called the universal city. Megapolis and countries had been continuously growing since the last centuries and very soon the Earth will be covered by one big human settlement.

3.2 Sustainability

Over the past few decades, the definition of sustainability was primarily in environmental terms, but today the focus has shifted to the Triple Bottom Line, which looks at economy, environment, and social equity where many professions have adopted in their field of work. Human beings are at the center of concern for sustainable development and therefore all other species are dependent on their activities (Anon., 2002).

Sustainability is believed to have first originated in forestry where it meant that man should never harvest more than what the forest produces in new growth (Stenzel, 2010). This means that to be sustainable, the total amount of harvested forest produce should be less than or equal to the total amount of new growth of the forest in its next cycle. i.e. Sustainability = The Total amount of harvested forest produce ≤ total amount forest produce in new growth.

Sustainability is the condition or the state that would allow the continued existence of homo sapiens on the planet. In order to achieve this state, there is the need to balance the needs of humans with the carrying capacity of the planet, and with the need to protect that capacity so that the needs of future generations can continue to be met (Anon., 2002). This does not imply the survival of current and future homo sapiens, but to be able to live in an environment that provides a certain quality of life. i.e. the ability to have safe, healthy and productive life in harmony with nature, local cultural and spiritual values.

The United Nation's 1987 Report of the World Commission on Environment and Development (Anon., 1987) noted that sustainability is the ability of society to meet the needs of the present without compromising the ability of future generations to meet their own needs. This means that in development, consideration must be given to the impact on the generations unborn.

Many a times, the term sustainability and sustainable development are used to mean the same but their meanings are different. Sustainable development is not just development that can be maintained or sustained, but it is meant to be the kind of development that is needed to be pursued in order to achieve the state of sustainability. It is the process of maintaining a dynamic or changing balance between the demands of people and what is ecologically possible (Anon., 2002). According to Sharma and Rani (2014), Sustainable development is concerned with the development of a society where the costs of development are not transferred to future generations, or at least an attempt is made to compensate for such costs.

It can also be defined as improving the quality of human life whilst living within the carrying capacity of the ecosystems (Anon., 1991).

According to Schlebusch (2015), a sustainable community seeks to maintain and improve the three principles of sustainable development (Economic, Environmental and Social Equity) so that community members can continue to live healthy, productive and enjoyable lives.

Thus the environmental aspect of sustainability is a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while maintaining the capacity of its supporting ecosystems (Morelli, 2011).

However, a lot of features of present day cities interact with the changing climate to worsen the risks and increase weakness to climate change. These may include asphalt, concrete, pavement and other hard surfaces in the city which absorb radiation from the sun, causing the urban heat island effect, which increases heat waves and puts pressure on electricity generation and distribution systems. Hard surfaces also prevent absorption of rainfall, creating runoff that carries pollution to lakes and streams and can overpower storm water systems, leading to sewer backups and flooding during heavy rainfall events.

The concentration of people in urban centres puts pressure on vegetation and green spaces that could reduce heat, storm water runoff, pollution and social pressures. Urban sprawl and competition for building sites has also led to construction in locations such as flood prone areas or steep slopes that are vulnerable to extreme rainfall. It is very important for future settlement designers to balance the relationship between urban design and urban climate at macro/regional level (Shahreen and Voghera, 2009).

Thus the economic aspects of sustainable development seek the development of an economic system that enables equitable or fair access to resources and opportunities and the fair distribution of finite naturally productive space that enables sustainable livelihoods and establishes viable businesses and industries. thus attempting to create prosperity for all, not just profits for a few.

Social sustainability refers to the personal and societal assets, rules and processes that empower individuals and communities to participate in the long term and fair achievement of adequate and economically achievable standards of life, based on self-expressed needs (Shahreen and Voghera, 2009). The Social aspect is to enable the development of fair and just societies that foster positive human development and provide people with opportunities for self-actualisation and an acceptable quality of life.

3.3 Sustainable Human Settlement

According to the Global Sustainable Development Goals report 2016, Sustainable Development Goal 11, seeks to make cities and human settlements safe, resilient and ensure dignified conditions are created for residents to have easy access to urban amenities and opportunities to realise their future aspirations (Anon., 2016). Sustainable human settlement or communities are communities organised so as to enable all its citizens to meet their own needs and to enhance their well-being without damaging the natural world or endangering the living conditions of other people, now or in the future (Girardet 1999).

The increase human activity and the resulting demand on resources, as well as the generation of waste byproducts that exceed the planet's regeneration and absorption capacities, has resulted in the current trajectory of sustainable human settlements. It is observed that, in positively performing urban areas, poorer residents have access to opportunities and facilities generated by the wealthy (Ben-Ali, 2015; Anon., 2005). This implies that it is important to integrate different classes of people to avoid classes segregation.

3.4 Sustainable Human Settlement Design (SHSD)

Settlements design is the process of shaping the physical setting for life to deal with the three dimensional space in cities, towns and villages, so that the design is in accordance with the vision of the future that they represent. It involves coordinated and self-conscious actions in designing new cities and other human settlements or redesigning existing ones and or their precincts in response to the needs of their inhabitants (Lang, 1994).

Urban Settlement design is related to urban planning, but it focuses more on the physical design of places and deals with appropriate and more detail design approaches (Shahreen and Voghera, 2009).

Settlements or Urban design for settlements as a discipline increasingly began throughout the second half of the 20th century as part of an evaluating the modern day urban situation and of the alleged failure of the established built environment professions such as architecture, planning, civil engineering, landscape architecture and the property professions to deliver places of quality (Carmona, 2009).

Sustainable dimension of Settlement design has been believed to have emerged throughout and even before the period of 20th century because most ideas about the designs of town and country, for example, can be traced back to the pioneers of the planning movement such as Ebenezer Howard, Patrick Geddes and Unwin which exhibits some concepts of local social and economic sustainability in their designs (Carmona, 2009).

Most concepts of urban design now include clear reference to a sustainable dimension, so that sustainable urban or settlements design now fits within the theoretical framework for urban design that already embraces well established visual, morphological, social, perceptual, temporal and functional concerns (Carmona *et al.*, 2003).

Sustainability is defined as a dynamic equilibrium in the process of interaction between a population and the carrying capacity of its environment such that the population develops to express its full potential without producing irreversible, adverse effects on the carrying capacity of the environment upon which it depends (Ben-Eli, 2015).

Settlement on the other hand refers to places where human habitats agglomerate (Akinrogunde, 2016). Design is a creative, analytical and problem-solving activity through which objectives and constraints are weighed and balanced; the problem and possible solutions explored and optimal resolutions derived (Tibbalds, 1992).

Therefore, the ability to analyse and create places of human habitation so that in an attempt to explore the place for their needs and development, their actions will not put into jeopardy the interest and well-being of future generations. This can be termed as Sustainable Human Settlement Design.

To create or design a sustainable human settlement means not just the design of public spaces, streets, neighborhood and homes, but the configuration of greenway systems, regions growth patterns, transportation network, water and sewerage systems and even industrial process, which requires thinking about how they relate to each other and all other elements of a given community, combining with public policy frameworks that can support such changes (Shahreen and Voghera, 2009).

A sustainable human settlement design is the one which create communities that provide the environment that allows people to flourish in the presence of each other. That is, there are win-win opportunities for the environment and the people through improvements in production which will reduce pollution thereby making the community and its economy sustainable (Porter and van der Linde, 1999).

Urbanisation is inevitable, so are the impacts. In order to minimise these impacts we must have urban infrastructure that are properly planned, designed, operated and maintained so that it provides optimal efficiency. Part of the problem with today's urban structure is that it was built at a time when planning awareness was substantially different from todays (Aibinu, 2001).

Today, designing towns or settlements is not as easy as it used to be in the past because, designers have to deal with problems that did not exist previously in the past. Designers therefore have to consider dealing with problems such as road network or traffic congestion, air, water and noise pollution, utility networks, among others.

3.5 Problems of Sustainable Settlement Design in Ghana

Designing human living environment is obviously easier said than done. The physical, social, economic and environmental aspects are currently of major concerns to most developed and developing countries in designing communities. Planning and managing the urban areas has become the utmost task in dealing with issues of tremendous development growth in Ghana since the country has been faced with many spatial development challenges such as, squatter's growth, congestion and haphazard development in most of its cities which is as a result of increase in population, which can result in resource exhaustion.

Barriers to sustainable urban development are phenomena which actively counteract and are in a way of slowing the achievement of set targets. Andersson *et al* (2016), outlined factors such as limited political will, inadequate technical, financial and institutional capacities as some of the factors responsible for unsustainable systems and missed opportunities to tackle overlapping and interacting sustainable settlement design challenges.

Inadequate physical structures and technical systems, unclear or insufficient legislation, groups of actors with different targets and agendas, cultures with approaches which change slowly, time-consuming planning and work forms are different types of barriers (Anon., 2017b).

3.6 Sustainable Urban Design Approach

The approach to sustainable urban design in the long term, should assist the continuance of city and suburbs through the active protection and sustainable utilization of natural sources as stated by Ahmadi and Toghyani (2011), sustainable urban design approaches can be focused on a few basic principles which are;

i. Economic stability which can be defined as outcome of better allocation and efficient management of resources and continuous flow of private and governmental investment.

ii. Social sustainability which means: creating development process, that its continuance is depended on another growth. Here the goal is creating human civilization with a fair distribution of assets and earnings to reduce the gap between the rich and the poor.

iii. Ecological sustainability, which could be strengthened by using the following levers: (a) Limiting the consumption of all kinds of fuel and its sources which are exhaustible; (b) Reducing the extent of wastes, pollutions and recycling the sources; (c) Promoting economical use of the sources; (d) Trying to find technologies which can reduce wastes; (e) Determining the appropriate laws and legal system.

iv. The sustainable spatial development, whose aim is to achieve a more balanced rural- urban institution and a better distribution of land from a human settlement view which has a focus on the following points: (a) Decreasing the radical focus in the suburb areas; (b) Avoiding damage of vulnerable ecosystem as to the migration process and the uncontrolled wandering; (c) Promoting new methods of agriculture and forestry among small farmers; (d) Discovering and exploiting the environmental potential for a centralized industry with the new technology and with special focus on biomass industries and their roles in creation of a non-agricultural employment; (e) Establishing a network of natural grazed to maintain biodiversity.

v. The cultural continuity which includes finding endogenous roots of renewal patterns, and farming systems and the processes that can create some changes in the cultural continuity.

These approaches can provide enough assurance to promote a better quality of life of the people and future generations. By comparing what should be done with what is common in today's urban development planning, urban sustainability can be achieved by making necessary structural reforms and creating fundamental changes in all levels of society, especially in the three levels of: 'government and management', 'technology' and 'life methods' (Bramley *et al.*, 2010).

3.7 Principles of Sustainable Urban Design

Principles of sustainable urban design are guidelines that a city adopts to direct its long term strategy. Different research studies have elaborated on the key principles that should be incorporated into urban design to promote sustainability. Selman (1996) and Carmona (2001) highlighted the major tenets of sustainable development that should be integrated with urban design. These principles include intergenerational equity, public trust doctrine (maintaining environmental diversity and carrying capacity), precautionary principle, intra-generational equity, participation and polluter pays principle. Atkinson and Ting (2002) proposed a framework of transformative sustainable urban design with the following principles: acknowledgement of fundamental ecological patterns and limits, environmental and social restoration and regeneration, seeking better quality of life through liveability, employing integrative and holistic strategies and solutions and recognising sustainable urban design as a process and product.

These principles are not totally different from each other and tend to portray the same idea and can be grouped into five; and these are discussed in the subsequent sub headings.

3.7.1 Adequate space for streets and an efficient street network

This principle according to the UN Habitat discussion note 3 of urban planning aims to develop an adequate level of street network not for only vehicles and public transport but also specifically aims to attract pedestrians and cyclists. This includes a street hierarchy with arterial routes and local streets based on traffic speed differences. The street network will also shape the urban structure which, in turn, sets the pattern of development blocks, streets, buildings, open spaces and landscape.

To design street network in a high density city, the land needed for roads and parking needs should be determined. According to a research in urban impervious surface coverage in Olympia, Washington, by Arnold and Gibbons (1996), high populated density areas requires high street coverage. They estimated that, twenty to thirty (20-30) % of urban land and 40-60% of commercial centre land should be used for roads and parking. In high density mixed-use urban areas, it was also recommended that at least 30% of the total land should be allocated for roads and parking, and at least 15-20 % should be allocated for public open spaces.

Frey (1999) also suggested that, urban design must include individual space at city district and city/conurbation levels as this will encourages efficient traffic, sustainable accessibility, social interaction, public safety and access to amenities.

3.7.2 High Density

This principle is a direct response to the global population explosion and rapid urbanization. High density is very important and a fundamental principle for sustainable neighbourhood because it prevents urban sprawl and promote sustainable urban extension.

According to Jabareen (2006), high density essentially means a concentration of people and their activities. For a sustainable neighbourhood design, there should be at least 15,000 people per km^2, which is 150 people/ha or 61 people/acre. Also, according to Anon (2014c), cities in developing countries had an average built-up area density of 129 p/ha which is slightly lower than the sustainable neighbourhood; cities in such countries may set a higher target and work progressively towards increased density.

However, the compactness of the city must be decided with due consideration to the cultural, social and environmental context of the city otherwise may result in sprawl development (Aina *et al.*, 2013).

3.7.3 Mixed Land-Use

This is aimed at developing a range of compatible activities and land uses close together in appropriate locations and flexible enough to adapt over time to the changing market. Jabareen (2006) suggests that for a particular area of land use, there should be diversity of functional land uses i.e. economic and residential land-use must be well balanced by careful design and management. Service and light industrial jobs should be available, residential development projects introduced as well as the consideration of the growth in population density and activities.

In a mixed land-use neighbourhood, job opportunities are generated for residents from different backgrounds and with different income levels. People live and work in the same neighbourhood and form a diverse social network.

This helps to promote the local economy, reduce car dependency, encourage pedestrian and cyclist traffic, reduce landscape fragmentation, provide closer public services and support mixed communities (Dehghanmongabadi *et al.*, 2014).

3.7.4 Social Mix

Principle 4 aims to promote the cohesion of and interaction between different social classes in the same community and to ensure accessibility to equitable urban opportunities by providing variety, permeability, mixed development and hierarchy of services and facilities as argued by Carmona (2001).

Social mix provides the basis for healthy social networks, which, in turn are the driving force of city life. It can be argued that social mix is not an urban planning panacea for social problems such as poverty and social segregation, but it can contribute significantly to their solution by helping to:

i. promote more social interaction and social cohesion across groups;
ii. generate job opportunities;
iii. overcome place-based stigma;
iv. attract additional services to the neighbourhood.

3.7.5 Limited Land-Use Specialisation

The aim of principle five (5) is to limit single function blocks or neighborhoods and this helps to increase economic diversity.

According to this principle, a single function neighbourhood must be converted into a vibrant multi-functional community and a single function blocks should cover less than 10 per cent of any neighbourhood (Dehghanmongabadi *et al.*, 2014). It recognises that in a democratic, multi-cultured society, all communities, individuals and cultures are to be accorded equivalent respect.

The Five Principles balance population growth, economic growth, rapid urbanization, sustainable urban development and other factors, and try to establish a new urban system. In this system, population and urban infrastructure accomplish economies of scale; diversified social networks and the diversity of land-uses support each other and develop together; and urban space and urban dwellers live and develop in harmony (Dehghanmongabadi *et al.*, 2014).

A sustainable settlement design when implemented should result in sustainable community. The first international urban planning and architecture design congress which was held in 18th -11th May, 2014 indicates the six main components of sustainable communities as: social well-being, built environment, housing, transport and connectivity, community services and community governance and is summerised in figure 3.1.

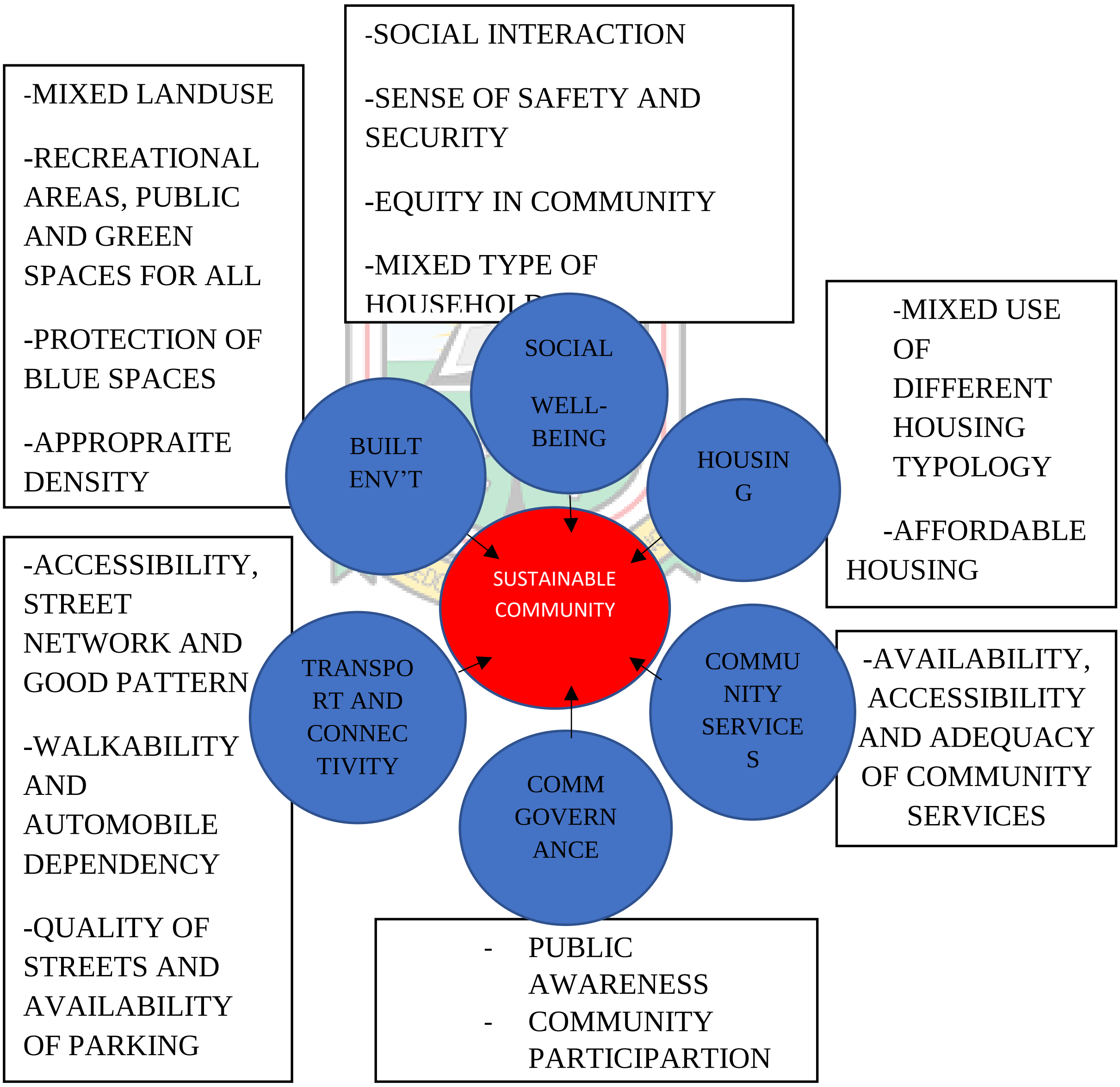

Figure 3.1 Components of a Sustainable Community (Source; Ozden and Ecran, 2014)

3.8 Types of Urban Design Models

There are several models used to understand and explain how settlements or infrastructure are arranged in cities and urban areas. The models reviewed for this research were the Concentric, Sector, Multi nuclei, and Neighbourhood model. The model adopted after the research was the neighbourhood model.

3.8.1 Concentric Model

This is one of the ancient and most simpler model theory used to explain urban structure. It was propounded by Ernest Burgess in 1926 to explain the structures of some American cities such as Chicago. The idea behind the concentric model is that the development of a city takes place outwards from its central area in a series of rings to form zones. Some assumptions of this theory are that;

- There is a relationship between household incomes and distance from the Central Business District (CBD).

  Accessing better and quality housing is done at the expense of longer commuting times and costs to go to work or the CBD

- Land is flat everywhere
- There is equal distance from the CBD in all directions (Riley, 1958)

The zones were grouped as follows;

- Zone I, CBD; This is located at the Centre of the

  city where most routes like roads and rails converge. It contains only commercial activities such as shops, entertainment, business', among others. Land within this area are expensive.

- Zone II, Transitional zone; this is where industrial factories are located to take advantage of labor and market. This area has high population density and the people living in this zone are the poorest in society. The zone is characterised by the lowest housing condition and high rate of crime activities.
- Zone III, Inner city (low class residential homes); this is an area or these are areas closer to zone II

and are settled by families of workers of the factories. The accommodation in this area has better conditions than that of the transitional zone. It is characterised by mix of old and new orderly development. People living in this zone are mostly second generation immigrants as many move out of zone II to this zone whenever they can afford.

- Zone IV, Outer suburb; better quality middle class homes linked with more commuting cost. This zone is mostly occupied by the elite in society and the homes are expensive therefore less likely to be rented.
- Zone V; these are small cities and dormitory towns occupied by high class homes with larger compound and parks. The people living in this place can afford to commute into the city center for work and entertainment. The commuting time to the working place may be at almost an hour ((Riley, 1958).

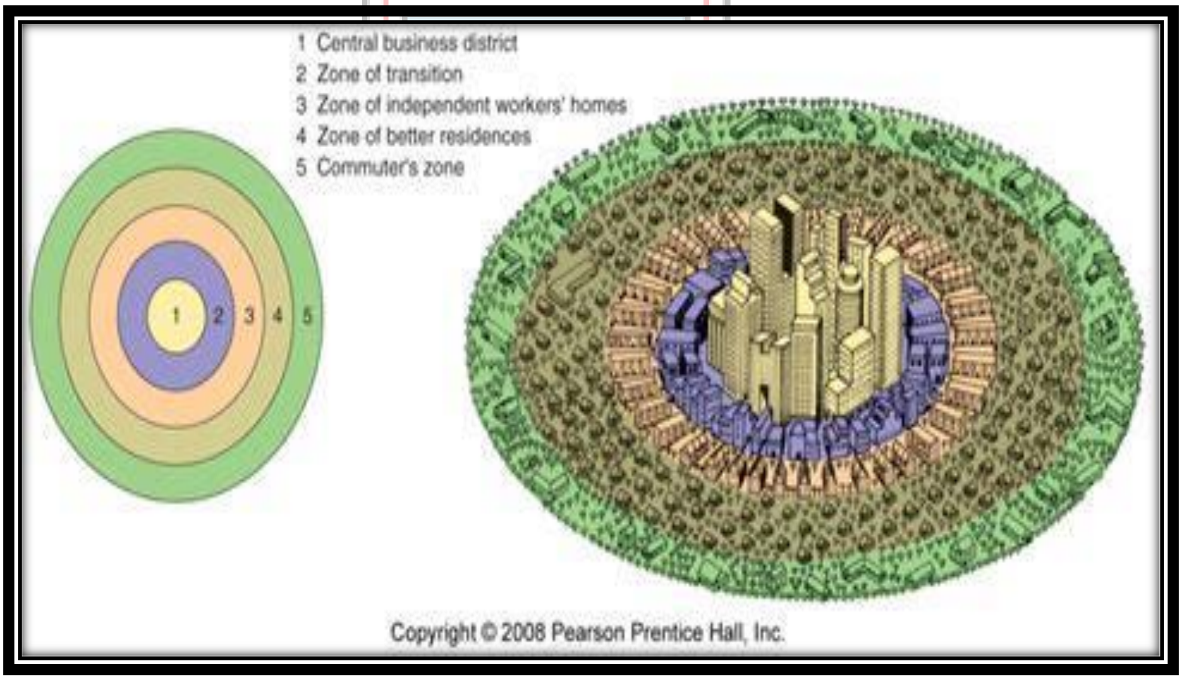

Figure 3.2 Concentric Model (Source, Anon,2018b)

Some strengths of the concentric model are;

- There is orderly classification of workers' residence and business.
- Transitional zones have commercial sectors which service the residential area.

Some weaknesses of the concentric model are;

- It is too simple and has limited applicability to historical and culture elsewhere.
- The model encourages segregation of classes of people which defeats the principle of social mix in sustainable community design.
- It does not take into account the effect of political forces and the restrictions imposed by the government for the improvement of living conditions.
- In reality, there are no distinct boundaries between zones as overlapping of areas is possible in every town. The preference of people changes over time depending on the importance they place on particular benefit (Anon., 2018c).

3.8.2 Sector model

This type of model was propounded by a land economist called Homer Hoyt in 1939. Hoyt argued that instead of concentric sets of neighbourhoods, cities are primarily laid out in pie or wedge-shaped zones and corridors developed from the core of the city to the outskirts. Hoyt realised that, certain areas of the city are more attractive for some various types of activities either by rent or access to major transport routes. He explained that as the city grows and these activities flourish, there is an outward expansion in a wedge form and become a sector of the city (Riley, 1958).

With Hoyt's model, CBD also remains in the centre of the city because it is the easiest place to access and therefore there are more potential customers for commercial businesses, and the sectors are clearly visible in wedges radiating out from the centre. However, there are important differences. The manufacturing zone is found along transport routes, especially railways, highways and rivers or canals that link the city centre to other cities. The low class residential land is found nearby, with the high class residential the furthest away. The high class residential may also follow transport routes, especially highways, as wealthier people have private cars which they use to get to their jobs in the CBD (Burdett, 2018). This model has been found to work especially well in most of British cities. Figure 3.3 shows how the sector model looks like.

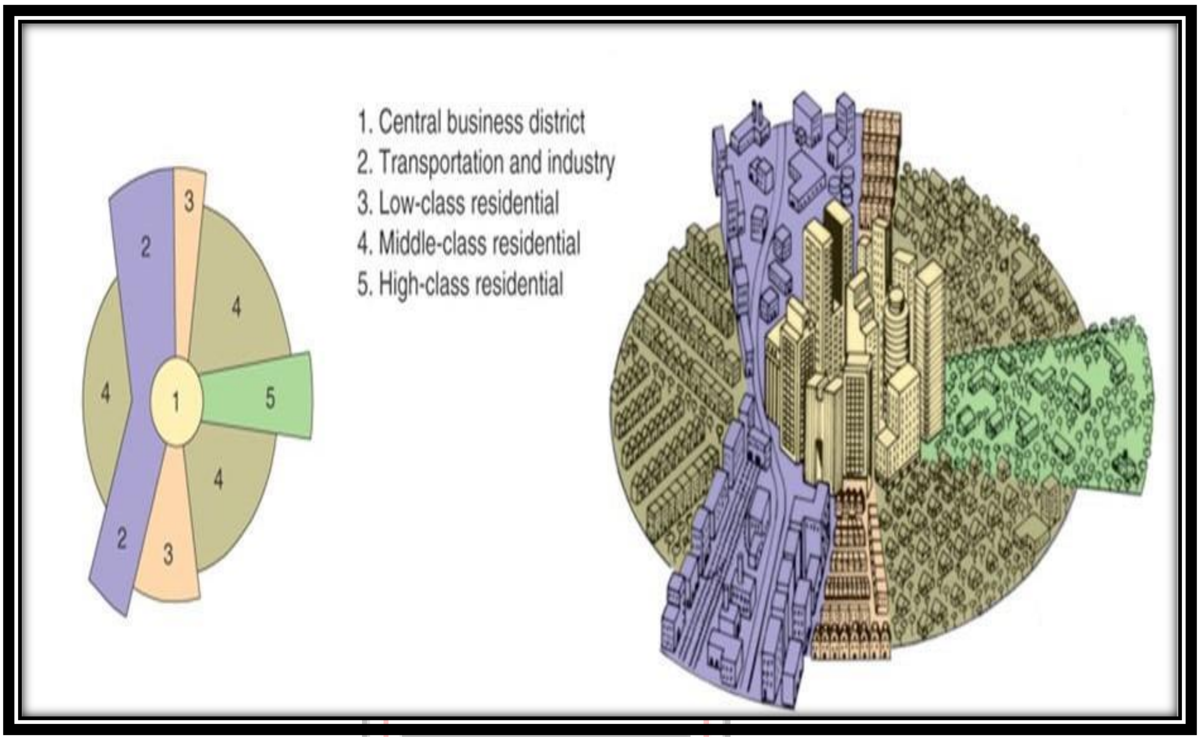

Figure 3.3 Hoyt Sector model (Source: Anon 2018a.)

Assumptions of the model

- Transport has directional effect on land uses.
- The effect of direction was added to the effect of distance.
- Cities grow in wedge-shaped sectors/patterns
- Higher levels of access mean higher land value

Strengths of the model

- It encourages the development of the road network and improvement of the public transport system.
- The model enhances the effective provision of facilities and services. It also provides easy access to roads, hence improves accessibility.

Some of the weaknesses of the sector model are*:*

- Physical features may restrict or direct growth along certain wedges.
- Also, growth of a sector can be limited by certain natural barriers
- In reality, most zones contain more than one land-use
- Only rail lines are considered for the growth of the sectors.

- In terms of population, there may be segregation which may weaken social relation.
- The model is rigid and therefore may be expensive to implement.

3.8.3 Multiple Nuclei model

As the name suggest, it is a type of model with multiple centres. It was propounded in 1945 by Chauncey Harris and Edward Ullman. They argued that towns and cities do not grow from one centre but rather from a number of separate nuclei or centres. Unlike the Concentric Zone Hypothesis which proposed that cities grow in zones from the center out, the Multiple Nuclei Theory or model proposes that these are not necessarily zones, but that similar activities are grouped together in certain areas in the city (Burdett, 2018). Thus we have Central Business District, Residential Districts, Light manufacturing Districts, Low-income Districts, Red light Districts, Suburban Districts, etc. though we have the CBD at the centre of the city, it does not serve as the only centre of growth within the town. However, the spatial distribution of these towns are more complex than that of the monocentric town (Moshin and Anwar, 2015). The figure 3.4 shows how the multiple nuclei look like.

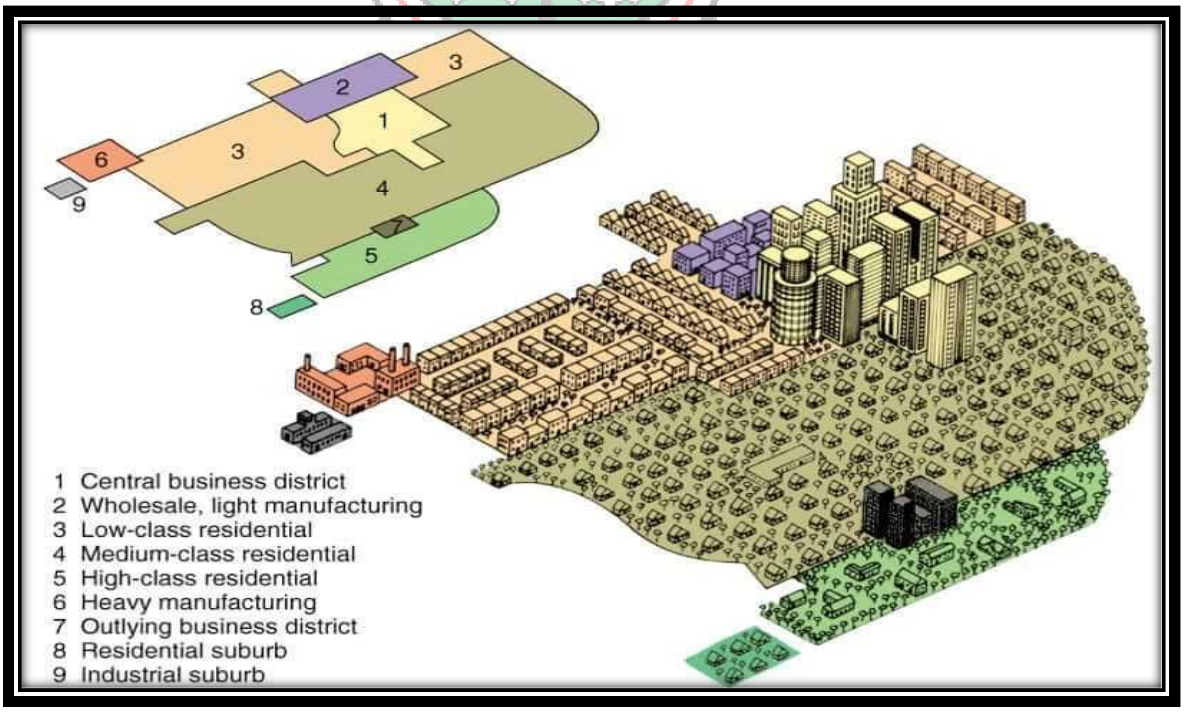

Figure 3.4 Chauncey Harris and Edward Ullman Multiple nuclei model (Source; Anon, 2018a)

Some of the assumptions are outlined below;

- Each nucleus acts as a growth point
- Growth occurs outwards from each nucleus, until they all merge into one large urban area
- Profit maximisation; here activities are established at places where profits can be maximised. The location is taken into account rent, transportation cost, labour cost, among others. This location also takes into account the restrictions over the activity and the need to be separated from other non-compatible activities such as locating residential areas away from industrial areas.
- Equal transportation cost; the cost of transportation in the city are the same irrespective of the location.
- Evenly distribution of resources; resources are distributed evenly, no one enjoys privileges over the other.
- Land is not flat.

Some of the strengths of the model are outlined below;

- Reduces congestion and promotes decentralization in an urban town.
- It promotes integration and agglomeration of activities.
- It is economically viable.
- It promotes interdependencies

Some weaknesses are

- It is very expensive to adopt.
- It may result in the duplication of facilities and services.
- The theory is highly informed by economic factors.
- Negligence of height of buildings (Chesney and Amsbaugh, 2015).

3.8.4 Neighbourhood Concept Model

Human settlements have been spatially divided into districts and neighbourhoods which signifies the importance of neighbourhoods in the form of cities.

Various theories and models have been developed since the early 20th century, with the purpose of creating better and more liveable neighbourhoods. Also, the emergence of the concept of sustainable development and the emphasis it places on the local level has led to the increased interest in planners and urban visionaries in pursuing sustainability goals through neighbourhood planning which sustainability principles are used as a guide in the planning and development process (Ayyoob, 2015) (Luederitz *et al.*,2013).

The neighbourhood concept was established in response to environmental degeneration as a result of the industrial revolution in the 1900's. It was first modelled by Clarence Arthur Perry between 1872-1944 to act as a framework for urban planners attempting to design functional, self-contained and desirable neighbourhoods (Meenakshi, 2011).

Perry's Neighborhood Unit concept has played an important role in the evolution of neighborhood planning movements. In his plan, he proposed that, the total land area of each neighbourhood unit would be around 65 ha that provides housing for a population of 5000 to 10000 people with basic public facilities such as elementary schools and places of worship would be located at the centre to serve as an anchor of the neighbourhood and shops at the end of the unit with roads bounding each neighbourhood (Forsyth and Crewe, 2009).

The proposed design of Perry allows residents to walk no more than 400 m without crossing arterial roads to reach civic facilities and commercial areas.

Perry outlined six basic principles of a good neighbourhood which are explained below:

- The unit was to be ideally a shape in which all sides were fairly equidistant from the centre, and its size was to be fixed.
- A central neighbourhood or community centre was to contain various institutional sites, including a school, grouped round a central green space.
- Local shops or shops and apartments were to be located at the outer corners of the neighbourhood.
- Scattered small parks and open spaces should be located in each quadrant of the neighbourhood and this was to form 10 per cent of the total area.
- Arterial/ Major streets were to bound each side of the neighbourhood.
- The layout of the internal street was to be a combination of curvilinear and diagonal roads to discourage through traffic. Vehicular and pedestrian traffic was to be segregated (Patricois, 2002).

The Neighborhood concept theory has been and still is, used as a good model of neighborhood design by many planners around the world as a foundation to model many cities such as Radburn in New Jersey, Greenbelt in Maryland and Greenhills, Ohio.

Some of the strengths of the concept are outlined below:

- It distributes the city into smaller subareas therefore making it easier to manage them.
- This model provided specific guidelines for the spatial distribution of residences, community services, streets and businesses.
- The model's principles can be related to today's sustainability principles such as social mix, limited landuse specialisation, and adequate spaces for street network therefore implementing it will be easier.
- The concept could be used to order development in space.

However, there are some limitations of the model. Some of which are outlined:

- The model has been criticized for advocating social homogeneity, which can lead to compulsory class groupings that might be used to discriminate against some groups in the society.
- Perry's idea to separate work and living areas in the model is regarded as a principle that gave rise to the widespread of suburban development in many countries such as the US in the years after World War II (Meenakshi, 2011).
- Neighbourhood could be too large to promote social behaviour and neighbourly relations.

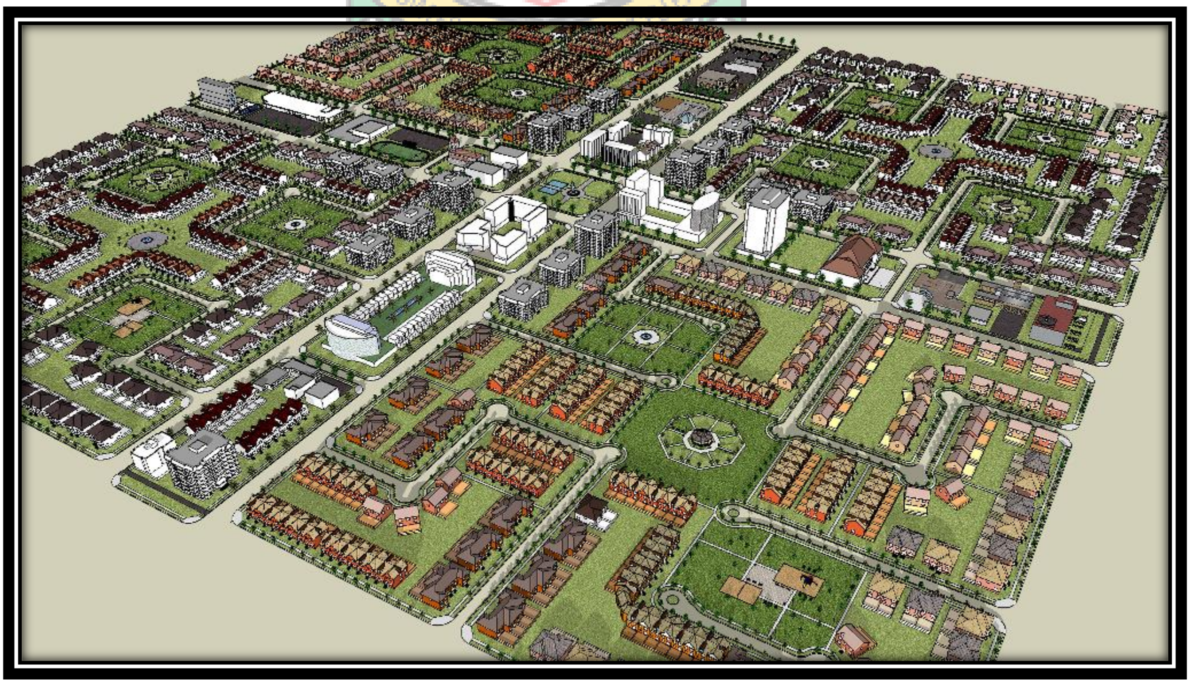

Figure 3.5 Model of Neighbourhood (Source; Anon., 2008)

3.9 Urban Planning models in Ghana

Urban Planning Models are used to indicate relationships and patterns in demographic, geographic and economic data. They might be used to deal with short term issues such as movement of people through cities or long term issues such as landuse patterns and growth. According to the Ministry of Local Government and Rural Development, 2012, the country's Planning models comprises of National Spatial Development Framework, Regional Spatial Development Framework, Structure Plans and Local Plans.

3.9.1 National Spatial Development Framework (NSDF)

National Spatial Development Framework (NSDF) aids in bringing about more balanced territorial development patterns, ultimately contributing to peace and economic growth by setting out a 'spatial' vision and strategy specific to a particular area. NSDF helps to evaluate the strengths and weaknesses of settlements and also help in the prioritization of actions and allocation of resources (Boerboom *et al.*, 2015).

According to (Anon., 2015), The NSDF is the strategic framework for the spatial development in Ghana in the coming 20 years. The NSDF includes initiatives for better infrastructure, food supply, areas of certain focus and better education. All of these initiatives aim at improving a coordinated structure for the future development of the land-pool in general. The initiatives will at the same time contribute to accomplish some of the national objectives adopted for social, infrastructural, environmental and agricultural development. The framework is based on initiatives regarding:

i. Better and coordinated infrastructure (roads, railways, harbours and airports)
ii. Food and agriculture (development of better food supply)
iii. Social development (Appointment of the northern region as focus area for development)
iv. Climate change (knowledge sharing of climate technology)

The NSDF is expected to provide the following according (Anon., 2015):

i. Perspectives and proposals for what kind of developments should take place,

how much of it should occur, where this should happen, and how this should happen in order to take advantage of presented opportunities.

ii. A spatial strategy for achieving defined social, economic and environmental

interventions related to employment, housing, infrastructure services (waste, water, energy, *etc*.), education, health care, tourism and leisure, transportation, communications, culture and nature and the environment.

It is also expected that the NSDF will serve as a guide for a coordinated delivery of development infrastructure and services based on a hierarchy of human settlements to propel the Nation into a higher middle income status and is prepared or shall hold for a period of twenty (20) years (Anon., 2015).

3.9.2 Regional Spatial Development Framework (RSDF)

RSDF is prepared for each administrative region and districts of the country for a period of twenty (20) years just as a NSDF and only after a NSDF has been approved. The Regional Spatial Planning Committee prepares the RSDF for the various administrative regions within a specified time and this is done in consultation with the District Assemblies and other public sector agencies, and with public consultation. The RSDF prescribes the spatial aspects of the Regional Integrated Plan and related human settlement issues and is prepared in accordance with the scope, objectives, minimum content and methodology prescribed by regulations and guidelines issued by the Authority and its key goal is to ensure the judicious use of land and support spatial strategy for exploiting unique regional prospects and challenges for increasing regional and national prosperity.

3.9.3 Structure Plans

The framework for spatial planning in the country also comprises of a structure plan for each district, part of a district or multiple districts but these structure plans are only prepared for each district, part of a district or multiple districts unless they conform to certain prescribed criteria and may cover the whole or a part of an urban area or rural area within the district or any specific land area (Anon., 2016).

Structure plans are prepared for a period of fifteen (15) years to ensure that there will be judicious use of land, sustainable human settlement development and environmental protection and contain planning aims, objectives and principles and development proposals, plans, maps and background studies, reports and information as well as the designation of uses or broad zoning of land that is subject to the plan for the purpose of ensuring the continuous supply of land to meet identified needs (Anon., 2016).

3.9.4 Local Plans or Landuse Plans

Local or Land use plans are plans that provide a shared vision of a city's future and how to get there. Cities and towns need homes, schools, parks, roads and other infrastructure to support their residents' daily lives. Most municipalities organize city spatial activities by making land use plans to guide long-term development. These plans help to make sure homes and amenities are organized to support residents, and that there are efficient ways to travel to work, shopping and fun.

In Ghana, Local plans are prepared for each community in a district by zoning regulations to guide spatial development. The plan for a community can last for a period of five (5) years of which it is updated over time (Anon., 2016).

According to the Ghana Land Use and Spatial Planning Act (2016), local plans may be prepared to establish legally binding regulations for:

i. the land coverage for a construction on a plot in the zone;
ii. the type of structure on the land;
iii. the form and height of buildings;
iv. tree preservation;
v. the preservation of buildings with a cultural heritage and historical structures; and
vi. any landscaping or tree planting requirements.

According to Anon 2011, it is mandatory in Ghana for a community with a population of 5000 and above to have at least the following community facilities such as;

i. A nursery
ii. A primary school
iii. A junior secondary school
iv. A neighbourhood shopping centre or a local market with attached retail shops adjacent to a parking space
v. A health post,
vi. A postal agency,
vii. Public open space for out-door meetings, or other activities such as a foot

ball field and a children's play area.

viii. Public refuse space/sanitary area.

ix. Police post.

3.10 Goals and Objectives

Goals can be said to be general guidelines that explain what you want to achieve in future. They are usually long-term plan and mostly represent national or global visions. Here, according to Hart (2012), a Sustainable Community seeks to maintain and improve the Economic, Social Equity and Environmental development so that community members can continue to lead healthy, productive and enjoyable lives. Therefore, the goals set must encompass all the elements that a sustainable community seeks to achieve.

Objectives on the other hand are strategies or implementation steps to attain the identified goals. Unlike goals, objectives are specific, measurable, achievable, realistic and have a defined completion date.

Resources to achieve goals are scarce and so it is efficient for the decision maker to prioritize every goals set to avoid misuse of resources. Prioritisation can be said to be placing goals in order of importance. Several methods are used to prioritize goals, some of which are the Analytical Hierarchy Process (AHP), the Compatibility Matrix, the Fuzzy based approach, the Out-Ranking order, among others. A good goal prioritization helps the decision maker to know which goal to be implemented first. It also helps the decision maker to minimise cost since the achievement of some goals might automatically lead to the achievement of others.

3.11 Multi-Criteria Decision Making(MCDM)

Decision making is sometimes difficult for managers of most organizations especially when there are a lot of alternatives to be considered, which may sometimes conflict each other. The Process of decision making may cover broad perspective to take into account cost benefit analysis, long and medium-term investments and results, among others. In this aspect, the decision maker has multiple criteria to consider in making a decision.
Multiple Criteria decision making (MCDM) is a procedure in which a decision maker gets the most desirable alternative from a set of feasible alternatives with respect to some predefined attributes (Dey *et al.*, 2016). Generally, the traditional motive of analysing

decisions is to minimise cost and maximise profit. MCDM is an important decision making tool, which can help the decision makers to arrive at better choices once there are more than one criteria (Bogetoft and Pruzan, 1997). It has been applied in many kinds of practical fields such as engineering technology, economics, operations research, management science, military, urban planning, etc (Dey *et al.*, 2016).
Despite the criticism that multiple Attribute or Criteria making tool have received, some are still widely used such as The weighted sum model (WSM), which is the earliest and probably the most widely used method, the weighted product model (WPM), which is the modification of the WSM to solve some of its weaknesses (Triantaphyllou *et al.*, 1998). The analytic hierarchy process (AHP), as proposed by (Saaty, 1980), is a later development and has recently become increasingly popular. The Elimination and Choice Translation Reality (ELECTRE) by Benayoun, Roy and Sussman (1966), Grey Relational Analysis (Fung, 2003) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Hwang and Yoon, 1981) has also been used by researchers for selection, ranking and evaluation of choice of decision.

Each of the methods that have evolved from MCDM, has varied underlying assumptions, information requirements, analysis models, and decision (Aruldoss *et al*, 2013). This suggests that it is critical to select the most appropriate method to solve the problem one is dealing with, because the choice and use of unsuitable method always leads to misleading decisions which can lead to heavy losses (Singh and Malik, 2014).

MCDM application has been used in the field of environment to select a management alternative that minimizes human health and ecological risks and cost while maximizing public acceptance (Kiker et al., 2005). It has also been applied in industrial site selection (Ohri *et al.*, 2010), fire control (Varela *et al.*, 2005), urban water supply (Abrishamchi et al., 2005) and site design for city delivery centres (Awasthi et al., 2011).

3.11.1 The Analytical Hierarchy Process (AHP)

This technique was proposed by Thomas L. Saaty in 80s. It is a technique for analysing complex decisions, based on mathematics and psychology (Christopher and John, 2014). Also, the technique can help express the general decision operation by decomposing a complicated problem into a multilevel hierarchical structure of objective, evaluation criteria and decision alternatives. it is an active decision method which performs a pairwise comparison matrices to break down and solve a multiple criteria decision making problems with different and conflicting criteria. AHP method is based on three main principles. i.e. structure of the model, comparative judgment of the criteria and/or alternatives, synthesis of the priorities (Jagadish, 2015).

With the first principle, a decision problem is arranged in order with the goal being first, the decision criteria and alternatives in that order.

The comparative judgement of the criteria and or alternatives are formed by matrices and pairwise comparisons are conducted. Here, Decision criteria are compared in the corresponding level using fundamental comparison scale starting from 1 to nth. Where 1 is the least attached important and nth is the highest attached importance. Table 3.1 shows the comparison scale used by AHP.

Table 3.1 Fundamental scale for pairwise comparison (source: Yucel and Gorener, 2016)

Intensity of importance	**Explanation**
1	Two activities or criteria contribute equally to the objective
3	Experience and judgement slightly favour one over another
5	Experience and judgment strongly favour one over another
7	An activity or criteria is strongly favoured and its dominance is demonstrated in practice
9	Importance of one over another affirmed on the highest possible order
2,4,6,8	When compromise is needed

This pairwise comparison can be shown by a square and reciprocal matrix. The result of the pairwise comparison on n criteria can be summarized in an (n x n) evaluation matrix.

The last principle has to do with normalising the matrix and checking consistency and then ratio to whether to accept or reject the decision.

3.11.2 Grey Relational Analysis (GRA)

The advancement in science, technology and the development of mankind has resulted in the gradual improvement of human understanding in matters concerning systems' uncertainties. The Grey theory or system was established by Deng (1989), to solve these system of uncertainties. It is a system in which part information is known and part information is unknown. Up to now, grey system theory has been developing a set of theories and techniques including grey mathematics, Grey relational analysis, grey modeling, grey clustering, grey forecasting, grey decision making, grey programming and grey control, and has been applied successfully in many engineering and managerial fields such as industry, ecology, meteorology, geography, earthquake, hydrology, medicine Landuse planning and military (Ziliang and Sifeng, 2004). Grey Relational Analysis (GRA) has been used by researchers to deal with information that are incomplete and disconnected (Fung, 2003). It is based on geometrical mathematics, which complies with the principles of normality, symmetry, entirety, and proximity. GRA is suitable for solving complicated interrelationships between multiple factors and variables and has been successfully applied on cluster/ group analysis, robot/ automation path planning, project selection, prediction analysis, performance evaluation, and factor effect evaluation and multiple criteria decision (Chang and Yeh, 2005; Lu and Yeh, 2000). The term "grey" is used to describe uncertain, poor, incomplete among others (Julong,1986). Mostly, the word grey is used to explain the mixture, appearance or feature of black and white. Where black means the information necessary is not exactly provided and white means vice versa. It is normally used to describe the intermediate features between black and white. There are three stages in GRA. The first stage is data pre-processing, which normally deals with a range or unit in one data sequence different from others, or sequence whose range is too large. It is a method of transferring the original data sequence into comparable sequence. Therefore, data must be normalized, using either of the parameters where smaller is better or larger is better based on what you want to achieve at the end of the research. The data is then scaled and separated first into a comparable sequence. The processing is called generation of grey relation or standard processing. The second step is to calculate or locate the grey relational coefficient, then the grey relational grade is calculated at the last stage and then ranked to select the best options.

Researches have employed these two techniques (GRA) and AHP in optimising select of suitable decisions among multiple characters, attributes or criteria. Among others some of which are; The AHP and ELECTRE technique employed in the acquisition of suitable company. Here, A1 alternative was selected to be the best company to be acquired by the international investment group in Turkey (Yucel and Gorener, 2016).

Dey et al., (2016), used the GRA in interval neutrosophic uncertain linguistic setting where the arms company G2 was selected to be the best choice for investment purposes.

Chen *et al.*, (2000), proposed the integration of GRA and the Taguchi Method to resolve multiple quality characteristics. This method transforms multiple quality characteristics into single grey relational grades. By comparing the computed grey relational grades, the arrays of respective quality characteristics were obtained in accordance with response grades to select an optimal set of process parameters.

The GRA and AHP was used by (Sen and Demira, 2016), for a new public hospital location selection. Alternative 1 (a1) was selected by the group and was concluded that, a1 and a3 were very close apart and almost of equal sizes which shows that, the results correspond to the actual situation on the ground.

3.12 Aerial Photography and Unmanned Aerial Vehicles (UAVs) Survey

Aerial photography has historically been used by the military for many purposes such as surveying and planning of warfare. Following enhancements in aerial photography in the post-Second World War period, it became increasingly useful to many institutions apart from surveyors such as landuse planning in the application of urban planning, i.e. from landuse survey through to estimation of the population of areas and before long, the aerial view became institutionalised as a central tool of planning (Lo, 1973).

Aerial photography typically produces aerial imagery at a resolution where individual parcels of land and individual buildings could be identified, but not always clearly so, depending on the height and the angle at which the device is set. It helps in the exploration of plots and structures for planning enforcement. However, photographic images are 'static', showing images at a point in time, and cannot be used over a long period of years (Harris, 2015).

Today, with the introduction and the utilisation of Unmanned Aerial Vehicle (UAV) such as drones has led to another leap in the surveying profession. With the development of smart cities and Building Information Modelling (BIM) technologies, it has become easy to create a 3D model of a terrain using UAVs and exporting it to a 3D Geographic Information System (GIS) (Meouche, 2016).

A UAV is a system of a set of complementary technologies brought together with their own class to fulfil a specific task. A UAV such as a drone can range in size and form and are typically described according to weight, endurance, purpose of use and altitude of the operation. (Norzailawati, 2016).

UAVs are becoming easier to use with automated flight planners and automatic obstacle detection.

The most common applications and operations associated with UAVs are generation of base map for landuse and urban planning, stockpile measurements and quarry monitoring, precision agriculture, infrastructure inspection, forest management, coastal erosion studies and other environmental and archaeological projects (Fernandez and Gutierrez, 2016). UAVs are extremely efficient for these applications, particularly for quarries, since they actually provide high precision with less time and safe conditions (Arango and Morales, 2015).

Also, UAVs are very useful in Search And Rescue (SAR) operations in the sense that, when public communications networks are interrupted, UAVs can provide timely disaster warnings and assist in speeding up rescue and recovery operations. Medical supplies to areas that are classified as inaccessible can be carried by UAVs. In disastrous location like gas infiltration, wildfires and search for missing persons, UAVs can be useful in playing such roles (Silvagni *et al.*, 2017).

However, UAVs are limited by their Energy consumption is also an important challenge facing UAVs. Usually, UAVs are powered by batteries and are used for hovering, wireless communications, data processing and image analysis. In some SAR operations, UAVs need to be operated for a period of time over disaster stricken regions. Due to the power limitations, decision has to be taken on whether the device should perform data and image analysis on-board in real-time, or data should be stored for later analysis (Gupta *et al.*, 2016). Weather conditions and natural disasters, such as Tsunamis and Hurricanes might result in deviations in their predetermined paths. Also, man-made disaster such as terrorist attacks render the UAVs failure in their mission (Jordan, 2015).

CHAPTER 4

MATERIALS AND METHODS

This chapter focuses on methods and materials in obtaining a sustainable settlement design of a community.

4.1 Materials Used

The materials used for the achievement of the objectives of the research were two sets or types of data and the use of software.

4.1.1 Primary and Secondary Data

Primary Data

Flying of a phantom drone at an altitude of 250m to capture the existing features of the study area and a South Static GNSS Receiver was used to measure control points at ten minutes' time intervals and used to georeference the drone imagery and the local planning scheme of the study area.

Questionnaire Administration

The population of the study area from the year 2000 to 2010 from the central region statistical service department was used to project for the current and the planning period. Household size was determined and used to calculate for the sample size at 90 percent confident interval. The simple random selection was used to administer the questionnaire because it represents the entire data population and randomly selects individuals from the population without any other consideration unlike the other sampling methods such as stratified random sampling which divides the population into smaller groups, or strata, based on shared characteristics. Also the simple random sampling is unbais since each individual in the large population set has the same probability of being selected.

Demographic information such as the ages, educational background, ethnicity, religion etc. of the people in the study area was obtained through the administration of the questionnaire. Also, information about employment status and type of employment of the people was also acquired through the administration of the questionnaire. This was done to have an idea about the people who move to settle at the study area. A sample of the household questionnaire is shown in appendix A.

Field observation

Data such as existence of other transportation modes (bicycle lane, pedestrian walk ways etc.), evidence of mixed use and some physical problems within the community were obtained through observation for the analysis of the local scheme.

Secondary Data

Secondary data such as the existing local scheme or the layout of the study area was obtained from the physical planning department.

Information from the Municipal Assembly's Medium Term Development Plan and the Ghana's Zoning guidelines and Planning Standards was also obtained for the research. Table 4.1 summarises the data and the institution from which they were obtained and the local scheme of the study area is shown in Appendix B.

Table 4.1 Data Obtained from Institutions

No.	**Institution**	**Type of Data Obtained**
1	Upper Denkyira East Municipal Assembly's Physical Planning Department	A scale of 1:2500 Local Scheme of the study area and Ghana Zoning guidelines and Planning Standards
2	Upper Denkyira East Municipal Assembly	Medium Term Development Plan

4.1.2 Software

Agisoft Photoscan professional was used to mosaic and georeference the flight images. ArcGIS 10.1 was also used to georeference the local scheme of the study area and for the generation of various maps such as contour, DEM, flood accumulation, among others and output for the spatial analysis. Microsoft Word 2016 and Microsoft Excel 2016 was used for the report and the Multi Criteria Decision Making (MCDM) analysis and Statistical Package for Social Science (SPSS16.0).

4.2 Method Used

The methods used or adopted for the research were grouped under three main headings. i. e Survey, Analysis and Plan. Under them were several activities performed. Figure 4.1 shows the summarised methods used for the research.

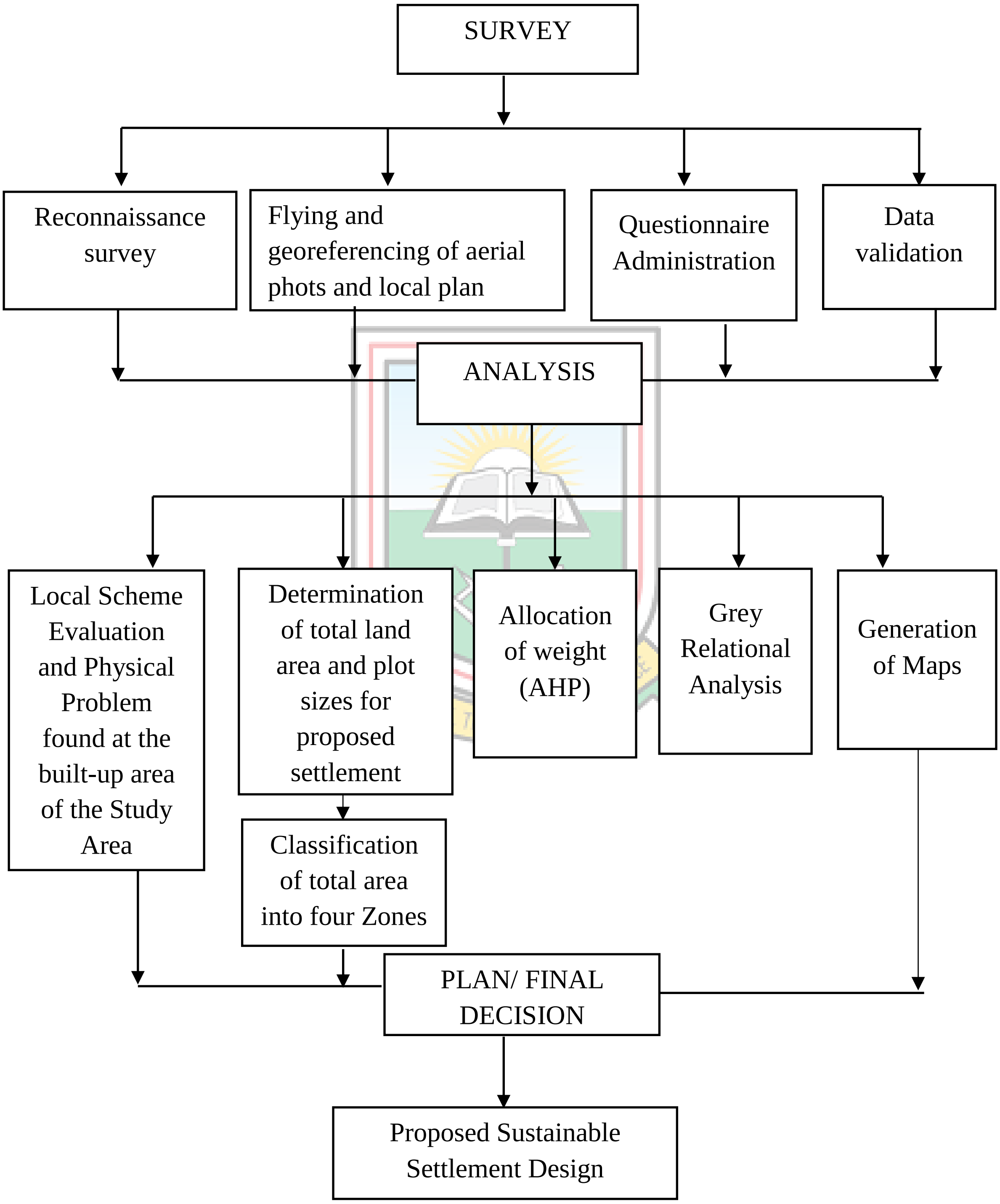

Figure 4.1 Flow chart for Methods Used

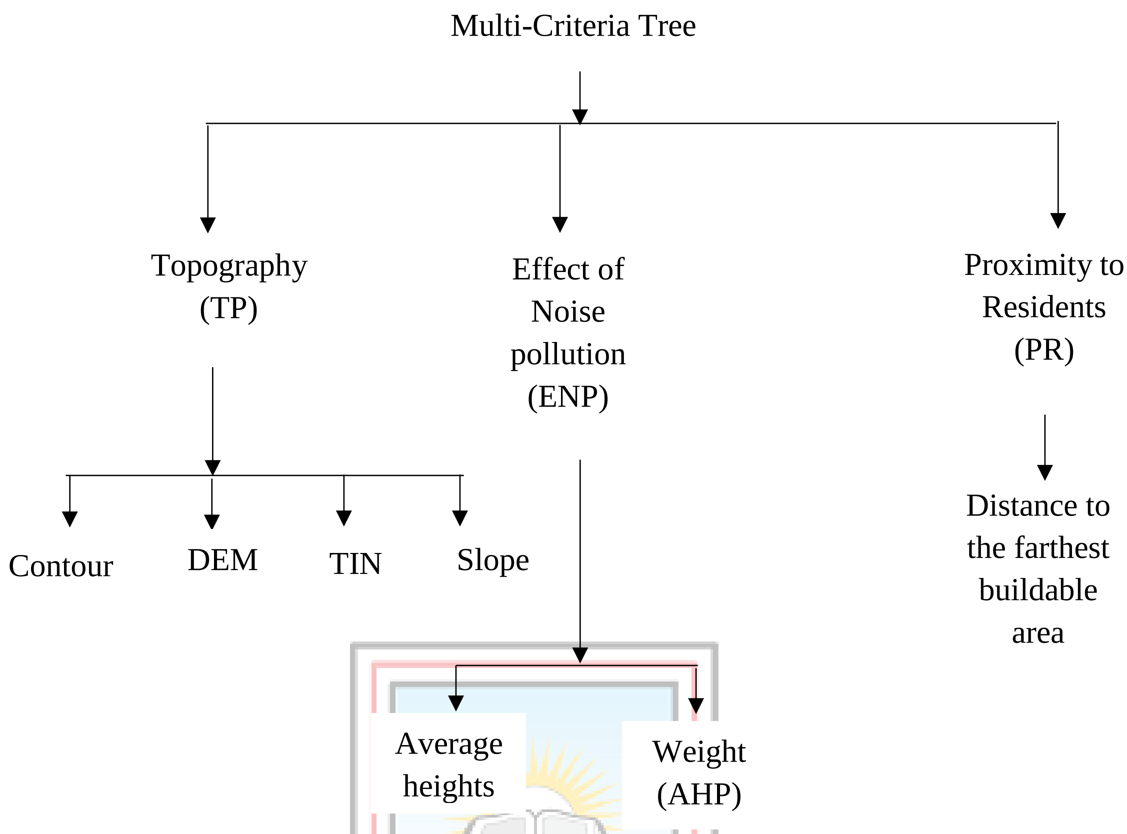

Figure 4.2 Multi-Criteria Tree Used

4.2.1 Reconnaissance

Preliminary survey was carried out to have a first-hand information and to familiarize with the community. The study area was then divided into two sections i.e., the northern and southern section's using the main road running through the community.

4.2.2 Calculation of Number of Questionnaire Administered

Firstly, the population for the community (Mfuom) was projected from the year 2010 to 2019. The growth rate from the year 2000 to 2010 was calculated and held constant for the projected year and the planned period.

To ensure accurate and reliable future predictions certain variables were held constant for the planned period. The Assumptions were as follows:

- The annual growth rate of Mfuom was held constant;
- Changes in the trend of migration into Mfuom was insignificant;
- The age cohorts remained unchanged;

- Child mortality rate remained constant; and
- Life expectancy at birth also remained constant

The total number of household of the study area for the year 2010 was obtained from the Ghana Statistical Service in central region. The household was then projected to the current year (2019) and was used to calculate for the sample size at 90 percent confident interval. The Simple random sampling technique was used to administer the questionnaire. Appendix D shows the calculations for obtaining the projected figures and Table 4.2 summarises the projected population and household of the study area from 2000 to 2029.

Table 4.2 Projected Population and Household

YEAR	2000	2010	2019	2029
GROWTH RATE	3.7	3.7	3.7	3.7
NO. OF HOUSEHOLDS		203	282	406
PROJECTED POPULATION	3241	4441	6160	8858

4.2.3 Georeferencing of drone images and local plan of the study area

This was done to orient the images and the local plan so that features on the images or the local plan will correspond to that on the ground. Ground control points were measured using a south static GNSS receiver and the area was marked with surveyor’s spray. The sprayed or marked areas of the points were to make it more identifiable when Georeferencing the drone images.

The local plan was also georeferenced using the coordinates of identified features which can be found on both ground and on the scheme. The coordinates for the georeferencing is shown in Appendix D, and D1.

4.2.4 Data validation

The methods used for validating the data was ground truthing and setting out. With ground truthing, coordinates of some features on ground were picked and plotted on the georeferenced image to see whether they fall on the exact features. With setting out, coordinates from the orthophotos were also measured and demarcated on ground to see whether it falls at the same place.
Validating the georeferenced local Plan, it was superimposed on the validated drone image to see whether existing features like roads and old buildings that are identifiable on both images and local scheme will correspond to that on the image.

4.2.5 Determination of total land area

Here, the current population of the study area was subtracted from the projected population of the planning period to get the actual population to be planned for. The type of population density for the new settlement was then decided to be a medium density. This was because, currently, the study area is a low density area which does not support the principle of sustainable settlement design. The minimum and maximum population per every $1000m^2$ were then obtained from Ghana's zoning and planning standards which was used to calculate the total land area for both ranges. The total land area of minimum medium population density was selected to be the land area for the proposed settlement. The reason for the selection of the medium population density was to maximise the use of the land since currently, the community is a low population density, thereby under utilising the land. The total area was further divided/ classified into four zones according to a range of average heights. The maximum residential plot sizes for medium density populated area was also obtained from Ghana's Zoning and Planning Standards to be $450m^2$. The calculation for the proposed land area for the design is shown in Appendix E.

4.2.6 Data analysis

The primary and secondary data were analysed both quantitatively and qualitatively. Quantitatively, the Statistical Package for Social Science (SPSS 16.0) and Microsoft Excel 2016 were employed to provide quantitative output such as tables presentations of the data acquired from the household questionnaire. Qualitatively, quantitative outputs were analysed descriptively. The Analytical Hierarchy Process and the Grey Relational Analysis

(GRA) were used for the selection of the best sustainable urban design model and the optimal site selection for land uses and facilities, respectively.

Analytical Hierarchy Process (AHP)

Here, weights were assigned to the types of spatial design models which were reviewed in the literature by experts in settlement design using their principles and their applicability in this current stage as criteria. Highest weight was assigned to the model type that is more applicable. A pairwise matrix was then formed using the weights assigned to the models and then normalised to obtain the respective weights. A consistency check was then calculated for the weights on the pairwise matrix to show if the opinions were consistent with their respective scoring.

Values less than 0.1 shows that the AHP is consistent with the expert advice so the weights are accepted. However, if the value is greater than 0.1, the weights are rejected because they are inconsistent with the views of the expert according to Saaty (1980).

The AHP was calculated based on the following equations (Saaty, 1980):

$$Xij = \frac{Cij}{\sum_{i-1}^{n} Cij} \qquad (1)$$

where Cij, is the pairwise criteria matrix.

Xij, is the normalised pairwise matrix and;

n, is the number of criteria used

$$Wij = \frac{\sum_{j-1}^{n} Xij}{n} \qquad (2)$$

where Wij, is the weighted matrix.

To check for the consistency vector, the weighted sum has to be calculated and its given by:

$$Wij \times Cij = Ws \qquad (3)$$

where Ws is the weighted sum vector from Equation (3).

∴ the consistency vector is given by the equation

$$Ws \times {}^{1}/_{Wij} = Cv \qquad (4)$$

where; Cv, is the consistency vector.

To calculate for the Consistency Index (CI), Equation (5) was applied.

$$CI = \frac{\lambda max - n}{n-1} \tag{5}$$

The CI provided a measure of deviation from the consistency λmax, which is the maximum Eigen value obtained from the average of the consistency vectors.

The Consistency Ratio (CR) was also calculated using the equation;

$$CR = \frac{CI}{RI} \tag{6}$$

where RI is the random inconsistency based on the number of criteria used and its value can be obtained from Table 4.7.

Table 4.3 Random Inconsistency Indices (***RI***) for Rank Values (N) = 10 (Source; Saaty, 1980).

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

The mathematical calculation of the AHP is shown in Appendix F

Grey Relational Analysis (GRA)

The Grey Relational Analysis (GRA) was used for the optimal and most suitable site selection for some proposed landuses or community facilities. A lot of factors were considered for the most suitable location for siting the facilities. Among them were topography (TP), effect of noise pollution (ENP), proximity to residents or the farthest buildable areas (PR). The average heights were calculated for the areas of community facilities within the various zones and used as the value for topography. This was calculated as:

$$TP = \frac{(Lowest\ height\ within\ zone) + (Highest\ height\ within\ zone)}{2} \tag{7}$$

To check for the proximity of the various facilities to the residents, the distances from the centre of that parcel of the facility to the last buildable area was measured in metres and used as the values for proximity to residents.

The effect of noise pollution within a zone was indirectly proportional to that of its topography or height. i.e. the higher the average height of a zone, the lesser the zone is affected by noise pollution and vice versa. This will guide in siting various community facilities. AHP was used to weight the various zones in the order of highest average height to the lowest. i.e. the zone with the highest average height was given the highest weight in that order.

A pairwise criteria matrix C_{ij} was generated on a 4x4 matrix and was given as;

$$Xij = \frac{Cij}{\sum_{i-1}^{n} Cij} \quad (8)$$

where Cij, is the pairwise criteria matrix.

Xij, is the normalised pairwise matrix and;

n, is the number of criteria used

$$Wij = \frac{\sum_{j-1}^{n} Xij}{n}$$

where Wij, is the weighted matrix.

The sum of weighted values for the various zones were then used as the values for the effect of noise pollution.

After getting values for all the criteria, using the parameter smaller value is better as the reference sequence, the formula for equation (9b) was used to normalise the values of the criteria which transforms them ranging from 0-1 (Fung, 2003), and is given as:

i) Data with "larger-is- better" characteristics

$$x_i^* = \frac{x_i^o(k) - \min x_i^o(k)}{\max x_i^o(k) - \min x_i^o(k)} \quad (9a)$$

ii) Data with "smaller-is- better" characteristics

$$x_i^* = \frac{\max x_i^o(k) - x_i^o(k)}{\max x_i^o(k) - \min x_i^o(k)} \tag{9b}$$

The deviation sequence was then calculated by subtracting current comparable sequence from the reference sequence and given using Equation (10);

$$\Delta_{0i}(k) = |x_0^*(k) - x_i^*(k)| \tag{10}$$

Where $\Delta_{0i}(k)$ is the deviation sequence between the reference sequence $x_0^*(k)$ and the comparable sequence $x_i^*(k)$.

Calculating Grey Relational Coefficient (GRC) and Grey Relational Grade (GRG)

Grey Relational Coefficient was calculated after obtaining the deviation sequences (Yang, 2006) using Equation (11).

$$\gamma[x_0^*(k), x_i^*(k)] = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{0i}(k) + \xi\Delta_{max}}, 0 < \gamma[x_0^*(k), x_i^*(k)] \leq 1 \tag{11}$$

The term ξ is known as standardised value or the distinguishing coefficient in [0, 1] and its value is usually given as 0.5.

The Grey Relational Grade (GRG) is finally computed as the weighted sum of the Grey Relational Coefficients as shown in Equation (12);

$$\gamma[x_0^*, x_i^*] = \sum_{k=1}^{n} \beta_k \, \gamma[x_0^*(k), x_j^*(k)] \tag{12}$$

Where $\gamma[x_0^*, x_i^*]$ is the GRG, which shows the level of connection between the reference sequence and the comparable sequence and $\sum_{k=1}^{n} \beta_k \, \gamma[x_0^*(k), x_j^*(k)]$ is the sum of weight of the various criteria. The GRA determines the level of influence of each alternative.

The GRG is then ranked and the first is selected. The calculation for the selection of suitable site for the various community facilities are shown in Appendix G.

4.2.7 Local scheme evaluation

The local scheme of the study area was georeferenced and then evaluated to see whether it was a sustainable design or can stand the test of time. This was done by critically looking out for some of the principles of sustainable settlement design and also some features of a sustainable neighbourhood. Physical problems within the built-up was also identified.

4.2.8 Generation of maps

Contours were generated from the georeferenced images using ArcGIS 10.4 and was used to generate contour map of 5m intervals. This was to give a more detailed depiction of the terrain. The Triangular Irregular Network (TIN) was then generated using the contours. This was done to have a clearer picture of areas that are low and areas that are high. This was then used to generate the Digital Elevation Model (DEM) for the study area. The DEM was then used to generate the slope map for the study area. The slope map also showed areas that are high and low and was used to compare with the TIN generated. Disaster risk map, specifically flood accumulation map was also created to show areas that are susceptible to flooding. These areas were mapped out and tagged as non-buildable areas so as to get the actual areas that are buildable for the proposed settlement design.

4.2.9 Setting up of Goals and Objectives

Development of Broad Local Goal or the vision

To make the settlement design stand the test of time, problems identified at the current built-up areas of Mfuom were taken into consideration when setting up goals and objectives for the new settlement. The broad goal which is also the vision for the community at the end of the planning period was "Transforming Mfuom to enhance development and growth through sustainable Human settlement design".

Development of Local Goal

The broad Vision was broken down to specific achievable sub-local goals (LG) and was given as below:

- LG1 - Ensure compact spatial development growth. (This will avoid leap frog development in the new settlement)
- LG2 - Improve quality environmental condition and health care. (This will avoid lack of provision of spaces for health facilities)
- LG3 - Improve transportation system and mobility. (This will help achieve principle one of the sustainable design).
- LG4 - Improve economic welfare of the population. (will solve the problem of inadequate space for shopping centre).

- LG5 - Improve social relation and interaction within the community. (this will help achieve principle four of the sustainable design principles).

The set Local goals were compared with the municipal goals by generating a compatibility matrix or table using four elements with values to see whether the set goals for the study area are compatible and can be achieved. The Municipal Assembly's goals were as follows:

- To strengthen Institutional capacity of the Municipal Assembly
- To promote high standard of education and good health conditions in the Municipality.
- To improve the financial base of the Assembly.
- To improve sanitation and waste management
- To support the government flagship policies (One district one factory, planting for food and Jobs, Free SHS etc.) (Anon.,2018).

Goal Prioritization

Using the compatibility matrix as a method of prioritization, using table 4.4 as parameters, the results are shown in table 5.2 in the next chapter.

Table 4.4 Values of various Parameters

Values	Parameters
2	Highly Compactible
1	Compactible
0	Neutral
-1	Non compatible
-2	Highly non Compatible

Meaning of the parameters

Highly compatible: This was where the achievement of a particular goal will automatically lead to the immediate achievement of the compared goal

Compatible: This was where the achievement of a particular goal lead to a long run achievement of the other.

Neutral: This was where the achievement of the two goals were neither positively nor negatively affected each other.

Non – Compatible: This referred to the case where the achievement of one goal had a negative impact on the other.

Highly non- compatible: This was used for situations where the implementation of one goal will obstruct the total attainment of the other goal.

M1…. n: Municipal Goals.

L1…. n: Local Goals which is also community goals.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Georeferencing

Figure 5.1 shows that the georeferenced drone image was correct and therefore can be relied upon since the tracked main road was lying in place of the same image road. The local scheme georeferenced result is shown in Figure 5.2.

The total Root Mean Square (RMS) of 0.00280495m for the local scheme implies a reliable and confident georeferencing with five (5) points.

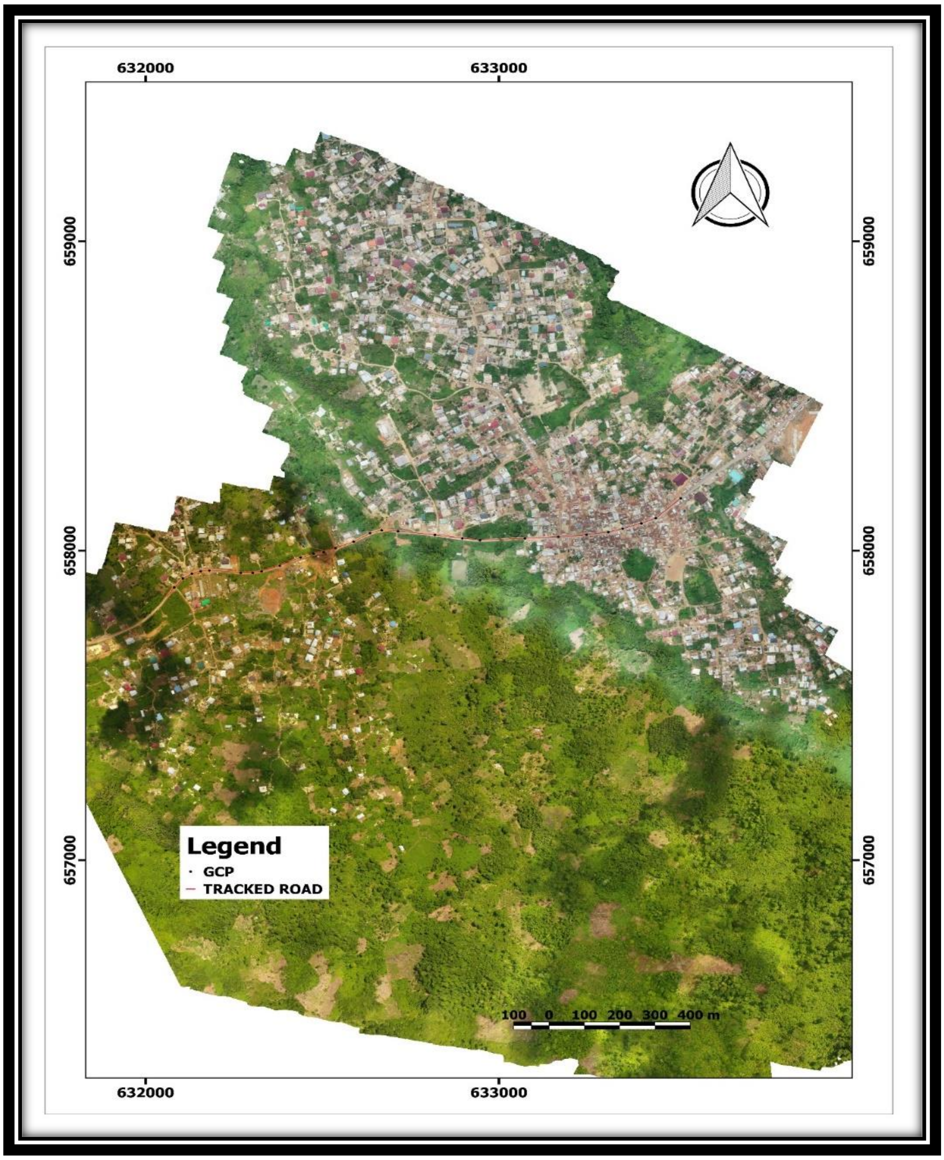

Figure 5.1 Aerial Photo Validated

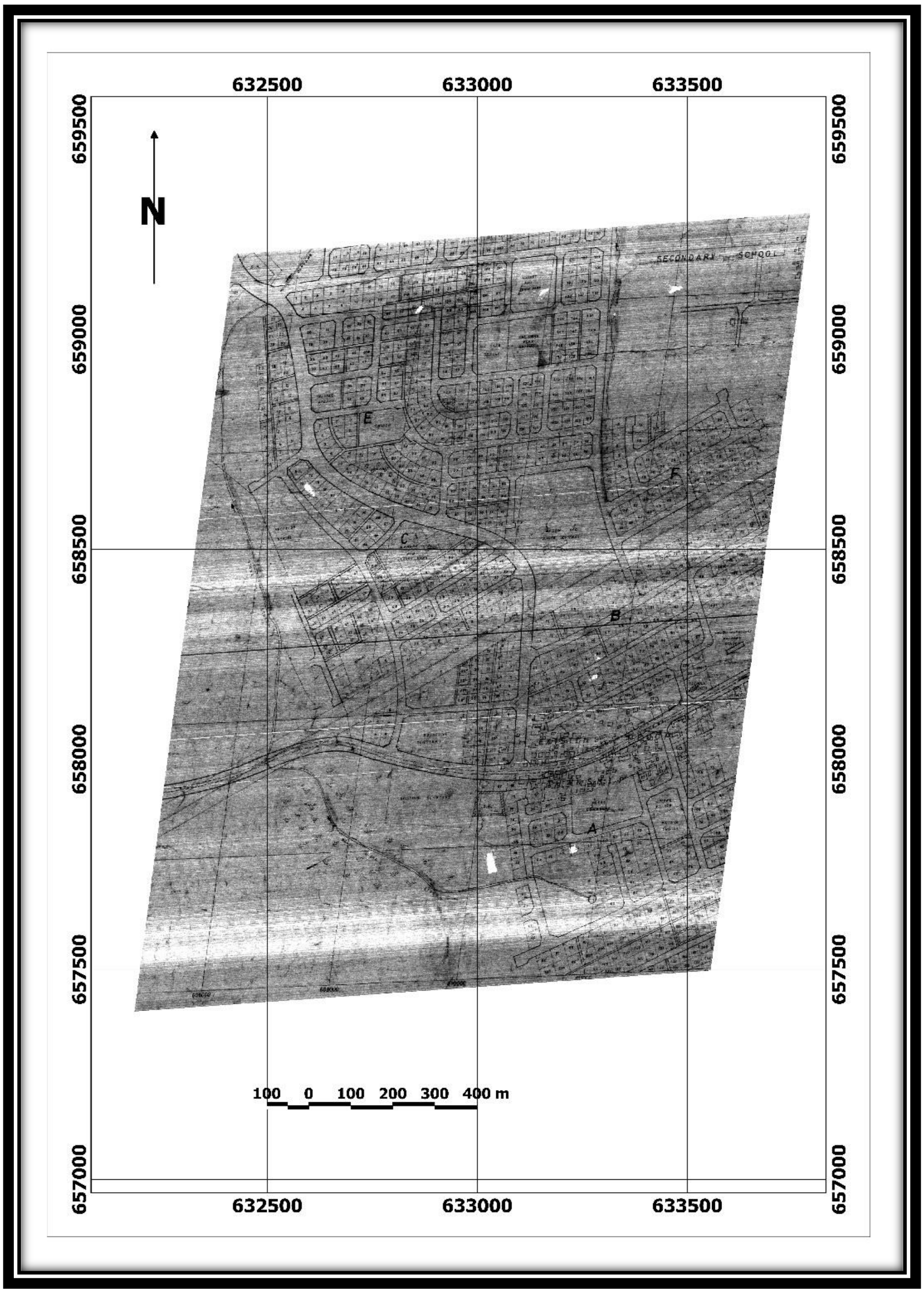

Figure 5.2 Georeferenced Local scheme of the Study Area

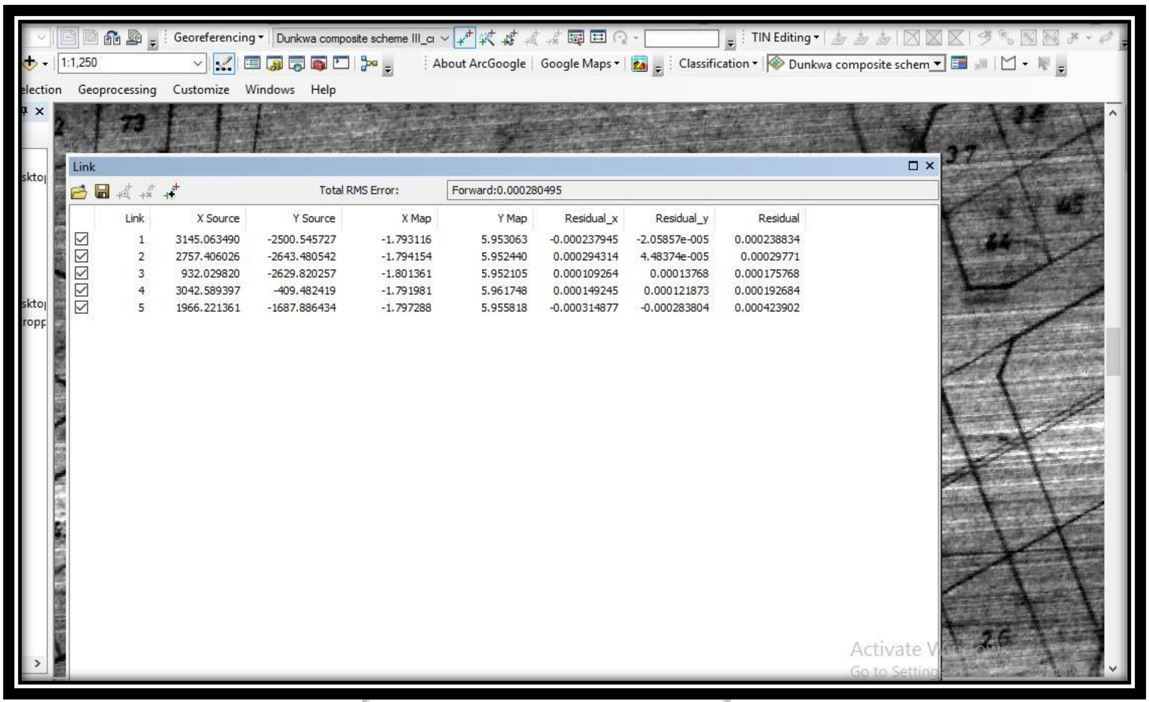

Figure 5.3 RMS Error of Georeferenced Local Scheme

5.2 Evaluation of Existing Layout of the Study Area

5.2.1 Validation of Data on Local Plan

Parcels of various landuse were digitised from the georeferenced local scheme and overlaid on the validated georeferenced drone image to verify whether or not identified features on both data will fall in place.

It was revealed in Figure 5.4 that features such as roads and stream were not lying in place with that of the image and was attributed to incorrect data for base map, hence has resulted in wrongly positioning of landuses and wrongly proposing of landuses in areas that are not suitable for development.

Landuses such as schools and playing field on the local scheme were also not lying in place with that on the images and this can be concluded that, development in the community does not conform to the local scheme. There is therefore the need to validate any data that will be used for any scheme.

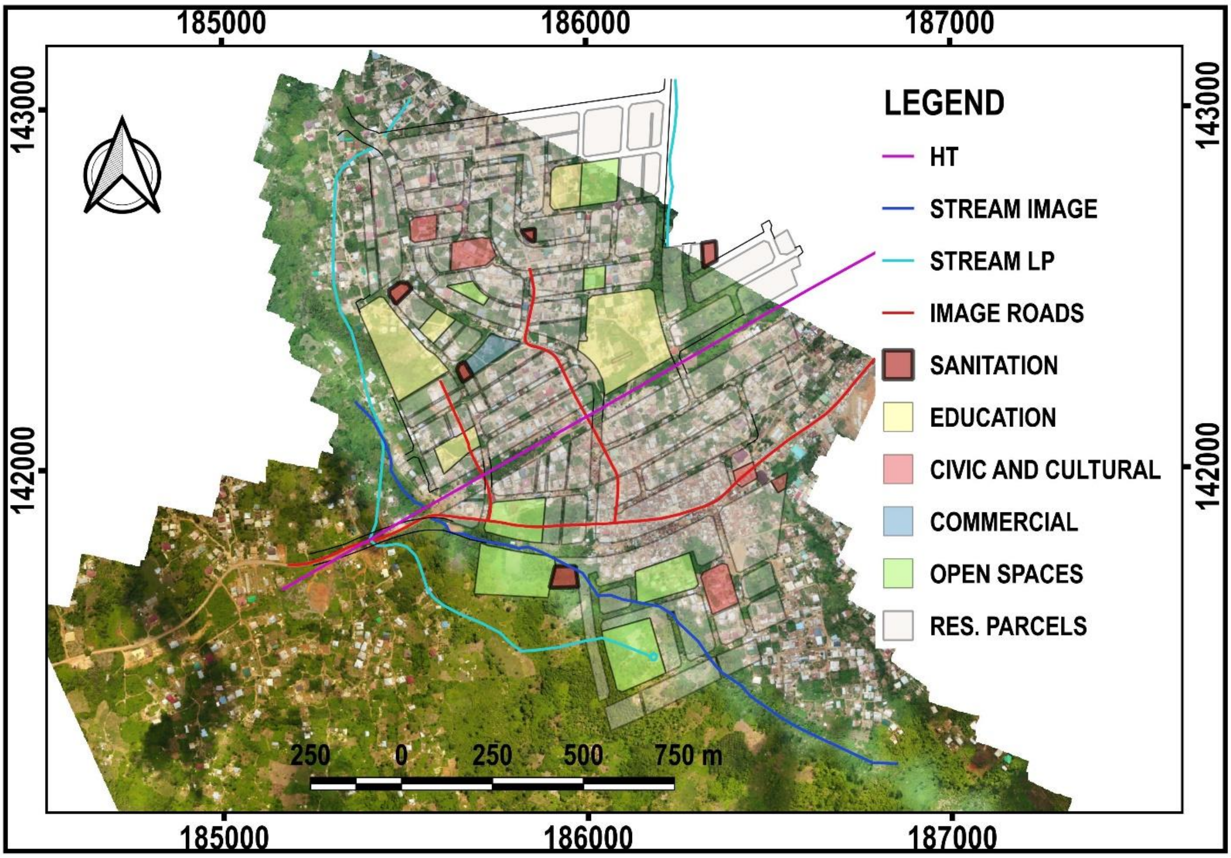

Figure 5.4 Overlaid Digitised Local Scheme on Image

5.2.2 Lack of terrain Data

Terrain data such as contours give a generalized view of the landform of an area. It also explains why certain landuses are proposed at certain locations. It can be seen from the local scheme that basic information about the terrain like the contours, which guides designers in siting propose various landuses on ground was missing. This makes it difficult to have an idea about how the topography or land form of the area covered by the local scheme is.

5.2.3 Indefinite boundaries of planning scheme

To avoid future boundary conflict among stools, it is advisable that, every local scheme should have a definite jurisdiction or boundary features such as proposed roads or an existing natural feature such as water body which separates one jurisdiction from the other. However, it was not the case with the local scheme of the study area. There was no feature either natural or artificial separating the communities and this can bring litigation during demarcation stage.

Even though the local scheme of the study area does not exhibit or propose mixed landuse, observations made from the study area exhibited mixed type of landuses specifically, residential and commercial mixed type of landuses along the main road running through the town to asikuma community and the other route through to Atechem community.

The presence of public transportation routes with alternative public transit modes such as bicycle paths, pedestrian-friendly walkways and sidewalks, and well-connected street networks are significant elements to reach optimum accessibility and connectivity in sustainable neighbourhoods for all members of community (Ozden and Ecran, 2014). The local scheme of Mfuom did not make provision for such transit modes i.e. bicycle and pedestrian walk ways or lane. Both bicycle, motor cycles, pedestrian and vehicles were using the same streets. Also, most roads in the local scheme were hanging and not connected.

These were manifested on ground where most roads have dead ends which can cause accidents.

Even though there are spaces on the local scheme designated for active open spaces and parks for recreational activities, it was observed that, those spaces for recreation have been changed to other landuse predominately residential. This scarce and insufficient green spaces for recreational activities does not have a negative effect on the social life of the population alone, but can affect the environment as well by causing a deficiency in environmental pollution insulation.

Even though spaces such as market and lorry park, open spaces, sanitation and postal agency as required by the planning standards in Ghana have been provided on the local scheme, such landuses have been used as residential purposes.

5.2.4 Non Conformity with the principles of Sustainable Design

The principles of sustainable design contribute to that of the components of a sustainable community because, if a community local scheme exhibits the principles of sustainable design, when implemented, will show signs of components of sustainable community. A Sustainable settlement design should meet a five basic principles such as Adequate spaces for streets and efficient transportation network, Mixed-uses, High Density, Social Mix, Limited Specialised use and Affordability (Dehghanmongabadi *et al.*, 2014).

It was realised that, these principles could not be identified on the local scheme of the study area. Landuse specialisation can be seen in the design since 70 % of the total land has been zoned and into one use (residential). Also, it can be seen from the design that some roads were hanging and not linking up, they also lack cycle and pedestrian walkable spaces.

5.3 Existing Landuse Pattern of the Study Area

It was revealed that, 1510000sqm and 2650000sqm are built-up and non-built-up respectively. The non-built-up area were predominantly used for farming activities. Table 5.1 summarises the total land area covered by the various landuses in the built-up and Figure 5.6 shows the graphical representation of the landuses. The undeveloped land within the built up forms a total land area of 400000sqm, representing 26.5%. These showed that, majority of developers leave the site for speculative increase of land price.

Table 5.1 Land Use Inventory

Land use	**Land area (m^2)**	**Percentage**
Residential and Roads	910000	60.3
Commercial	7000	0.5
Civic and culture	20000	1.3
Education	30000	2
Nature reserve	100000	6.6
Undeveloped	400000	26.5
Open space	40000	2.6
Sanitation	3000	0.2
Total	**1,510,000**	100

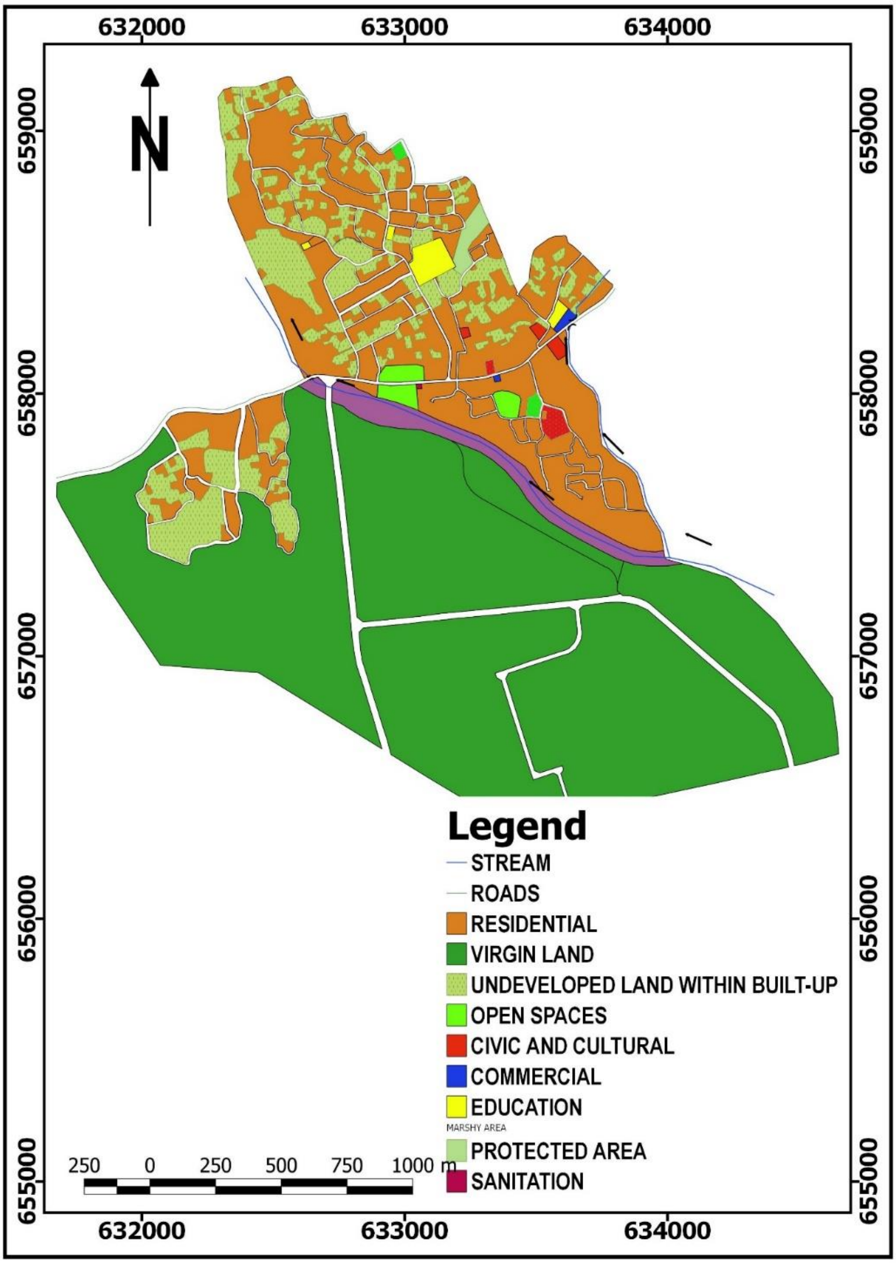

Figure 5.6 Landuse Inventory from the Drone Image of Mfuom

5.3.1 Problems identified in the study area

The physical problems identified in the study area included;

leap frog development

This is where spaces are left within the developed or built-up areas for either speculative increase in land prices, or waiting for a certain facility to be serviced at the area before developing. Such areas within the community are mostly used as refuse disposal site by neighbors and also serve as a hiding place for predators such as snakes.

Access to health facilities

It was revealed in the local scheme that, because provision was not made for any health facility, this has resulted to its non - existence in the community after the implementation. This can put the community in danger when residents face health problem.

Inadequate space for market and Taxi ranks

A community such as Mfuom area must have at least one shopping centre where the residents can trade. Even though a market area was proposed on the local scheme, it was observed that, the area has been used for residential purposes. This has brought about encroachment of road reservation within the community which can result in road accidents since it was observed that both traffic and traffic users were using the same space.

Inadequate open spaces for recreational activities

Open spaces for recreational activities though were provided on the local scheme, physically, there was no area demarcated for such purposes. The community use the spaces at schools for open spaces purposes.

5.4 Determination of Proposed land area for the Proposed Settlement Design

The current population of 6160 was deducted from the projected population of 8858 to be 2698 people and was taken as the actual population who are going to stay in the new settlement. This figure was then used to calculate the total gross residential land area using the medium residential density from the Zoning and Planning standards to be 89 people per 1000m^2. The total gross residential land area was calculated to be 303000m^2. This included all the other supporting land uses to make the settlement liveable and sustainable and excluded existing land uses such as nature reserve and non-buildable area. The total plot size for the medium residential density was 450m^2.

5.5 Goals and Objectives

Table 5.2 shows the results of the Local goals compared with the Upper Denkyira East Municipal Goals.

Table 5.2 Local Goal –Municipal Goal Compatibility Analysis Matrix

GOAL	M1	M2	M3	M4	M5	TOTAL	RANK
L1	0	0	0	1	0	1	5th
L2	0	2	2	2	0	6	1st
L3	0	0	2	0	0	2	4th
L4	0	1	2	0	2	5	2nd
L5	0	1	2	1	0	4	3rd

After comparing the Local goals to that of the Municipal goals, the ranked local goals become the Operational Goals (OG) as follows;

- OG1 - Improve quality environmental condition and health care
- OG2 - Improve economic welfare of the population
- OG3 - Improve social relation and interaction within the community
- OG4 - Improve transportation system and mobility
- OG5 - Ensure compact spatial development growth

These ranked Operational Goals were then tested using the AHP whether the ranked goals will be in consistence with the AHP.

AHP

A pairwise comparison was conducted using the weights or the relative importance assigned to the Operational goals to come out with a pairwise matrix which is shown in Equation (2).

Improve quality environmental condition and health care - 9

Improve economic welfare of the population- 7

Improve social relation and interaction within the community- 5

Improve transportation system and mobility- 3

Ensure compact spatial development growth- 1

Pairwise comparison

$$\begin{bmatrix} 1 & 2 & 4 & 6 & 8 \\ 0.5 & 1 & 2 & 4 & 6 \\ 0.25 & 0.5 & 1 & 2 & 4 \\ 0.17 & 0.25 & 0.5 & 1 & 2 \\ 0.13 & 0.17 & 0.25 & 0.5 & 1 \end{bmatrix} \quad (2)$$

The results of the normalisation matrix is shown in Equation (3)

$$\begin{bmatrix} 0.49 & 0.51 & 0.52 & 0.44 & 0.38 \\ 0.24 & 0.26 & 0.26 & 0.30 & 0.29 \\ 0.12 & 0.13 & 0.13 & 0.15 & 0.19 \\ 0.08 & 0.06 & 0.06 & 0.07 & 0.10 \\ 0.06 & 0.04 & 0.03 & 0.04 & 0.05 \end{bmatrix} \quad (3)$$

The steps taken to check consistency is shown in Equation (4) to (9)

$$\begin{bmatrix} (0.49+0.51+0.52+0.44+0.38)/5 \\ (0.24+0.26+0.26+0.30+0.29)/5 \\ (0.12+0.13+0.13+0.15+0.19)/5 \\ (0.08+0.06+0.06+0.07+0.10)/5 \\ (0.06+0.04+0.03+0.04+0.05)/5 \end{bmatrix} = \begin{bmatrix} 2.34/5 \\ 1.35/5 \\ 0.75/5 \\ 0.37/5 \\ 0.22/5 \end{bmatrix} = \begin{bmatrix} 0.47 \\ 0.27 \\ 0.15 \\ 0.07 \\ 0.04 \end{bmatrix} \quad (4)$$

$$0.47\begin{bmatrix} 1 \\ 0.5 \\ 0.25 \\ 0.17 \\ 0.13 \end{bmatrix} + 0.27\begin{bmatrix} 2 \\ 1 \\ 0.5 \\ 0.25 \\ 0.17 \end{bmatrix} + 0.15\begin{bmatrix} 4 \\ 2 \\ 1 \\ 0.5 \\ 0.25 \end{bmatrix} + 0.07\begin{bmatrix} 6 \\ 4 \\ 2 \\ 1 \\ 0.5 \end{bmatrix} + 0.04\begin{bmatrix} 8 \\ 6 \\ 4 \\ 2 \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} 0.47+ & 0.54+ & 0.6+ & 0.42+ & 0.32 \\ 0.24+ & 0.27+ & 0.3+ & 0.28+ & 024 \\ 0.12+ & 0.14+ & 0.15+ & 0.14+ & 0.16 \\ 0.08+ & 0.07+ & 0.08+ & 0.07+ & 0.08 \\ 0.06+ & 0.05+ & 0.04+ & 0.04+ & 0.04 \end{bmatrix} = \begin{bmatrix} 2.35 \\ 1.33 \\ 0.71 \\ 0.38 \\ 0.23 \end{bmatrix} \quad (5)$$

Consistency Vector

$$\begin{bmatrix} 2.35/0.47 \\ 1.33/0.27 \\ 0.71/0.15 \\ 0.38/0.07 \\ 0.23/0.04 \end{bmatrix} = \begin{bmatrix} 5 \\ 4.93 \\ 4.73 \\ 5.43 \\ 5.75 \end{bmatrix} \quad (6)$$

$$\lambda max = \frac{25.8}{5} = 5.168 \quad (7)$$

Consistency Index

$$CI = \frac{5.168-5}{5-1} = \frac{0.168}{4} = 0.042 \quad (8)$$

Consistency Ratio

$$CR = \frac{0.042}{1.12} = \underline{0.0375} \quad (9)$$

The consistency ratio for the assigned weights is 0.0375 which indicates that the opinion is consistent with the scoring since the value obtained is less than 0.10, therefore the prioritisation of the goals was accepted and used.

Objectives and strategies to achieve the various goals were outlined in table 5.3.

Table 5.3 Recommended Operational Goals, Objectives and Strategies

GOALS	OBJECTIVES	STRATEGIES
OG1; Improve quality environmental condition and health care	-Improve drainage and liquid waste disposal methods by 2029 -Increase capacity of waste collection systems by 2029 - Enhance efficient and easy access to waste disposal methods - Construct, furnish and operate health facility for the community by 2029	-Provide drains along major access routes -Provide adequate waste bins and skip containers to neighbourhood. -organise clean up exercise in the community. -Make spatial provision for the skip containers. -Provide effective and efficient waste management systems and control --Make spatial provision for the health facility.

OG2; Improve economic welfare of the population	-Establish economic related infrastructure by the end of 2029. -integrate informal activities into the economy	- make spatial provision for a local market. -Make spatial provision for taxi and lorry station. -Make spatial provision for informal activities.
OG3; Improve social relation and interaction within the community	-Establish social related infrastructure by the end of 2029.	-Make spatial provision for facilities. -Organise programmes to bring the people together.
OG4; Improve transportation system and mobility	-Reduce road encroachment and Traffic congestion. -Improve surface condition of major and local roads by 2029	-Discourage on-street parking. -Provision of bus stop along major routes -Discourage commercial activities on shoulders of road. -Provision of walkways along major routes - Tare major local routes to increase mobility

OG5; Ensure compact spatial development growth	-Discourage leap-frog development by end planned period -Encourage site and services by the 2029	-Enforce development control measures on housing maintenance -Provide site services like road, water, electricity and proper plot demarcation before development.

5.6 Disaster Risk Map (Flood Map)

The flood map was generated by first generating contours from the georeferenced images and then used to generate the Digital Elevation Model (DEM) of the extracted total land area. This was then generated into Triangular Irregular Network (TIN) to have a proper view of the elevation changes in the area. The DEM was then generated into a slope map of the area to know the percentage of rise and fall of the area.

As shown in Figure 5.7, the highest elevation is depicted with a deep brown color with height higher than 161.4m above sea level and areas less than 144.9m above sea level are depicted with very light shade of brown. Figure 5.8 also shows the TIN of the area to give it a proper view.

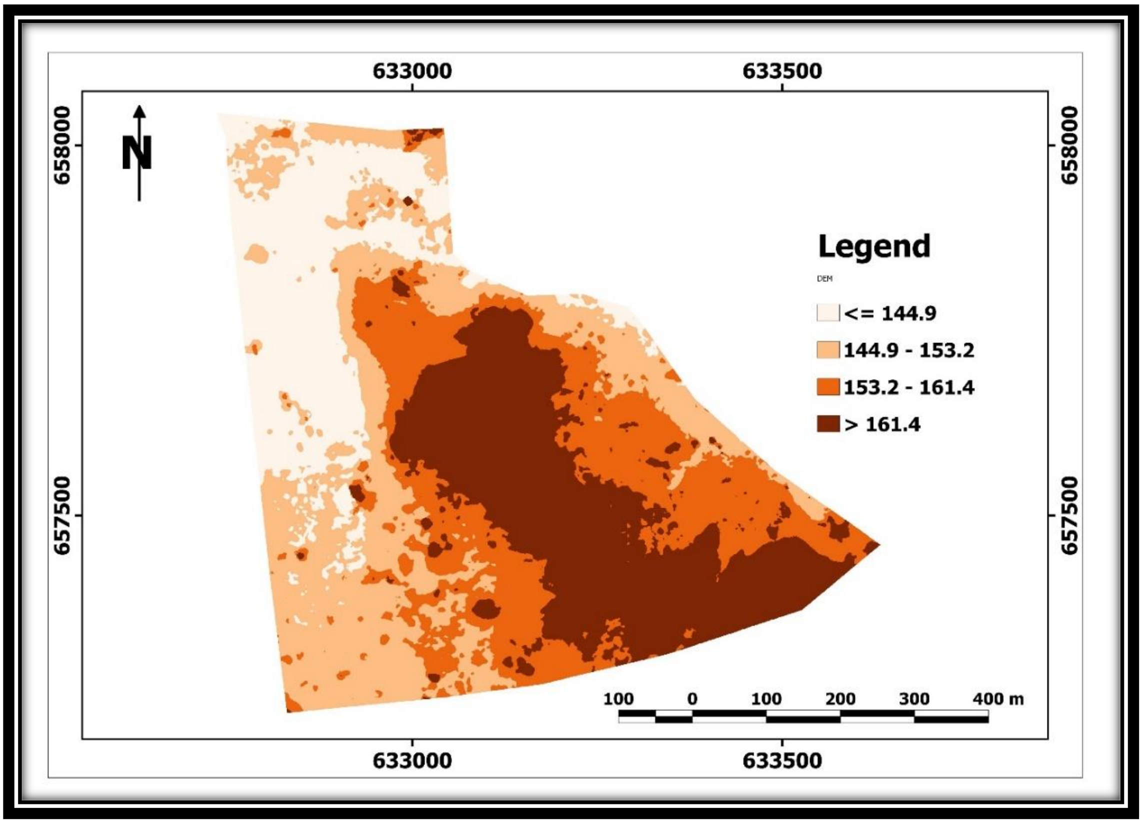

Figure 5.7 Digital Elevation Model of Proposed Settlement

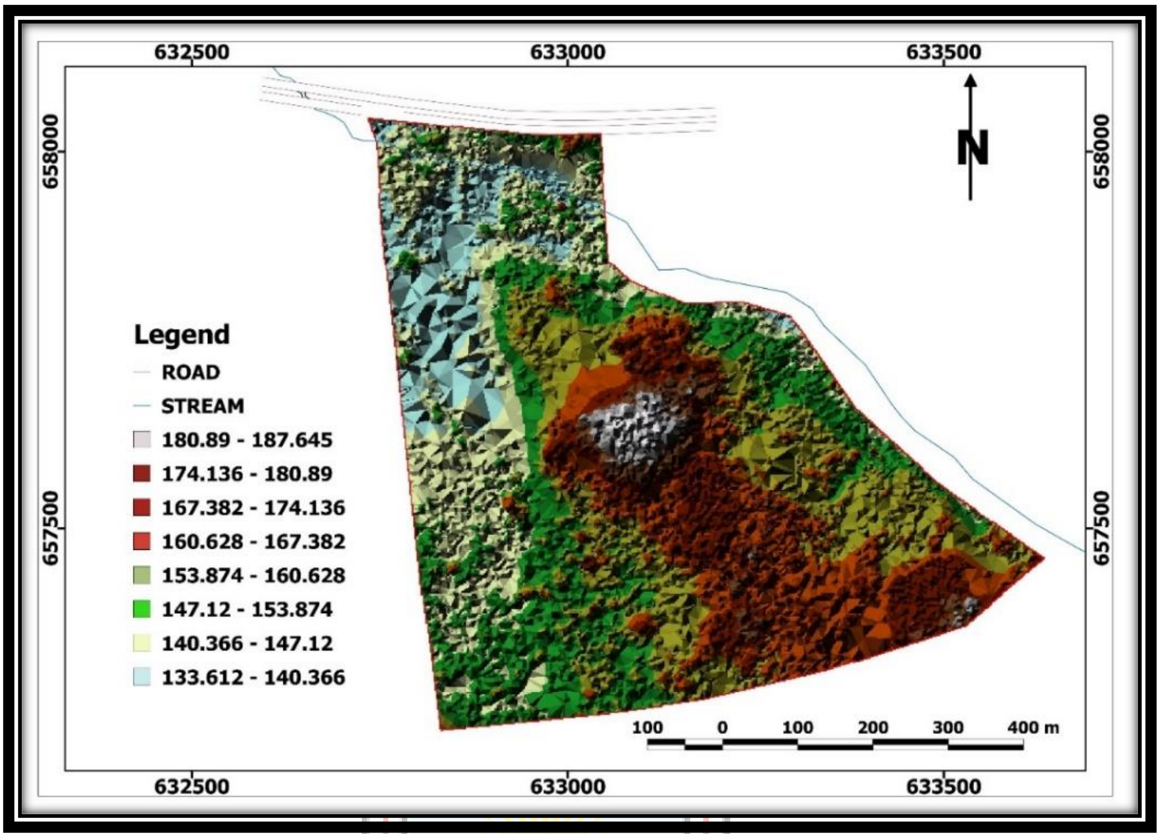

Figure 5.8 Triangular Irregular Network of Proposed Settlement

Figure 5.9 shows the slope map of the area for the proposed settlement. The lowest elevations are depicted by dark brown with the highest slopes depicted by blue colorations. followed by yellow then to the highest elevation areas shown in red coloration. It showed the changes in rise or fall of elevation with respect to distance.

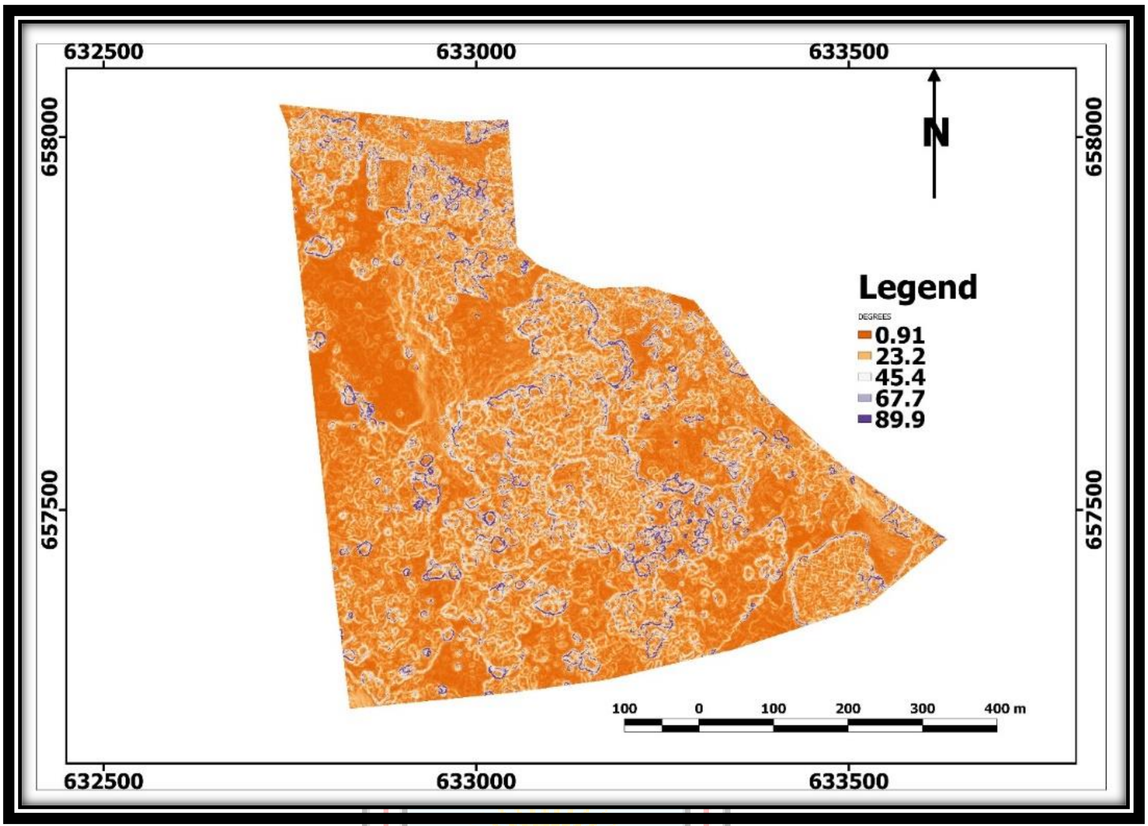

Figure 5.9 Slope of the settlement site

The slope map, contours and the landuse map were then used for the generation of the flood map. Figure 5.9 shows the areas that are prone to flood in case of heavy down pour. Areas towards the northern part are highly liable to flooding because it has greater part of the land to the lowest gradient of 0.91%. Therefore, run off water from the southern part with most of the area with high gradient 45.4% to 89.9%. This was well interpreted when it the flood map was compared with the TIN map of the area.

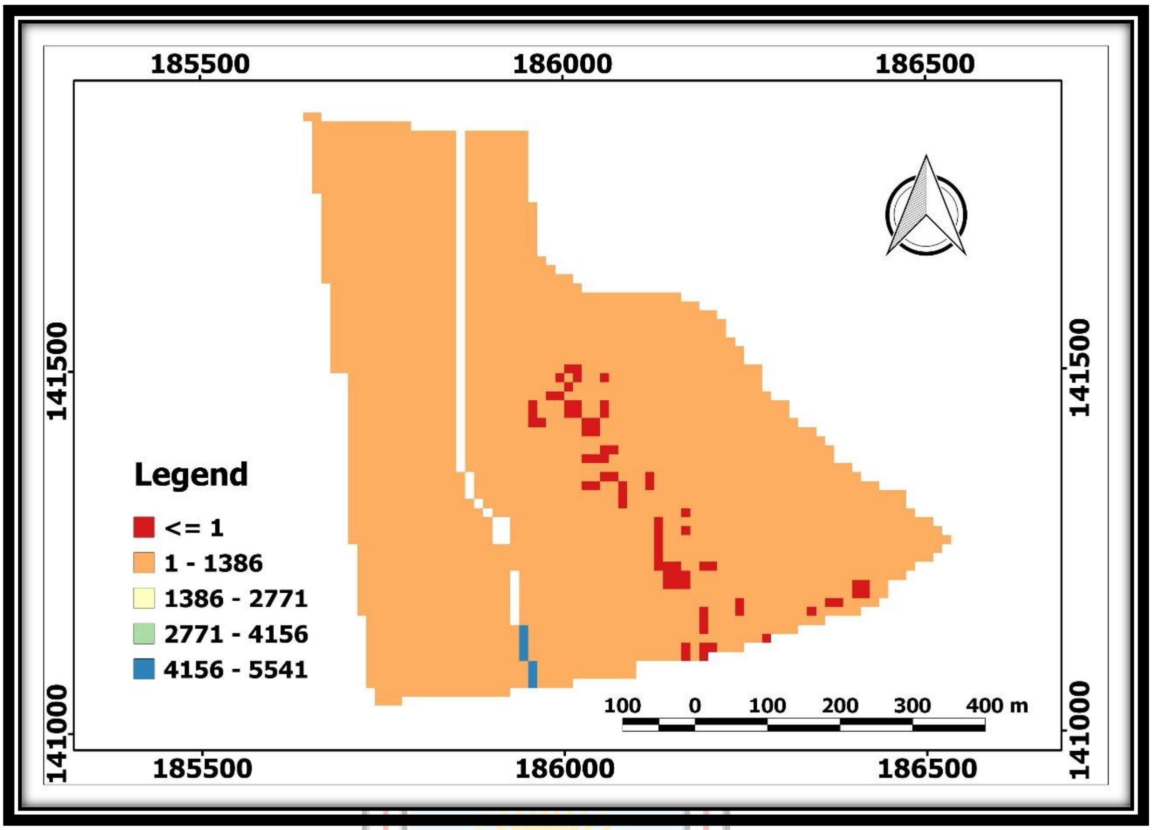

Figure 5.10 Flood Accumulation Areas of the proposed settlement site

5.7 AHP and GRA

5.7.1 Selection of Suitable Spatial Model

AHP was employed in the selection of best suitable spatial design model for the research. Weights were assigned to the types of the design model based on their advantages and disadvantages and their applicability to the present day settlement design. Equation (10) shows a matrix as a result of the pairwise comparison of relative applicability of the design models.

Weights assigned by experts to the criteria or the elements.

Neighborhood model	7
Multi-Nuclei Model	5
Sector Model	3
Concentric Model	1

Pairwise Comparison

$$\begin{bmatrix} 1 & 2 & 4 & 6 \\ 0.5 & 1 & 2 & 4 \\ 0.25 & 0.5 & 1 & 2 \\ 0.17 & 0.25 & 0.5 & 1 \end{bmatrix} \tag{10}$$

(1+0.5+0.25+0.17) (2+1+0.5+0.25) (4+2+1+0.5+0.25) (6+4+2+1) =

$$[1.92 \quad 3.75 \quad 7.5 \quad 13]$$

The normalisation matrix is shown in equation (11)

$$\begin{bmatrix} 0.52 & 0.53 & 0.53 & 0.46 \\ 0.26 & 0.27 & 0.27 & 0.31 \\ 0.13 & 0.13 & 0.13 & 0.15 \\ 0.09 & 0.07 & 0.07 & 0.08 \end{bmatrix} \tag{11}$$

The weighted matrix was calculated and is given in equation (12)

$$\begin{bmatrix} (0.52+0.53+0.53+0.46)/4 \\ (0.26+0.27+0.27+0.31)/4 \\ (0.13+0.13+0.13+0.15)/4 \\ (0.09+0.07+0.07+0.08)/4 \end{bmatrix} = \begin{bmatrix} 2.04/4 \\ 1.11/4 \\ 0.54/4 \\ 0.31/4 \end{bmatrix} = \begin{bmatrix} 0.51 \\ 0.28 \\ 0.13 \\ 0.08 \end{bmatrix} \tag{12}$$

The consistency check is shown from equation (13) to (18)

$$0.51 \begin{bmatrix} 1 \\ 0.5 \\ 0.25 \\ 0.17 \end{bmatrix} + 0.28 \begin{bmatrix} 2 \\ 1 \\ 0.5 \\ 0.25 \end{bmatrix} + 0.13 \begin{bmatrix} 4 \\ 2 \\ 1 \\ 0.5 \end{bmatrix} + 0.08 \begin{bmatrix} 6 \\ 4 \\ 2 \\ 1 \end{bmatrix} \tag{13}$$

$$\begin{bmatrix} 0.51+ & 0.56+ & 0.52+ & 0.48 \\ 0.25+ & 0.28+ & 0.26+ & 0.32 \\ 0.13+ & 0.14+ & 0.13+ & 0.16 \\ 0.09+ & 0.07+ & 0.07+ & 0.08 \end{bmatrix} = \begin{bmatrix} 2.07 \\ 1.11 \\ 0.56 \\ 0.31 \end{bmatrix} \tag{14}$$

Consistency Vector (CV)

$$\begin{bmatrix} 2.07/0.51 \\ 1.11/0.28 \\ 0.56/0.13 \\ 0.31/0.08 \end{bmatrix} = \begin{bmatrix} 4.06 \\ 3.96 \\ 4.31 \\ 3.88 \end{bmatrix} \tag{15}$$

$$\frac{4.06+3.96+4.31+3.88}{4} = \frac{16.21}{4} = 4.05 \qquad (16)$$

Consistency Index (CI)

$$CI = \frac{4.05-4}{4-1} = \frac{0.05}{3} = 0.017 \qquad (17)$$

Consistency Ratio (CR)

From the Random Inconsistency Indices (RI) table, Rank Values (N) equal to 4 is 0.9

$$CR = \frac{0.017}{0.9} = 0.019$$

(18)

The consistency ratio for the assigned weights is 0.019 which indicates that the opinion is in consistent with the scoring since the value obtained is less than 0.10. Hence, the weights obtained for the types of the design models "Neighborhood Design model", "Multi Nuclei Model", "Sector Model" and "Concentric Model" are 0.51 or 51%, 0.28 or 28%, 0.13 or 13% and 0.08 or 8% respectively.

5.7.2 Classification of the Area in Zones

The figure 5.10 showed the proposed road pattern of the proposed settlement site after knowing the suitable design model. Some of the principles of the adopted design model informed the proposal of roads to bound the site so as to have a definite boundary. This may also help to avoid any future litigation. Again, proposed roads within the settlement were carefully designed taken into consideration the slope and the areas that are liable to flood. It can be seen that, 80% of the major proposed roads were designed across contours especially areas with higher elevation for easy road construction and easy accessibility to avoid any road accident. Buffer was also created around suspected floodable area and around an existing stream to prevent disaster in times of long hours of rainfall and encroachment by developers to the stream respectively. The site was classified into four zones i.e. zone A, zone B, zone C, and zone D based on the topography and the proposed road pattern for the appropriate location of community facilities. Zone C exhibited the highest land form among the zones. Zone A had an average height of 147.12m with the total land area of 71000m^2, zone B had 157.25m for height with the total land area of 58000m^2, zone C had an elevation of 170.759m with land size of 86000m^2 and zone D had an elevation of 164.005m with a land size of 116000m^2.

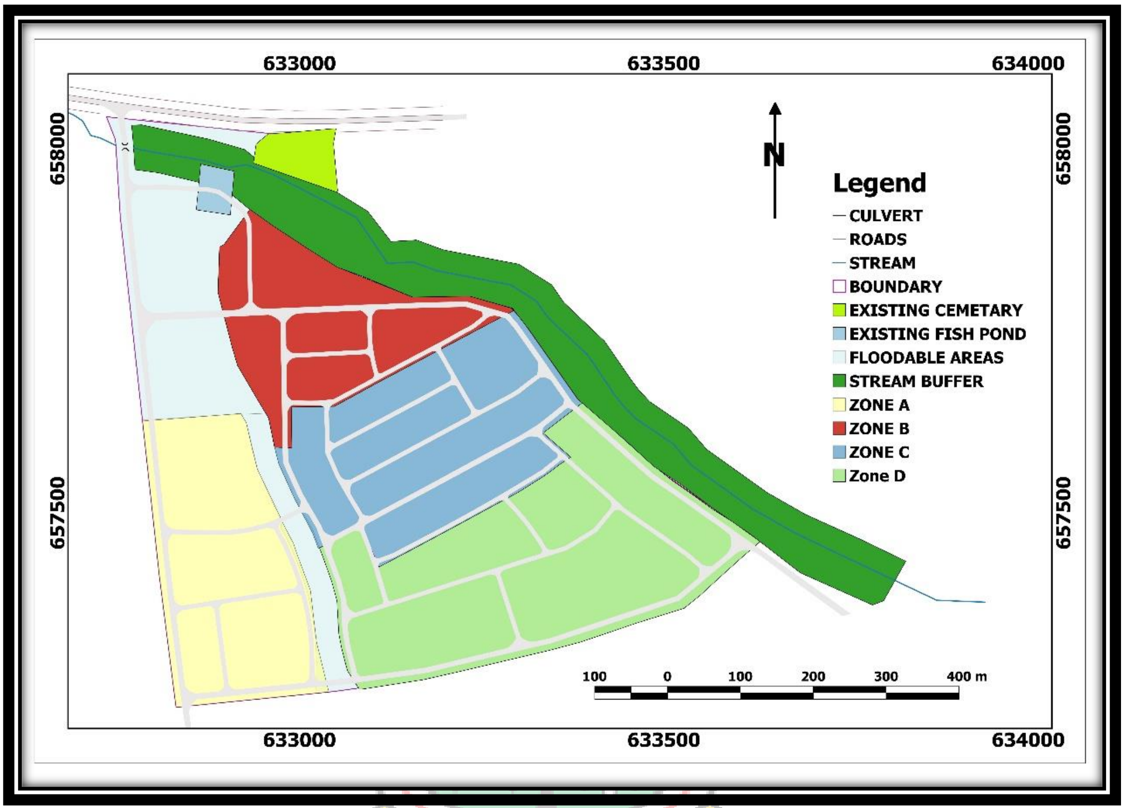

Figure 5.11 Classification of Site into Zones

5.8 Selection of Suitable Locations for Community Facilities

Here, the criteria used were the topography, effect of noise pollution and proximity of residents to community facilities. Weights were assigned to various zones based on heights because heights or topography has an indirect relationship with noise pollution. The higher the height the lesser the noise pollution, therefore, the better to locate certain facilities.

The AHP was employed to assign weight to the zones using equation (19) to (21).

Zone A=1

Zone B =3

Zone D =5

Zone C =7

Pairwise Comparison

$$\begin{bmatrix} 1 & 2 & 4 & 6 \\ 0.5 & 1 & 2 & 4 \\ 0.25 & 0.5 & 1 & 2 \\ 0.17 & 0.25 & 0.5 & 1 \end{bmatrix} \tag{19}$$

(1+0.5+0.25+0.17) (2+1+0.5+0.25) (4+2+1+0.5+0.25) (6+4+2+1) =

$$[1.92 \quad 3.75 \quad 7.5 \quad 13]$$

The normalisation matrix is shown in equation (20)

$$\begin{bmatrix} 0.52 & 0.53 & 0.53 & 0.46 \\ 0.26 & 0.27 & 0.27 & 0.31 \\ 0.13 & 0.13 & 0.13 & 0.15 \\ 0.09 & 0.07 & 0.07 & 0.08 \end{bmatrix} \tag{20}$$

The weighted matrix was calculated and is given in equation (21)

$$\begin{bmatrix} (0.52+0.53+0.53+0.46)/4 \\ (0.26+0.27+0.27+0.31)/4 \\ (0.13+0.13+0.13+0.15)/4 \\ (0.09+0.07+0.07+0.08)/4 \end{bmatrix} = \begin{bmatrix} 2.04/4 \\ 1.11/4 \\ 0.54/4 \\ 0.31/4 \end{bmatrix} = \begin{bmatrix} 0.51 \\ 0.28 \\ 0.13 \\ 0.08 \end{bmatrix} \tag{21}$$

The weighted sum given to the various zones are; Zone A is 0.08, Zone B is 0.13, Zone C is 0.51 and Zone D is 0.28. Appendix D gives an in-depth calculation for the weighted sum assigned to the zones. Table 5.5 shows the Grey Relational Coefficient, Grey Relational Grade and ranking of Grey Relational Analysis for the various community facilities which are required for a neighbourhood in the zoning standards of Ghana. The facilities considered were Education (Primary and JHS), Health (Health Centre), Commercial (Neighbourhood Shopping Centre), Civic and Cultural (Post office) and active and passive recreational centers (Resource centre and P. O. S).

Here distances of various proposed sites from the facilities to the farthest buildable point were measured in meters and used as the values for proximity of facility to residents. Also, the average heights of the various proposed sites of facilities were calculated in meters and used as the topography. Here, the smaller is better was used as the reference sequence, because, the cost of travelling distance to access a facility, if lower, the better and also a sustainable settlement should be cost effective to ensure proper implementation.

The normalisation of the data was done to convert the values into range of 0-1 using smaller is better.

Deviation Sequences (DS) were measured to check how far the comparable sequence deviates from the reference sequence. Here, if the value is closer to 1, it is meant that the comparable sequence is far from the reference sequence and if the value is closer to 0, it is meant that the comparable sequence is closer to the reference sequence.

The GRC and that of GRG were calculated after the DS to show the relationship between the reference sequence and the comparable sequence. Here, the maximum relationship was ranked first and selected as the best choice.

Table 5.5 GRC and GRG for Ranking Community Facilities

Active Recreation Centre (i=1,2,…n)	GRC			TOTAL	GRG	RANKING
	TP	ENP	PR			
ZONE A	0.708	1.000	0.371	2.079	0.52	2nd
ZONE B	1.000	0.812	0.333	2.145	0.54	1st
ZONE C	0.333	0.333	0.785	1.451	0.36	4th
ZONE D	0.403	0.518	1	1.921	0.48	3rd
Shopping Area (i=1,2….n)						
ZONE A	1	1	0.333	2.333	0.583	1st
ZONE B	0.385	0.872	0.502	1.699	0.425	3rd

ZONE C	0.454	0.333	0.471	1.258	0.315	4th
ZONE D	0.333	0.518	1	1.851	0.463	2nd
Health Centre (i=1,2,3)						
ZONE B	1	1	0.44	2.44	0.813	1st
ZONE C	0.50	0.33	1	1.83	0.61	2nd
ZONE D	0.333	0.56	0.33	1.22	0.41	3rd
Nursery and Primary (i = 1,2,3)						
ZONE B	0.333	1	0.333	1.666	0.555	3rd
ZONE C	1	0.333	0.491	1.824	0.608	2nd
ZONE D	0.430	0.557	1	1.987	0.662	1st
Police Post (i=1,…n)						
ZONE B	0.597	1	0.333	1.93	0.643	2nd
ZONE C	1	0.333	1	2.333	0.778	1st
ZONE D	0.333	0.559	0.362	1.254	0.418	3rd

5.9 Selected Suitable sites for Community Facilities

Figure 5.11 and 5.12 show maps of the proposed sites for the community facilities and the selected sites of the community facilities by Grey Relational Analysis respectively. The

Grey decision was based on the proximity of community facility to residents, the effect of noise pollution caused by facilities, the topography for the construction of the facility.

The appropriate land area for community facilities were taken from the zoning and planning standards of Ghana. The rest of the buildable area were then sub divided into various residential plots. The size of the plots was gotten from the document of the Country's Zoning and Planning Standards. Table 5.6 shows landuse pattern or distribution in the proposed sustainable settlement design.

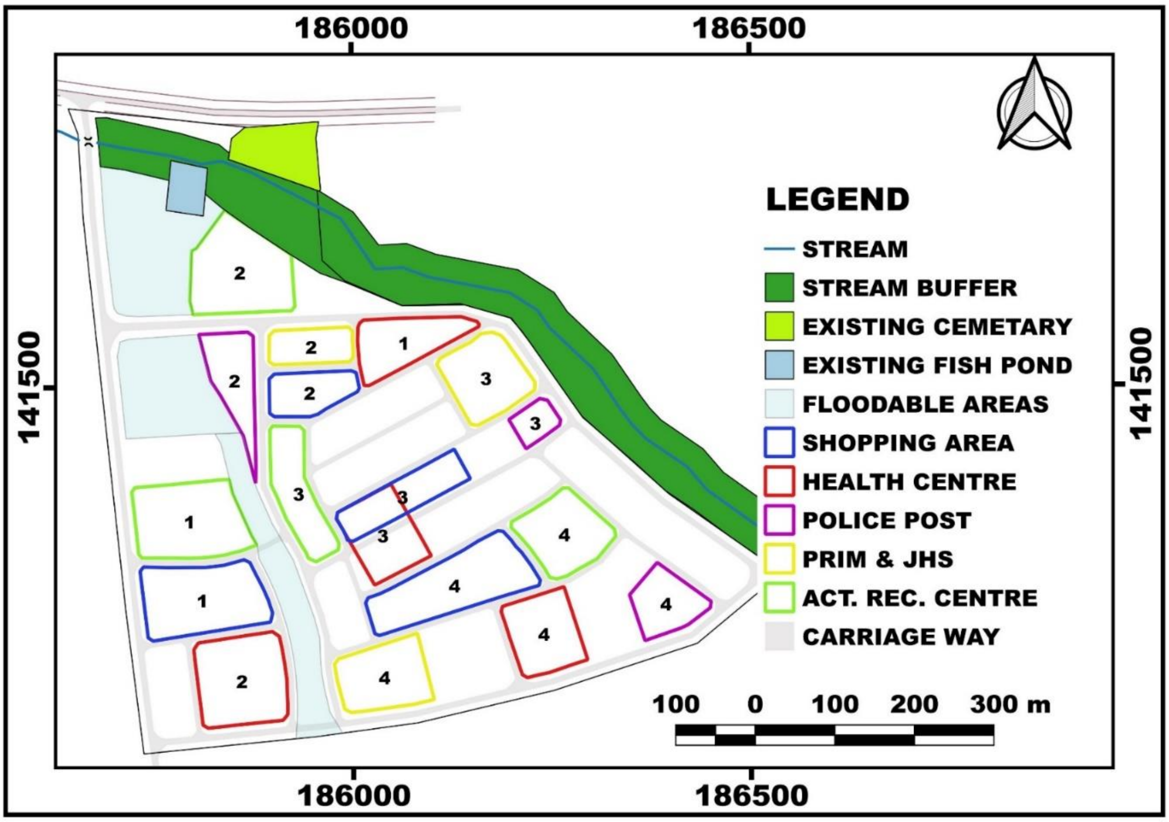

Figure 5.12 Proposed Sites for Community Facilities

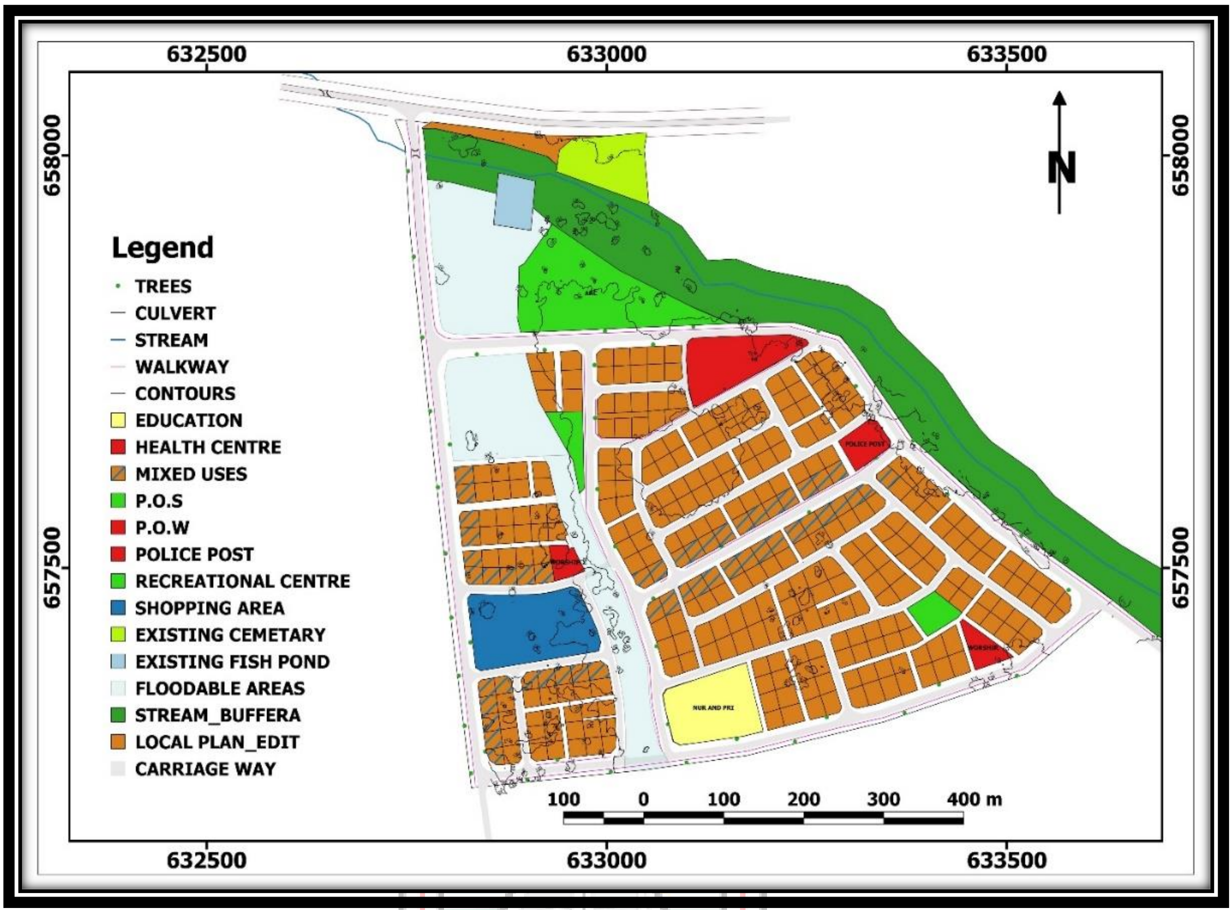

Figure 5.13 Proposed Sustainable Settlement Design

Table 5.6 Landuse Inventory of the Proposed Settlement Design

Landuse	Total Area (m^2)	Percentage (%)
Residential	144000	47.5
Mixed use	23000	7.6
Commercial	14000	4.6
Civic and cultural	13000	4.3
Education	9000	3
Open spaces	4000	1.3
Accessibility	96000	31.7
Total	303000	100

Residential is the most prominent proposed landuses in the settlement design followed by accessibility, Mixed Uses, Commercial, Education and open spaces which had the lowest land area.

5.10 Evaluation of Proposed Settlement Design

The proposed settlement design was evaluated using the five basic principles of sustainable settlement design i.e. Adequate spaces for streets and efficient transportation network, Mixed-uses, High Density, Social Mix, Limited Specialised landuse and Affordability (Dehghanmongabadi *et al.*, 2014).

5.10.1 Adequate Space for Streets and Efficient Street Network.

The principle states that, to achieve this principle, one-third of the total land to be developed should be used for various levels of accessibility. Thirty-one percent which is also approximately one-third of the total land had been used for all levels of roads. Here to ensure safety and cost effectiveness roads have been designed across contours to reduce the level of steepness, and have been designed to join each other at 90º. Also, sharp curves and cross roads were also avoided in the design to ensure road safety and reduction in traffic. With this type of design when implemented operational goal 4 will be also be achieved.

5.10.2 Social Mix

Here, conscious effort was made to site major public landuses across each zone of the settlement. Each zone had at least on public landuse located within it. This according to the principle when implemented will improve interaction among the people thereby reducing class or social segregation within the settlement. This will also ensure in the attainment of operational goal 3.

5.10.3 High Density

With this principle, high density is to maximise the use of land. Here, the medium class residential gross land area was used, where the plot sizes for residential was 450m^2 or 21.2m x21.2m. A total land area of just 303000m^2 was needed to settle a population of 2698. This will ensure in the achievement of operational goal 5. Currently, a total gross residential land area of 1110000m^2 excluding undeveloped land within the built up is being used to accommodate a population of 6160. Ideally, using the medium residential standard, the actual total land area to accommodate the current population should be 691913.6m^2.

5.10.4 Limited Landuse Specialisation

Conscious effort was made to use less than half of the total land area for a single landuse. This is to achieve a vibrant multi-functional community neighbourhood.

5.10.5 Provision of Mixed Landuse

To create local jobs, residential and commercial type of mixed landuse was proposed along the major roads to boost economy of the settlement. This will lead in the achievement of operational goal 2. Also spatial provision has been made within the width of the main collector's type of road to improve walking or cycling in the settlement. Walking and cycling is a form of exercise which improve the health condition of a person. With the introduction of this, it will reduce traffic since the use of cars will be limited hence, will result in the reduction of noise and air pollution from especially the horns and fumes of cars.

5.10.6 Preservation of the Blues and Greens

Here, it is referring to the protection of water bodies and forest. According to the Ghana Planning and Zoning Standards, rivers within forest should have at least 10m and at most 50m buffer. A buffer of 25m on both sides was created along the main Sia river within the settlement to prevent encroaching and polluting of the stream. Since the whole area will be deforested when people settle, buffer has been left around areas that has higher risk of flood accumulation. These areas can be used for farming activities or areas which slopes to the lowest non buildable parts can be used to harvest rain water to irrigate the farm. Also proposal was made to plant trees along the major roads within the settlement to ensure cool temperature.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

In this study, a local planning scheme of Mfuom community in the Upper Denkyira East Municipality of Central Region was evaluated using validation of Data and principles of sustainable settlement design. The study has revealed that proposals made in the existing Mfuom planning scheme is not in conformity with development on the ground due to use of inaccurate topographical data for the design. Also, the design lacked definite boundary, which can lead to ligation between two stools. There is therefore the need to acquire accurate topographic data for the update of the local scheme.

The proposed model has been designed taking into consideration all the principles of settlement design which when implemented can lead to a sustainable community. Landuses has been sited appropriately with the use of Grey Relational Analysis. Also the design can easily fit into the nation's development framework because it was guided by the country's zoning and planning standards.

6.2 Recommendations

It is recommended that, the methods used in achieving the settlement design be adopted and used especially in area that have similar features like Mfuom. However, further research should be done on other methods or ways to come out with more best model for sustainable settlement design.

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APPENDICES

Appendix A

Household Questionnaire for Mfuom Community

NAMES OF HOUSEHOLD MEMBERS	AGE	GENDER		MARITAL STATUS (PLEASE TICK)			EDUCATIONAL BACKGROUND		ETHNICITY	TRIBE	RELIGION			OCCUPATIONAL STATUS					
		M	F	MARRIED	NOT MARRIED	DIVORCED	EDUCATED	NOT EDUCATED			CHRISTIAN	ISLAMIC	TRADITIONAL BELIEVER	EMPLOYED	UNEMPLOYED	TYPE OF EMPLOYMENT. (PLEASE TICK)			
																SERVICE	COMMERCE	AGRIC	INDUSTRY

A. TYPE OF HOUSE, HOUSING OWNERSHIP, AND BASIC HOUSING FACILITIES

1. Do you own the House?

   a. Yes ( ) b. No ( )

2. If No, by what means are you occupying the House?

   a. Rented ( ) b. Staying there for free ( )

3. What is the type of house?

   a. Detached ( ) b. Semi-detached ( ) c. Flats/ Apartment ( ) d. Compound House ( )

4. What is the type of construction?

   a. Landcrete ( ) b. Sandcrete ( )

5. What source of water does the household use?

   a. Pipe Borne ( ) b. Bore hole( ) c. Hand dug well ( ) d. Rain Water( ) e. Stream( )

6. Is the source of water connected to the residence? Yes ( ) No ( )

7. If No, how do you access it?

   a. Fetching from community bore hole for free b. Fetching from connected houses at a fee.

8. How do you dispose your refuse?

   a. Community Skip Bins ( ) b. Refuse Container ( ) c. Backyard and

9. Does the house has a toilet facility?

   a. Yes ( ) No. ( )

10. If No, how do you access toilet facility?

    a. through Public toilet b. Open Defecation

Appendix B

Local scheme of the built up part of the study area

Appendix C

Calculation of Population and Household Projection

The projected population for Mfuom was calculated as follows.

- Calculation of growth rate from 2000 to 2010 given population as 3241 and 4441 respectively (Statistical Service Department, 2018).

Growth rate = $\frac{Pt-Po}{Po}$ x 100 divided by the number of years where

Pt = is the current Year

Po = is the previous year

∴ Growth rate = $\frac{4441-3241}{3241}$ x 100

= 0.37 x 100

= $\frac{37}{10}$ = $\underline{\underline{3.7}}$

- Population projection for current year (2019) is given as

Pt = Po $(1 + r)^t$

Pt = Population at the end of the period.

Po = Population at the beginning of the period.

r = Constant rate of change.

t = Inter-censual period.

Pt = 4441 $(1 + 3.7/100)^9$

Pt = $4441(1 + 0.037)^9$

= $4441(1.037)^9$

= 4441(1.387)

= $\underline{\underline{6160}}$

The population for the planned period of 10years (2029) is given as:

6160 $(1 + 3.7/100)^{10}$

Pt = $6160(1 + 0.037)^{10}$

= $6160(1.037)^{10}$

= 6160(1.438)

= $\underline{\underline{8858}}$

- Projection of household in Mfuom from 2010 to 2019 is given as

Pt = Po $(1 + r)^t$

Where Po = household for the year 2010 which was given as 203 households (Statistical Service Department, 2018).

Pt = household for projected year (2019).

∴ Pt = Po $(1 + r)^t$

Pt = 203 $(1 + 3.7/100)^9$

Pt = 203$(1 + 0.037)^9$

= 203$(1.037)^9$

= 203(1.387)

= <u>282 households</u>

Projected household for the planning period (2029) is given as:

Pt = Po $(1 + r)^t$

Pt = 282 $(1 + 3.7/100)^{10}$

Pt = 282$(1 + 0.037)^{10}$

= 282$(1.037)^{10}$

= 282(1.438)

= <u>406 households</u>

- Calculation for sample size for household questionnaire.

n = $N/1+N(\alpha)^2$

n = Sample Size

N = Number of household in Mfuom in 2019.

α = Level of confidence (90%) = $\frac{100-90}{100}$ = <u>0.1</u>

n = $\frac{282}{1+282(0.1)^2}$ = $\frac{282}{3.82}$ = <u>73.8≈ 74</u> household questionnaires

Appendix D

Coordinates used for Georeferencing Drone Images

GCPs	Eastings (m)	Northings (m)	Heights (H)
GCP1	633222.184	657557.619	169.709
GCP2	633516.876	657478.19	168.674
GCP3	633461.889	657055.562	187.346
GCP4	633420.788	656915.698	243.022
GCP5	633224.867	656994.798	185.763
GCP6	633047.342	657145.083	154.668
GCP8	658027.706	632729.108	135.591
GCP9	657933.002	633489.065	155.956
GCP10	657353.768	633148.653	158.583
GCP11	657064.201	632253.347	150.404
GCP12	656673.835	632724.939	185.151
GCP13	656901.874	634169.125	256.330
GCP14	658926.532	632975.037	139.944
GCP15	658512.702	633098.808	150.267
GCP16	658867.756	632479.031	129.013
GCP17	658513.534	632601.262	128.837
GCP18	659204.394	632404.201	118.529
GCP19	659171.844	632752.462	133.946
GCP20	657661.672	631875.976	142.337

Appendix D1

Coordinates used to validate the georeferenced drone images.

GCPs	Eastings	Northings
1	632081.20	657881.30
2	632105.60	657910.70
3	632131.10	657925.20
4	632156.00	657934.10
5	632180.70	657936.30
6	632269.20	657928.60
7	632303.20	657928.90
8	632328.40	657933.60
9	632379.80	657951.60
10	632438.80	657978.70
11	633168.29	658044.82
12	632475.60	657990.70
13	632504.70	657995.80
14	632537.90	658008.70
15	632588.90	658029.30
16	632635.03	658056.48
17	632668.30	658066.30
18	632714.34	658063.17
19	632818.88	658051.75
20	632896.54	658040.21
21	632946.87	658034.38
22	633.73.82	658039.60
23	633248.09	658052.03
24	633309.60	658060.04
25	633350.50	658071.60
26	633403.30	658088.50
27	633444.05	658105.28
28	633514.64	658169.68

Appendix D2

Control points for georeferencing Local Scheme

GCPs	Eastings (m)	Northings (m)
1	633575.03	658200.13
2	633468.96	658126.02
3	632669.7	658064.9
4	633122.1	658471.3
5	633702.1	659142.03

Appendix E

Calculation for Total Land Area for proposed Settlement

Let A be the Population for the planning period.

Let B_1 be the Minimum population per $10000m^2$ ($p.p.m^2$) for medium density

Let B_2 be the Maximum population per $10000m^2$ ($p.p.m^2$) for medium density

Let C_1 be the maximum proposed area for minimum medium population density for the planning period.

Let C_2 be the maximum proposed area for maximum medium population density for the planning period

Where A=2698people, B1=89p.p.m^2, B_2=175p.p.m^2

Therefore $C_1 = \frac{A}{B1}$

$= \frac{2698}{89} X\ 10000m^2$ = $\underline{\underline{30.3 \text{ x } 10000 \text{ m}^2}}$

Total land area = 30.3 x10000

= $\underline{\underline{303000m^2}}$

$C_2 = \frac{A}{B2}$

$= \frac{2698}{175} X\ 10000m^2$

= $\underline{\underline{15.4 \text{ x } 10000 \text{ m}^2}}$

Total land area = $\underline{\underline{154000m^2}}$

Appendix F

Selection of Suitable Spatial Design Model

Weights assigned by experts to the criteria or the elements.

Neighbourhood model	7
Multi-Nuclei Model	5
Sector Model	3
Concentric Model	1

A pairwise matrix (Cij) is generated on a 4x4 matrix using the experts weights and its given as;

$$\begin{bmatrix} 1 & 2 & 4 & 6 \\ 0.5 & 1 & 2 & 4 \\ 0.25 & 0.5 & 1 & 2 \\ 0.17 & 0.25 & 0.5 & 1 \end{bmatrix}$$

$$\sum_{i-1}^{n} Cij \quad (7)$$

(1+0.5+0.25+0.17) (2+1+0.5+0.25) (4+2+1+0.5+0.25) (6+4+2+1) =

$$[1.92 \quad 3.75 \quad 7.75 \quad 13]$$

The normalisation matrix (Xij) is calculated by equation (8) as

$$Xij = \frac{Cij}{\sum_{i-1}^{n} Cij} \quad (8)$$

$$\begin{bmatrix} 1/1.92 & 2/3.75 & 4/7.75 & 6/13 \\ 0.5/1.92 & 1/3.75 & 2/7.75 & 4/13 \\ 0.25/1.92 & 0.5/3.75 & 1/7.75 & 2/13 \\ 0.17/1.92 & 0.25/3.75 & 0.5/7.75 & 1/13 \end{bmatrix} = \begin{bmatrix} 0.52 & 0.53 & 0.53 & 0.46 \\ 0.26 & 0.27 & 0.27 & 0.31 \\ 0.13 & 0.13 & 0.13 & 0.15 \\ 0.09 & 0.07 & 0.07 & 0.08 \end{bmatrix}$$

The weighted matrix (Wij) is given by the formula

$$Wij = \frac{\sum_{j-1}^{n} Xij}{n} \quad (9)$$

$$\begin{bmatrix} (0.52 + 0.53 + 0.53 + 0.46)/4 \\ (0.26 + 0.27 + 0.27 + 0.31)/4 \\ (0.13 + 0.13 + 0.13 + 0.15)/4 \\ (0.09 + 0.07 + 0.07 + 0.08)/4 \end{bmatrix} = \begin{bmatrix} 2.04/4 \\ 1.11/4 \\ 0.54/4 \\ 0.31/4 \end{bmatrix} = \begin{bmatrix} 0.51 \\ 0.28 \\ 0.13 \\ 0.08 \end{bmatrix}$$

The consistency check is given by the formula

$$Wij \times Cij = Ws \qquad (10)$$

where Ws is the weighted sum vector

$$0.51\begin{bmatrix}1\\0.5\\0.25\\0.17\end{bmatrix} + 0.28\begin{bmatrix}2\\1\\0.5\\0.25\end{bmatrix} + 0.13\begin{bmatrix}4\\2\\1\\0.5\end{bmatrix} + 0.08\begin{bmatrix}6\\4\\2\\1\end{bmatrix}$$

$$\begin{bmatrix}0.51+ & 0.56+ & 0.52+ & 0.48\\0.25+ & 0.28+ & 0.26+ & 0.32\\0.13+ & 0.14+ & 0.13+ & 0.16\\0.09+ & 0.07+ & 0.07+ & 0.08\end{bmatrix} = \begin{bmatrix}2.07\\1.11\\0.56\\0.31\end{bmatrix}$$

To calculate for the consistency vector, the weighted sum vector is divided by the weights and its given by the formula;

$$Ws \times {}^{1}/_{Wij} = Cv \qquad (11)$$

where; Cv, is the consistency vector

$$\begin{bmatrix}2.07/0.51\\1.11/0.28\\0.56/0.13\\0.31/0.08\end{bmatrix} = \begin{bmatrix}4.06\\3.96\\4.31\\3.88\end{bmatrix}$$

To calculate for the Consistency Index (CI), Lambda max (λmax) should be calculated first. And its given by the equation (12).

$$\lambda max = \frac{\sum_{j-1}^{n} Cv}{n} \qquad (12)$$

$$\frac{4.06+3.96+4.31+3.88}{4} = \frac{16.21}{4} = 4.05$$

∴ consistency Index (CI) is given by the equation (13):

$$CI = \frac{\lambda max - n}{n-1} \qquad (13)$$

$$CI = \frac{4.05-4}{4-1} = \frac{0.05}{3} = 0.017$$

To calculate for the consistency ratio (CR), equation (14) was used.

$$CR = \frac{CI}{RI} \tag{14}$$

NB. RI is read from the random inconsistency table which is given below

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

$$\therefore \quad CR = \frac{0.017}{0.9} = \underline{\underline{0.019}}$$

Appendix G

Calculation of Grey Relational Analysis for the siting of proposed Landuses

Location of suitable site for Shopping Area

Values for topography (TP), Effect of wind (EF), and Proximity (PR) for the various zones

	TP	EW	PR
Zone A	147.2	0.08	674.8
Zone B	160.6	0.13	585.6
Zone C	157.3	0.51	597.2
Zone D	164	0.28	497.8

Using Smaller is better, the reference sequence will be the smallest value in the column. And is given in the table as:

	TP	EW	PR
REF. SEQ	147.2	0.08	497.8
Zone A	147.2	0.08	674.8
Zone B	160.6	0.13	585.6
Zone C	157.3	0.51	597.2
Zone D	164	0.28	497.8

The values were normalised using equation 9b

$$x_i^* = \frac{\max x_i^o(k) - x_i^o(k)}{\max x_i^o(k) - \min x_i^o(k)} \quad (9b)$$

Where $x_i^* = Normalised\ value$

$\max x_i^o(k) = biggest\ Value\ in\ colomn$

$\min x_i^o(k) = smallest\ Value\ in\ colomn$

$x_i^o(k) = current\ Value$

By substituting the values in the table using the equation 9b,

$$Zone\ A(TP) = \frac{\max x_i^o - x_i^o(k)}{\max x_i^o(k) - \min x_i^o(k)} = \frac{164-147.2}{164-147.2} = 1$$

Zone B (TP) = $\frac{164-160.6}{164-147.2}$ = 0.202 Zone C (TP) = $\frac{164-157.3}{164-147.2}$ = 0.399

Zone D (TP) = $\frac{164-164}{164-147.2}$ = 0

Zone A (EW) = $\frac{0.51-0.08}{0.51-0.08}$ = 1 Zone B (EW) = $\frac{0.51-0.13}{0.51-0.08}$ = 0.884

Zone C (EW) = $\frac{0.51-0.51}{0.51-0.08}$ = 0 Zone D (EW) = $\frac{0.51-0.28}{0.51-0.08}$ = 0.535

Zone A (PR) = $\frac{674.8-674.8}{674.8-497.8}$ = 0 Zone B (PR) = $\frac{674.8-585.6}{674.8-497.8}$ = 0.504

Zone C (PR) = $\frac{674.8-597.2}{674.8-497.8}$ = 0.438 Zone D (PR) = $\frac{674.8-497.8}{674.8-497.8}$ = 1

	TP	EW	PR1
REF. SEQ	1	1	1
ZONE A	1	1	0
ZONE B	0.202	0.884	0.504
ZONE C	0.399	0	0.438
ZONE D	0	0.535	1

Deviation Sequence was calculated using equation (10) as;

$$\Delta_{0i}(k) = |x_0^*(k) - x_i^*(k)| \qquad (10)$$

Where $\Delta_{0i}(k) = Deviation\ Sequence$

$|x_0^*(k)| = Reference\ Sequence$

$| x_i^*(k)| = Comparable\ Sequence$

Deviation for Zone A (TP) = $|1 - 1| = 0$ Zone B (TP) = $1 - 0.202 = 0.798$

Zone C (TP) = $1 - 0.399 = 0.601$ Zone D (TP) = $1 - 0 = 1$

Zone A (EW)= $1 - 1 = 0$ Zone B (EW) = $1 - 0.884 = 0.116$

Zone C (EW) = $1 - 0 = 1$ Zone D (EW) = $1 - 0.535 = 0.465$

Zone A (PR) = $1 - 0 = 1$ Zone B (PR) = $1 - 0.504 = 0.496$

Zone C (PR) = $1 - 0.438 = 0.562$ Zone D (PR) = $1 - 0 = 0$

	TP	EW	PR
ZONE A	0	0	1
ZONE B	0.798	0.116	0.496
ZONE C	0.601	1	0.562
ZONE D	1	0.465	0

Calculating Grey Relational Coefficient using equation (11)

$$\gamma[x_0^*(k), x_i^*(k)] = \frac{\Delta_{min}+\xi\Delta_{max}}{\Delta_{oi}(k)+\xi\Delta_{max}}, 0 < \gamma[x_0^*(k), x_i^*(k)] \leq 1 \quad (11)$$

Where $\Delta_{min} = Smallest\ Value\ in\ the\ Colomn$

$\Delta_{max} = Largest\ Value\ in\ the\ Colomn$

$\Delta_{oi}\ (k) = Current\ Value\ in\ the\ Colomn$

$\xi = Standardise\ value\ or\ distinguishing\ coefficient\ in\ (0,1)\ and\ its\ given\ as\ 0.5$

$$\therefore GRC\ FOR\ Zone\ A\ (TP) = \frac{0 + 0.5X1}{0 + 0.5X1} = \frac{0.5}{0.5} = 1$$

$$GRC\ FOR\ Zone\ B\ (TP) = \frac{0 + 0.5X1}{0.798 + 0.5X1} = \frac{0.5}{1.298} = 0.385$$

$$GRC\ FOR\ Zone\ C\ (TP) = \frac{0 + 0.5X1}{0.601 + 0.5X1} = \frac{0.5}{1.101} = 0.454$$

$$GRC\ FOR\ Zone\ A\ (EW) = \frac{0 + 0.5X1}{0 + 0.5X1} = \frac{0.5}{0.5} = 1$$

$$GRC\ FOR\ Zone\ B\ (EW) = \frac{0 + 0.5X1}{0.116 + 0.5X1} = \frac{0.5}{0.616} = 0.812$$

$$GRC\ FOR\ Zone\ C\ (EW) = \frac{0 + 0.5X1}{1 + 0.5X1} = \frac{0.5}{1.5} = 0.333$$

$$GRC\ FOR\ Zone\ D\ (EW) = \frac{0 + 0.5X1}{0.465 + 0.5X1} = \frac{0.5}{0.965} = 0.518$$

$$GRC\ FOR\ Zone\ A\ (PR) = \frac{0 + 0.5X1}{1 + 0.5X1} = \frac{0.5}{1.5} = 0.333$$

$$GRC\ FOR\ Zone\ B\ (PR) = \frac{0 + 0.5X1}{0.496 + 0.5X1} = \frac{0.5}{0.996} = 0.502$$

$$GRC\ FOR\ Zone\ C\ (PR) = \frac{0 + 0.5X1}{0.562 + 0.5X1} = \frac{0.5}{1.062} = 0.471$$

$$GRC\ FOR\ Zone\ D\ (PR) = \frac{0 + 0.5X1}{0 + 0.5X1} = \frac{0.5}{0.5} = 1$$

	TP	EW	PR	TOTAL
ZONE A	1	1	0.333	2.333
ZONE B	0.385	0.812	0.502	1.699
ZONE C	0.454	0.333	0.471	1.258
ZONE D	0.333	0.518	1	1.851

Calculating for Grey Relational Grade is given in equation (12)

$$\gamma[x_0^*, x_i^*] = \frac{\sum_{k=1}^{n} \beta_k \, \gamma[x_0^*(k), x_j^*(k)]}{n} \tag{12}$$

$$GRG\ Zone\ A = \frac{2.333}{4} = 0.583$$

$$GRG\ Zone\ B = \frac{1.699}{4} = 0.425$$

$$GRG\ Zone\ C = \frac{1.258}{4} = 0.315$$

$$GRG\ Zone\ D = \frac{1.851}{4} = 0.463$$

	TP	EW	PR	TOTAL	GRG	RANK
ZONE A	1	1	0.333	2.333	0.583	1ST
ZONE B	0.385	0.812	0.502	1.699	0.425	3RD
ZONE C	0.454	0.333	0.471	1.258	0.315	4TH
ZONE D	0.333	0.518	1	1.851	0.463	2ND

Appendix G1

Following the same procedure for calculation for the other landuses, the following values were gotten:

RECREATIONAL CENTRE			
	TP	EW	PR
ZONE A	153.3	0.08	682.8
ZONE B	150.5	0.13	711.2
ZONE C	164.1	0.51	552.91
ZONE D	160.6	0.28	527.8
EDUCATION			
ZONE B	164	0.13	602.71
ZONE C	153.87	0.51	574.06
ZONE D	160.6	0.28	543.32
HEALTH CENTRE			
ZONE B	160.6	0.13	549.7
ZONE C	164.005	0.51	436.75
ZONE D	167.4	0.28	616.2
POLICE POST			
ZONE B	157.25	0.13	685.84
ZONE C	153.86	0.51	5853.82
ZONE D	164.002	0.28	673.87

Appendix G2

Reference sequence

RECREATIONAL CENTRE			
	TP	EW	PR
REF SEQ	150.5	0.08	527.8
ZONE A	153.3	0.08	682.8
ZONE B	150.5	0.13	711.2
ZONE C	164.1	0.51	552.9
ZONE D	160.6	0.28	527.8
EDUCATION			
	TP	EW	PR
REF SEQ	153.874	0.13	543.320
ZONE B	164.005	0.13	602.717
ZONE C	153.874	0.51	574.058
ZONE D	160.6	0.28	543.320
HEALTH CENTRE			
	TP	EW	PR
REF SEQ	160.6	0.13	436.75
ZONE B	160.6	0.13	549.7
ZONE C	164.005	0.51	436.75
ZONE D	167.4	0.28	616.2
POLICE POST			
REF SEQ	153.86	0.13	583.82
ZONE B	157.25	0.13	685.84
ZONE C	153.86	0.51	583.82
ZONE D	164.002	0.28	673.87

Appendix G3

Normalised Sequence for ranking site

RECREATIONAL CENTRE			
	TP	EW	PR
REF SEQ	1	1	1
ZONE A	0.794	1	0.155
ZONE B	1	0.884	0
ZONE C	0	0	0.863
ZONE D	0.257	0.535	1
EDUCATION			
	TP	EW	PR
REF SEQ	1	1	1
ZONE B	0	1	0
ZONE C	1	0	0.482
ZONE D	0.336	0.605	1
HEALTH CENTRE			
	TP	EW	PR
REF SEQ	1	1	1
ZONE B	1	1	0.371
ZONE C	0.499	0	1
ZONE D	0	0.602	0
POLICE POST			
REF SEQ	1	1	1
ZONE B	0.666	1	0
ZONE C	1	0	1
ZONE D	0	0.605	0.117

Appendix G4

Deviation Sequence for site ranking

RECREATIONAL CENTRE			
	TP	EW	PR
ZONE A	0.206	0	0.845
ZONE B	0	0.116	1
ZONE C	1	1	0.137
ZONE D	0.743	0.465	0
EDUCATION			
	TP	EW	PR
ZONE B	1	0	1
ZONE C	0	1	0.518
ZONE D	0.664	0.395	0
HEALTH CENTRE			
	TP	EW	PR
ZONE B	0	0	0.629
ZONE C	0.501	1	0
ZONE D	1	0.398	1
POLICE POST			
	TP	EW	PR
ZONE B	0.334	0	1
ZONE C	0	1	0
ZONE D	1	0.395	0.883

Appendix G5

Grey Relational Coefficient (GRC) and Grey Relational Grade (GRG)

RECREATIONAL CENTRE						
	TP	EW	PR	TOTAL	GRG	RANK
ZONE A	0.708	1	0.371	2.079	0.52	2ND
ZONE B	1	0.812	0.333	2.145	0.54	1ST
ZONE C	0.333	0.333	0.785	1.451	0.36	4TH
ZONE D	0.403	0.518	1	1.921	0.48	3RD
EDUCATION						
	TP	EW	PR	TOTAL	GRG	RANK
ZONE B	0.333	1	0.333	1.666	0.555	3RD
ZONE C	1	0.333	0.491	1.824	0.608	2ND
ZONE D	0.430	0.557	1	1.987	0.662	1ST
HEALTH CENTRE						
	TP	EW	PR	TOTAL	GRG	RANK
ZONE B	1	1	0.44	2.44	0.813	1ST
ZONE C	0.50	0.33	1	1.833	0.61	2ND
ZONE D	0.33	0.56	0.33	1.22	0.41	3RD
POLICE POST						
	TP	EW	PR	TOTAL	GRG	RANK
ZONE B	0.597	1	0.333	1.93	0.643	2ND
ZONE C	1	0.333	1	2.333	0.778	1ST
ZONE D	0.333	0.559	0.362	1.254	0.418	3RD

Appendix H

A Summary of road reservation standards

Road Classification		Right of Way (m)	Carriage Way (m)	Median (m)	Shoulder (m)	Layby (m)	Walkway /Bicycle (m)	Tarred width (m)	Remarks
Urban Roads	Major arterial	90	11.0 X 2 (3 lane	2.0 X 2		3.5 X 2	6.0 X 2	11.0 x 2	Drain, Service lane, Separator, buffer and utility considered
	Minor arterial	40-60	7.3 X 2	2.0 X 2			5.0 X 2	7.3 x 2	Drain and Service lane,

									buffer and utility considered
	Collectors	20-45	3.65 X 2			3.5 X 2	5.0 X 2	3.65 x 2	Drain, buffer and utility considered
	Local road	18-30	3.65 X 2			3.5 X 2			Drain, buffer and utility considered
	Cul-de-sac	12	3.0 X 2						

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