An Analysis of the Evolution of Urban Climate in Kurunegala

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LIST OF ILLUSTRATIONS

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Abstract

In this fast moving world the term energy is commonly the topic people talk about. As technology reached almost to its acme, it provides many amenities and facilities to the urban dwellers. People from the rural areas migrate to the city in search of better living conditions, and as such the building density of the city increases to cope up with the increasing population. Hence living in a city is difficult due to climatic and economic fluctuation. To rectify this uncomfortable situation, artificial alterations are sought after, such as air conditioning fans and many similar items consuming electricity. Even though it is expensive living in a city if climate conditions are salubrious it will gain mental satisfaction. This will effect the population both physically and mentally. Giving design strategies to cover the entire city will tend to ease this problem, and make living comfortable as a whole.

CHAPTER ONE

Introduction

Chapter One

1.1.Introduction

Lord Buddha pronounced that all human beings would become "Brahmins" or "Wasalaya", according to their deeds and not according to their birth. All humans in the world differ in their behavior patterns according to their culture creed birth and religion. It is a well-established fact that external factors, mainly environmental will make or mar any form of life since they are embryonic development. Genetically factors too contribute much to this process. However climatic patterns have a positive effect changing human structure formation as demonstrated by European, African, Chinese Japanese and the like, showing quite different features and behavior patterns mainly due to the climatic changes.

Human settlements differ from zone to zone in keeping with the climate. The zones are being tropical, arid, temperate and cool. The Arctic and Antarctic dwellers, braving the extreme cold live in igloos .In climates like Japan where earthquakes are common, wood and soft materials are used for the construction of dwelling. The desert dwellers make use of tents made generally of canvas and hides, to word off the extreme heat and sandstorms, common in the climates. Thus it is clear that the form and shape of a building depends mainly on the climate if undergoes.

Ammos Rapport a renowned Australian architect in his book named house form and culture states as follows,

"While I have suggested that climate determinism fails to account for the range and diversity of house forms climate is, nevertheless, an important aspect of the form generator forces, and has major effects on the forms man may wish to

create for himself. This is to be expected under conditions of week technology and limited environmental control systems, where man cannot dominate nature but must adapt to it"

Hiller B and Hanseon J (1998) in their book the social logic of space states that,

"Architecture and special form to be only a by-product of some extraneous determinative factor, such as climate, topography, technology, or ecology" (Which means the study of organisms in relation to their environments.)

Thus the form and shape of a building is decided paying much attention to the climate. It is a known phenomenon that every individual differs from each other. As the quotation goes on, **"One is unique from each other".** All these changers stem up from the climate as clearly emphasized by great authors on the subjective of architecture.

Therefore build environment should vary from each other according to climate in the area, zone or what ever demarcation of climate.

The modern trend towards urbanization and deviating from nature has changed the microclimate of the area concerned causing its occupants very uncomfortable even though there are other valuable advantages in urban areas. Architecture can solve this uncomfortable situation to an appreciable extent by designing the buildings to suit the changed climate.

1.2. Scope of study

Since the world is Globe and always rotating carved climatic changers, bitter cold in the arctic and Antarctic regions, extremely hot condition in deserts and arid areas, and moderately warm in tropical areas. Where, we consider countries, there area different zones too. Due to their geographical variations .Sri Lanka is a tropical country having

three climatic zones, namely wet, dry and transitional but even these categories differ as a result of their topography.

Since Kurunegala is a city, situated in the in Intermediate zone having both wet and dry, conditions. Its selection is undoubtedly worthy for this climate study.

This is an attempt to make urban design strategies to tropical urban cities. There are several factors, which regulate thermal comfort. Leaving others constant, radiant heat and relative humidity variations are use to evaluate the comfortable level. This is achieved by finding the temperature humidity ratio. By using this THI value we are able to find how natural comfortable level occurs. Apart from this thermal comfortable level could be analyzed by using independent variables.

1.3. Justification

Presently Kurunegala is a rapidly developing city. With a history even dating back to that of king "Vijaya:" After 1980's its development rate gathered momentum with the widening of roads giving rise to many commercial buildings and residential blocks, which come up like mushrooms, making the area highly commercialized, with a large floating population coming in from various parts of the country specially during the day time, for business activities. After 9.30 p.m. its activities slow down making it a dead city till the next dawn comes.

Kurunegala is a city situated in a plain, surrounded by five rock boulders namely "Athugala","Ibbagala", "Aandhagala" "Wew-agla" and "Elugala"."Athugala is the largest and in close proximity to the city center and provides very prominent effects to the microclimate of the city. The general belief is that this effort is not salubrious.

The urban development authority has its own set of rules and regulation governing building construction work in the city. But not proper regard has been taken to accommodate suitability in regard to the climate.

Proposing design strategies to an area like Kurunegala city will be of immense important, as these strategies could be made use of for construction work, anywhere in a tropical country.

1.4. Hypothesis

- The rock gains prominent effects on microclimate of the city.
- Buildings should orientate outward to the rock.
- Shadow of a buildings or a tree helps to increase the comfort.
- Water body uplifts the thermal comfort of the city.
- Even in the city center heat could reduce by introducing the vegetations.
- Shading and shaded area are the most comfortable areas over the city center.
- Rock boulders are good heat absorbers and they help to make comfortable during the daytime.
- Climatic comfortable level could be uplift by adding natural feathers like water bodies and greeneries.

1.5 Brief Methodology

The chosen case study is Kurunegala city. Because it is the only one, which is surrounded by rocks and have steep level drop in near the city center in Sir Lankan context.

The method of study is below,

- On-site data collection and subsequent thermal evaluation/ comparison of the city within the streets, which allow for the selection of focused urban special patterns.
- Collect data along the various cross sections through the city center and beyond. (Including the rock)
- Compare with the meteorological department temperature data's within last 30 years. (Meteorological department is away from the city center).
- Urban design implications and conclusions are drawn upon the comparisons of comfort levels for changers in the built massing in accordance with the hypothesis.
- Study the existing density, land use patterns and activity (functions of the buildings) conditions of Kurunegala derived.
- Module the city and compare with the collected temperature data by using the computer. Then analyze the requirements of the city (whether the building heights plot ratio etc....)
- Comparison does by using the drafts, formulas etc...

CHAPTER TWO

Back Ground Study

CHAPTER TWO - Background Study

2.1 Tropical Climate.

2.1.1 Climate,

Sun is the mother of earth and it gives life for earth. Suns radiation creates long-term effect of the surface and atmosphere. Rotation of earth also helps, to these effects. It could be understood most easily in terms of annual or seasonal averages of temperature and precipitation.

Land and sea areas, being so variable, react in many different ways to the atmosphere, which is constantly circulating in a state of dynamic activity. Day-by-day variations in a given area constitute the weather, whereas climate is the long-term synthesis of such variations (both can be viewed as sub disciplines of meteorology).

Weather is measured by thermometers, rain gauges, barometers, and other instruments, **but the study of climate relies on statistics**. Today, computers handle such statistics efficiently. A simple, long-term summary of weather changes, however, is still not a true picture of climate. To obtain this requires, it is necessary to have an analysis of daily, monthly, and yearly patterns. Investigation of climate changes over geological factors.

Time is the province of "Palaeo" climatology, which requires the tools and method of geological research.

The word climate comes from the Greek *klima,* referring to the inclination of the Sun. Besides the effects of solar radiation and its variations; climate is also influenced by

the complex structure and composition of the atmosphere and by the ways in which it and the ocean transport heat. Thus, for any given area on Earth, not only the latitude (the Sun's inclination) must be considered but also the elevation, terrain, distance from the ocean, relation to mountain systems and lakes, and other such influences. Another consideration is scale: a macroclimate refers to a broad region, a mesoclimate to a small district, and a microclimate to a minute area. A microclimate, for example, can be specified as good for growing plants in the deep shade beneath trees.

Climate has profound effects on vegetation and animal life, including humans. It plays statistically significant role in many physiological processes, from conception and growth to health and disease. Humans, in turn, can affect climate by changing their environment, both through the alteration of the Earth surface and the introduction of pollutants and chemicals such as carbon dioxide into the atmosphere([1]"Climate and Terrestrial Biomes," *Microsoft® Encarta® Encyclopedia 2000.* © 1993-1999 Microsoft Corporation.)

"*Weather*" **is the set of atmospheric conditions prevailing at a given place and time. "*Climate*" can be defined as the integration in time of weather conditions, characteristics of a certain geographical location.**

At the global level climates are formed by the differential solar heat input and the uniform heat emission over the earth's surface. The movement of air masses and of moisture-bearing clouds is driven by temperature differentials and strongly influenced by the Carioles force.

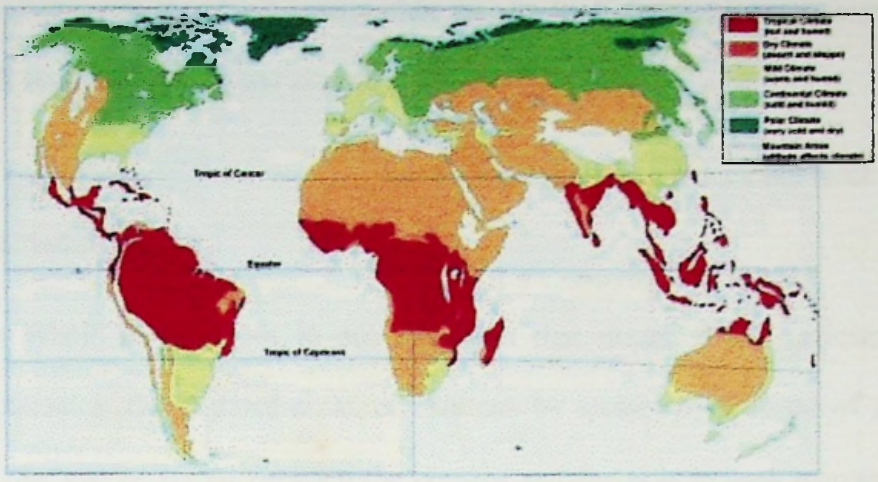

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Figure 1: Map of World's Climate

Many different systems of climate classification are in use for different purposes. Climatic zones such as tropical, arid, temperate and cool are commonly found for representing climatic conditions. For the purposes of building design a simple system based on the nature of the thermal problem in the particular location is often used.

- *Cold climates*, where the main problem is the lack of heat (under heating), or excessive heat dissipation for all or most parts of the year.
- ***Temperate climates***, where there is a seasonal variation between under heating and overheating, but neither is very severe.
- ***Hot-dry (arid) climates***, where the main problem is overheating, but the air is dry, so the evaporative cooling mechanism of the body is not restricted. There is usually a large diurnal (day - night) temperature variation.
- ***Warm-humid climates***, where the overheating is not as great as in hot-dry areas, but it is aggravated by very high humidity, restricting the evaporation potential. The diurnal temperature variation is small.

The topography, the vegetation and the nature of the environment on a regional scale (*mesoclimate*) or at a local level within the site itself (*microclimate*) (*macroclimate*) are influenced to the general climate.

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2.1.2.Climatic Zones

Whole earth is not in one condition that means it has various climatic characteristics. On a global scale, climate can be spoken of in terms of zones, or belts, that can be traced between the equator and the pole in each hemisphere. To understand them, the circulation of the upper atmosphere, or stratosphere, must be considered, as well as that of the lower atmosphere, or troposphere, where weather takes place. Upper atmospheric phenomena were little understood until the advent of such advanced technology as rocketry, high-altitude aircraft, and satellites.

Ideally, hot air can be thought of as rising by convection along the equator and sinking near the poles. Thus, the equatorial belt tends to be a region of low pressure and calms, interrupted by thunderstorms associated with towering cumulus clouds. Because of the calms, this belt is known as the doldrums. It shifts somewhat north of the equator in the northern summer and south in the southern summer. By contrast, air sinks in the Polar Regions. This leads to high atmospheric pressure, and dry, icy winds that tend to radiate outward from the poles.

Complicating this simplistic picture is the Earth's rotation, which deflects the northerly and southerly components of the atmosphere's circulation. Thus, the tropical and polar winds both tend to be easterlies (winds from the east), and two intermediate belts develop in each hemisphere. Around latitude 30° north and south is a zone of high pressure where, the upper air sinks and divides, sending air streams towards the

equator. Steady northeast trade winds blow in the northern hemisphere, and southeast trade winds in the southern hemisphere. These high-pressure areas lead to arid areas on the continents but to moist air over the oceans, because of evaporation. If these trade winds meet an island or mainland coast, moist air is pushed up into cooler elevations, and heavy rainfall might occur.

Around latitude 50° to 60° north and south is a belt of low pressure characterized by the prevailing westerlies, which are deflected to the south-west in the northern hemisphere and to the north-west in the southern hemisphere. These are relatively mild, moist winds that tend to bring frequent cyclonic precipitation to all elevations along the west-facing side of continents. The precipitation is characterized by polar fronts, where cold air from the polar easterlies drives in under the warm, moist air of the westerlies, which, on cooling, drop their moisture. In winter this is the cause of most snowfall on continents.

2.1.3.Climate of Tropical Areas.

The primary characteristic of the equatorial climate is its almost unchanging weather patterns. Unlike other climates, daily weather patterns dominate over seasonal weather. It is said that in this region, all seasons occur within a single day. There are;

- Cool mornings,
- Warm early day,
- Hot and humid daytime,
- Almost unbearably damp afternoons,

Generally climate condition of tropical areas as follows;

- Air temperature at 30-31oC (86-88oF)
- Relative humidity of 80%
- Air movement - 0.1m/s (3.3 ft/s) or less.

Tropical areas have mainly two monsoon seasons. They are north eastern and southwestern monsoons. Therefore wind streams passing through the cities by this directions and it could use for the ventilate buildings in equatorial tropics. Due to tall buildings wind seems could not pass through the buildings. They act as windbreakers. If water bodies are introduce on this wind direction cool breeze could get into this city automatically. Vegetation could be used to act as windbreakers to spread out these air streams. To spread out these air streams could use vegetation to act as windbreakers.

2.2 Urban Climate

2.2.1Urbanisation.

As a result of agricultural modernization and industrialization People migrate from rural to the urban areas. Various problems such as health hazards, social and economic problems etc are immerged due to concentration of people. ...All these problems are occurred as a result of the lack of space. This type of concentration of people and buildings is called **Urbanization**.

2.2.1.1 Development Of Cities.

Well-known author David Knox defined the cities as **"legally incorporated geographical areas, the inhabitants of which are engaged primarily in occupations other than farming"** in his book Living Sociology.

On the other hand city could be defined as a place (preferably an urbanized or metropolitan area) with 100,000 or more inhabitants. (Davis, 1973,p.3)

City is a result of the endless journey of the human beings. Modern Homo sapiens first appeared about 50,000 years ago and first lived as hunters. But due to foods, power and climatic factors they move to agricultural society.

According to the development cities could categorize as follows;

- Pre-industrial cities.
- Industrial cities.
- Cities of today.

Pre-industrial cities; archeologists regard Jericho is the first city. It had about 600 people and they had methods of protection from enemies and irrigation. Jericho developed in about 800 B.C.

Catal huyuk in present turkey is regarded as the next. it appeared about 6000B.C. and supposed to have a population of about 6000.

These cities developed as a result of the technology such as plough, which permit to cultivate large number of land. The first urban empires immerged in Mesopotamia, Egypt, the Indus river valley' china Central America and South America. The development of American cities occurred relatively late around 500B.C. These pre industrial cities ended up with various kinds of diseases.

Industrial cities; Industrialization began in the middle of the 18 th century. Animals and plough replaced by the machines like tractors machines in agriculture

and all the other works were done by the machines, which are activating using the fuel or other power. Telecommunication and transport facilities also developed. As a result of these facilities people migrate to the city and urbanization began. In 1790, only 5 percent of the American population lived in the cities but today only about 3 percent work in farms.

Cities today; today whole world act as one village and it is named as a global village. This is due to the high technology of telecommunication and transport facilities. As a result of this development, contemporary modern cities bear huge weight of population. Cities such as New York (14 million plus), Calcutta (10million plus), Moscow (9 million plus) have dense population, tall buildings, a lot of poor, elders like plus and minus points. (Knox .D., Living Sociology, p.470-474)

2.2.1.3.Pollutions In Cities.

Even though with the advancement in industrial revolution that comes forward during the 20th centaury mainly with regard to astrology, industry, transport and telecommunication various diseases came with it trail. Combustible materials were used, and theirs subsequent by-products coursed many ill effects to human beings.

Especially this effect could be clearly seen in the cities. Because most of the factories and automobiles emit, polluted particles liquids, gases, ...etc to the surrounding environment. Most of the pollutants get in to the air in burning materials. People start the day with lighting their own fires. That means their daily lives still depend on the process of combustion. On the other hand most of the cities burn their garbage.

Automobiles are highly mobile burners through out their active lifetime and when they are out moded, they too end on the pyre.

If one could see the city in the fine day from the airplane, thick brown haze envelops the city area. While still in the air one ask: **"How can any one go on breathing that stuff"** on the ground how ever, people do not notice any thing unusual. They blame the weather for just another gay day and go right to breathing.

When pollute the air in the city effects to the large number of people. Reason for that is they concentrate to the city in the daytime. As a result of the high-rise building this city dwellers live in this populated atmosphere day and night.

When a product is completely burned the resulting substances are water (H_20) and carbon dioxide (CO_2). But the very often the burning process is not completed and emit various elements to the air in various forms. Some times these are visible as fly ash, soot.

The cities of the world are divided into two major types. According to the chemical analysis of the pollution.

- **The London Type**-Sulfur compounds from burning of coal (for power and heat up the domestic space.)
- **The Los Angeles Type**- petroleum products known as loosely as hydrocarbons (from automobiles)

But today most of the cities in the world have a close relationship with the Los Angeles type. All the automobiles and machines are worked by using petroleum. In addition a lot of machines are worked by using the electricity. Majority of the

countries use petroleum to generate power. A Few countries us coal power. But these stations are away from the city.

Luckily Sri Lanka use hydraulic power. But unfortunately due to lack of rain petroleum generators are popular. On the other hand two major power stations are within the populated city Colombo. They are "Sapugaskanda" and "Kelanithissa" these two help to enrich the polluted air volumes. Polluted air effects to various parts of the human body. Specially skin, eyes, lungs and bronchial tubes.

- Eye-irritations
- Skin-cancer, rashers
- Bronchial tubes — Bronchitis
- Lungs — Emphysema

The ozone layer acts as a protective barrier to the ultra violet rays, and affected by this polluted layer.

It the ultra violet rays reach the earth various ill effects occur such as skin cancers, increasing temperature causing sea floods etc...(D.Kinggsley, 1973,p.132)

2.2.2.The Climate of Cities.

According to various researchers it has been proved the climate Conditions of the cities. In fact city is warmer than the countryside. On the other hand cities differ from the countryside not only in their temperature but also in all other aspects of climate.

Climate means the net result of several interaction variables, including,

1. Temperature
2. The amount of water vapor in the air
3. Speed of the wind
4. The amount of solar radiation.
5. Amount of the precipitation.

These factors do not vary in the same way in city and the countryside but naturally climate is same for both are as. Unfortunately it cannot be felt in this same way in cities due to 5 factors.

First; the surface material of the city and countryside: From the word "city" everyone imagines a city with full of buildings, using concrete, brick, bitumen and stone. This rock like material of the city buildings and streets could conduct the heat about three times as fast as it is conduct by wet sandy soil. On the other hand these materials could store heat than soil even at the night.

Second; the cities structures have a several shapes of buildings and orientation than the feature of the natural landscape. Whole surface of a city acts as absorbers of heat and conducts as radiations and reflect to other buildings. Air volume, which is above the city gain heat by the contact with warmer surfaces rather than by direct radiation. In

addition to these cities many structures have a breaking effect on the wind. There fore air volume is always in warmer condition.

Third; the city could be introduced as a center for heat generation. Because all the factories, vehicles and other heat generators such as air condition systems are found in a city.

As a result of proper drainage facilities in modern cities all excess water by way of rain will be quickly drained off, leaving no water to evaporation. Cooling effects are minimized

Countryside much precipitation remains on the surface or intermediate below it. Therefore the water is thus available for evaporation, which gives a cooling process to this area.

Finally the air in the city carries heavy load of solid and liquid particles of gasses. Most of the solid particles are small enough to remain suspended for several days in still air. On the other hand these reflect the sunlight and reduce the amount of heat, which come to the surface. They also retard the outflow of heat. Gas particles most often sulfur dioxide deposits in the clouds and it causes acid rain, which detrimental to all forms of life well as buildings.(D.Kinggsley,1973,p.141)

2.2.3 Factors Effecting To Urban Climate.

2.2.3.1. Shadow Umbrellas.

Shaded areas and spaces inside the buildings are more comfortable than open spaces. Specially in cities shade is the only one solution for comfort. In tropical cities the difference between shade and open area could be seen very clearly.

Due to the congestion of such a lot of building in cities, there are no spaces to vegetations. When designing the cities, much attention should have to be given to comfort of the city. To create a comfortable space, it is necessary to cater, relative humidity and temperature.

To gain shade the vegetations, canopies, arcades etc could be introduced...Cool breeze from water bodies also help to get comfort. Open water bodies cause the evaporation of water vapor. Comfort level goes down as a result of the humidity ratio. Humidity ratio goes up due to increasing of water vapor. Therefore water bodies should be given shade in tropical cities.

Controlling the road width and building height could maximize the shade in urban areas. If all roads are shaded, cities will be comfortable places to live in. This kind of shady areas called shadow umbrellas.

2.2.3.2. Urban Heat Island Effect.

When considering the air temperature it is being increased from rural to urban. Island, which has high temperature, called heat island. Specially this could be seen in urban areas. This occurs due to the various kinds of heat emits and polluted particles in the city.

Great author, Oke pronounced that there are many types of surfaces abound in urban areas, only two matter in terms of the heat island: natural and manmade. Within the manmade surfaces they found relationship between types of surfaces and heat island effect.

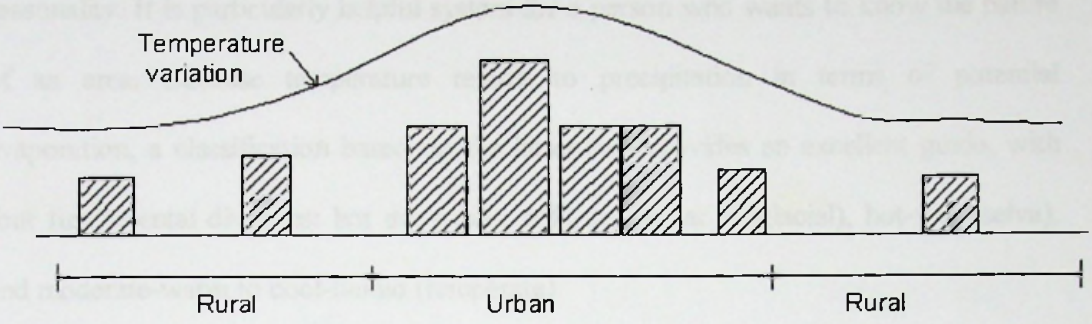

Fig.2: Temperature difference between urban and rural.

2.2.3.3 Canyon Effect

Urbanization, heat up the air cover, which above the city and this heated air, goes up. But surrounding air cannot come (in to the city) to fill the space. Due to this, the volume of air above the city also gains heat and goes up. Therefore vacuum develops gradually. Most often this is happening to places, which have high urbanization. Increasing of thermal capacity and lack of water evaporation occurs due to canyon effects.

2.2.3.4 Urban Vegetation

Vegetation, however, offers a useful guide, particularly in special cases, such as the "selva", or equatorial rainforest belt, hot with tropical rain much of the year; the savannah, warm-hot, with strong seasonality; and the tundra, cold, with strong seasonality. It is particularly helpful system for a person who wants to know the nature of an area. Because temperature relates to precipitation in terms of potential evaporation, a classification based on the latter two provides an excellent guide, with four fundamental divisions: hot dry (arid), cold-dry (polar or glacial), hot-wet (selva), and moderate-warm to cool-humid (temperate).

"Climate," *Microsoft® Encarta® Encyclopedia 2000.* ©

2.4 Urban Design And Climate

2.4.1 Factors Affecting Climatic Design

The local microclimate and site factors will affect the actual environmental conditions of the building. The important site-related factors should be considered when making the climate analysis:

- ***Topography*** - elevation, slopes, hills and valleys, ground surface conditions.
- ***Vegetation*** - height, mass, silhouette, texture, location, growth patterns.
- ***Built forms*** - nearby buildings, surface conditions.

Major thermal design factors to be studied include: solar heat gain, conduction heat flow and ventilation heat flow. The design variables in architectural expression that are important will include:

- ***Shape*** - surface-to-volume ratio; orientation; building height.
- ***Building fabric*** - materials and construction; thermal insulation; surface qualities; shading and sun control.
- ***Fenestration*** - the size, position and orientation of windows; window glass materials; external and internal shading devices.
- ***Ventilation*** - air-tightness; outdoor fresh air; cross ventilation and natural ventilation.

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2.4.2 Effects of Climatic Change

Word city relates with such a lot of words like heat, dusts, noice, lack of wind, less sunshine etc. The development rate of facilities and increasing of polluted things are goes equally. Today most of the cities are polluted. Artificial heating and air pollution thus become metrological significant as the day begins.

Polluted air particals, which are in the atmosphere break the sunshine and destroy the protective ozone layer, which is above the atmosphere. It cause to decrease the growth rate of the vegetation. And lets to ultra violet rays to come to the earth. As a result of UV rays and radiant heat temperature goes up on earth surface. The Air volume, is always in heated condition which, above the city. And

it is introduced as the heat island effect. The heat also affects socio-economy of the city.

Under the condition of the global warming glaciers are melted and Wind streams are changed. It cause to sea floods and cyclones. (Southern oscillation event EL Nino - in 1997-1998).

Smoke is the worst condition, in cities, could not endure anyone. Reductions of visual range by smoke harms the appearance of the city and affect the health of the living beings. As a result of smoke lighting level goes down. So that the energy consumption goes up

Heating up the sub soil, reduce the strength of the structure of the buildings. But cool condition helps to increase the strength of the structure.

2.4.3.Urban Design Goals.

When doing a climate conscious equatorial urban design has to prevent the heat build up at daytime and it help to encourage convective cooling at night. On the other hand design goals would be,

- Radiation reduction during day time,
- Ventilate cooling at night.

Peoples in equatorial tropics spend their time indoor as well as out door. To facilitate outdoor following actions could be taken.

- **Shadow umbrella-** This is a shadow canopy, which could shade an entire neighborhood outdoor area.

- **By introducing water bodies**. -Ex-lakes, pools or fountains.

These water bodies could deduct the thermal stresses. But large water bodies gain problems in urban designs. Therefore all these water bodies should be in a shaded area, especially in equatorial tropics.

- **By introducing vegetations**

Urban vegetation could change the physical and socio-economic of a city.

Because it help to enhance the micro-climate, air and water quality. On the other hand vegetation gains good appearance to the city.

Emmanuel .R: *Environment & Planning - B* 24(1997): 415-426

Orientation of buildings is also gain very important in urban designs. Because from that could govern the indoor environment as well as outdoor environment. Govern means convert to comfortable space.

To do that whole area has to be design. Specially, street patterns effects to the orientation of buildings. Building s effect to microclimate of the area. Specialy height.

According to Dr. Emmanuel, following design strategies could be gleaned.

1. The most preferred orientations are 0o80o (i.e. within the northeastern quadrant;

2. The urban density should be one that slopes towards the northeast (i.e. smaller buildings in the northeast and taller ones towards west);
3. Northeastern and southwestern corners of a development could be left open.

Within this overall shadow massing, it is now possible to determine location/s of natural elements that would enhance the thermal comfort aspects of the outdoor areas in the whole neighborhood.

2.4.4 Influences on Built Form

A lot of researches had been done to analyze the correct form, structures, and orientation of the buildings in each climatic zone. The buildings which, had applied these theories, could minimize the energy consumption.

1.form

The diagrams show the optimum building form for each climatic zone. Research has shown that the preferred length of the sides of the building, where the sides are of length x:y, are:

- Tropical zone - 1:3
- Arid zone - 1:2
- Temperate zone - 1: 1.6
- Cool zone - 1:1

Analysis of these ratios shows that an elongated form to minimize east and west exposure is needed at the lower latitudes. This form slowly transforms to a ratio of 1:1

(cylindrical) at the higher latitudes. This is a direct response to the varying solar angles in the various latitudes.

2.Oriantation

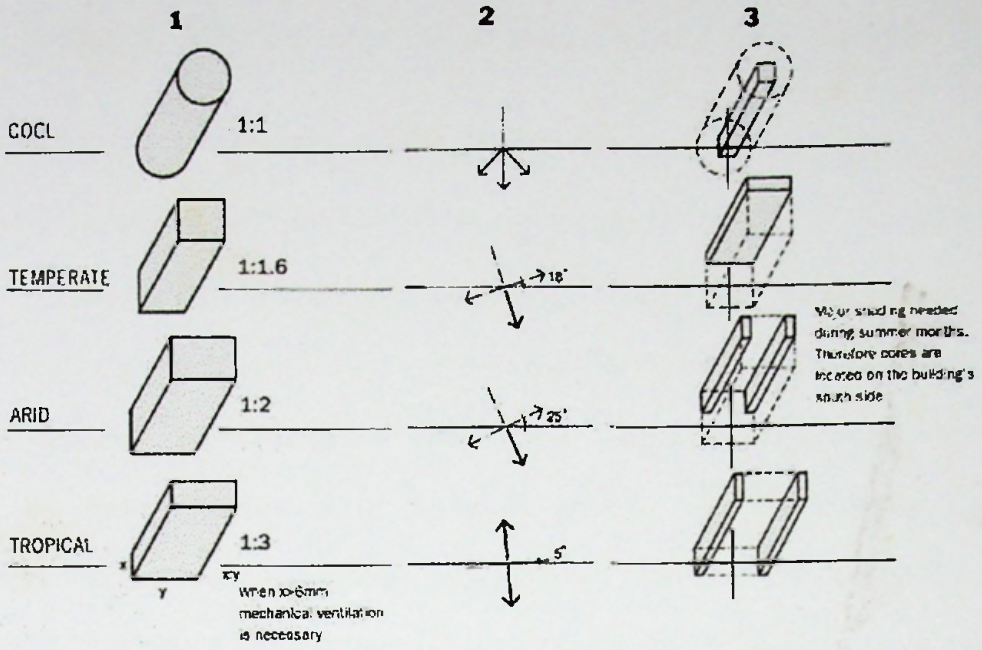
Orientation as well as directional emphasis changes with latitude in response to solar angles.

3.Vertical Core and Structure

The arrangement of primary mass can be used as a factor in climatic design as its position can help to shade or retain heat within the building form.

For the tropical zone, the cores are located on the east and west sides of the building form, so as to help shade the building from the low angles of the sun during the major part of the day. In arid zone, the cores should also be located on the east and west sides, but with major shading only needed during the summer. Therefore, the cores are located on the east and west sides, but primarily on the south side.

The arrangement of the primary mass in the temperate zone is on the north face, so as to leave the south face available for solar heat gain during the winter. The cool zone requires the maximum perimeter of the building to be open to the sun for heat penetration. Therefore the primary mass is placed in the centre of the building so as not to block out the sun's rays and to retain heat within the building



Zone	Building's main orientations	Directional emphasis
Tropical	On an axis 5° north of east	North-south
Arid	On an axis 25° north of east	South-east
Temperate	On an axis 18° north of east	South-south-east
Cool	On an axis facing south	Facing south

Fig.3: Design Methods for Various Climatic Zones.

(htt://arch.hku.hk/~cmhui/teach)

CHAPTER THREE

Historical Back Ground of Kurunegala.

Chapter Three - Historical Background Of Kurunegala

3.1Historical Background Of Kurunegala.

3.1.1Historical Background Of Kurunegala District.

According to earliest reports Kurunegala begins from the period of "Rawana". One ruler governed whole areas and their basic needs were very simple. They fulfilled their needs from the surrounding. The "Yaksha","Naga" randomly ruled this area.

Tolamis's map shows kurunegala was a center for commercial activities. Northwestern harbor, which was situated between "Kalpitiya" and "Chilaw", was one of the most popular center for foreign traders. In that area (2nd A.D) transport system was sea travelling.

Fig.4: Map of Tolamy.

During 543 A.D king "Vijaya" was the ruler of the area. And after that "Aryan" came to Sri Lanka. Therefore this area was also opened to world trade market and became more commercialized because of the harbor situated close to the area. (Sumanajoyhi. D.1965, p 30)

The history of kurunegala district can be categorized in to two parts. They are early period and medieval period. A lot of inscriptions have been found from the Kurunegala district, which was unscripted during the Anuradthapura period from 3rd century B.C to 2nd century A.D. Only a few inscriptions could be found throughout the area during medieval period of Anuradhapura. Sometimes it might be due the unpopular local rulers.

During the period from 1017B.C to 1505 B.C there were several local kingdoms. "Panduwasnuwara","Dabadeniya".'Yapahuwa" were among them.

Rebellious Prince "Keerthi" who was known as "Vijayabahu" i later came to "Rajarata" from "Rohana" camped at "Weudavilli" and built a fortress at "Bathalagoda" in order to launched a rebellion against the south Indian. Kurunegala played an important role due to its location, between "Rajarata" and "Rohana". Because always-Singhala kings secretly lived when there was a rebellion or an attack.

King "Parakramabahu" was the successor to king "Vijayabahu" who ruled the "Dhakkinadesa" before coming to the "Polonnaruwa". This had been done as the ruler of the "Paduwasnuwara" during that period, build up larger reservoirs like "Padawewa" and many other religious buildings with his place of grandeur.

Three kingdoms, "Dabadeniya","Yapahuwa","Kurunegala", locate in Kurunegala district. They could not be separate from each other, because various governors had ruled

this area since king "Vijaya" period. Therefore lot of ruins, litratry evidence regarding those kingdoms could be found throughout Kurunegala.

From those historical places "Resvehera", "Hasthikutchi Viharaya","Arankaele" "Ridee Viharaya" are could be seen even today. Most of the historical temples, which were built in various periods of the kurunegala area reconstructed during the Kandian period by this brought many types of image houses like "Tampita Vihara". There were direct influences to "Satkoralaya" because it was a part of a "Udarata" kingdom.

On the other hand kurunegala plays an important role due to its location, between "Udarata" and Rajarata".

Fig.5: "Satkoralaya"

3.1.2 Brief History Of Kurunegala Period.

Due to various reasons kingdoms were shifted to several areas throughout the sri Lankan history. Start from Anuradhapura, polonnaruwa, dabadeniya, yapahuwa, kurunegala, gampola, kotte, and ends up in Kandy.

After south Indian "Cholers" captured the Polonnaruwa, people left the kingdom and settled down in "Dakkina desa" and Ruhuna. Kingship also broke down. Many provincial rulers came to protect their area from "Cholers". After that new king ship was built in Dabadeniya. That dynasty also existed only for five generations, which lasted from king "Vijayabahu" III to "Parakramabahu" IV.

"Buwanekabahu" II (1291-1302) was the first king of the Kurunegala kingdom. "Parakramabahu" IV was the last king of Dabadeniya period. "Buwanekabahu" III (Vanni buwanekabahu),"Vijayabahu" V and Buwanekabahu IV shifted from kurunegala kingdom to Gampola kingdom to Gampola.

Unfortunately only a very few archeological significant factors could be seen within the kurunegala city even today. There are places, which can be identified as the place, which the tooth relic was kept in the percent governors office premise. Ruined boundary wall of the citadel could be seen at the foot of the "Athugala".

Present chief ministry office of the provincial council is the place, which is believed as the "Maligawa" in the past. And also ruined buildings, piles, steps magnificent by carved stone doors could be seen at present. Even though it is believed that there are many ruined things in the Athugala forest so far they are not identified.

3.2 History of city development in kurunegala.

3.2.1 Early City Planning.

In olden days the king primarily did city planning. Even those days there was city-planning system and city grew according to particular city plan.

In the past basic needs of the humans were very simple within the village. The villagers were evolved in various industries. Therefore they could exchange the goods and services called the Bata system. (Ananda, R.1973 p.38)

According to "Wathimi Bandara Puwatha" there was a fortification before actual kingdom was started. And according to fork tales ,king "Vijaya" introduced this fortress to this kingdom.

There was a supporting wall at the foot of the Atthugala and it has four fortifications in the ground and on the "Atthugala". In between the fortifications there were four palaces. In addition there were stores and four ponds writhing I mile from the main palace. These are supposed to be the villages.

Buying selling and exchanging of goods and services occurred in the place cold "Market". That market was at the center part of the village. Even in the past there were four main roads leading to four cardinal directions. These roads were introduced as the "weediya".they are follows; "Maha weediya" from north, "Salu weediya" from west, "Weu weediya" from east, "Demala weediya" from south. "Maha weediya" could be seen even today. Other names were changed.

Around the city there were aqueduct. Beyond the aqueduct there were three "devalas". They were as follows, "Maha devalaya", "Pathini devalaya" and "Katharagama devalaya".

Always trade system was occurred within the village. And main marketplace developed at the focal point of all surrounding villages. Likewise main trade center of kurunegala located at the citadel and center of all surrounding villages.

There were four villages, known as "Janapada". These could be seen in cardinal directions, and away from the city.

They are as follows, **"Vilbawa";** located at about 2.5 miles away from the middle of the town area. In early days it had been introduced as "Veerabahu janapadaya". Western part of that village covered by a rock.

"Maraluwawa"; this village was on the150ft high rock called "Adagala". In those days, this village was known as "Ahas pauwa" and the area was known as "Maraluwawa".

"Nathagane"; 9 miles away from the city and rock called nathagane kanda covers the western part of the village.

"Sangamuwa kanda"; this was located, 12 miles towards "Dambulla".

3.2.2 Factors Effects Develop As A City.

Trade is the chief factor for the development as a city. When considering the records of Ibban bathutha, Mr. Corinthian and Tennon's history of Sri Lanka could get more information about the trade system of Sri Lanka.

In the early periods to facilitate the exchanging system of goods and services **"Salpila"** was held at the center part of the village. This had a close relationship to present **"Pola"** concept. Most often this was held in the festival seasons. On the other

In 1884-1905 railway network came in to kurunegala and it gave high potential to develop as a commercial center. Those days' many people used this easy method to transport their goods. This railway gains the new bud of urbanization to kurunegala.

In 1900 sir Edward Barns the governor of the city and captain Dozen helped to build Colombo – Kandy road, Kurunegala –Kandy road and, Abepussa-Dambulla road . Kurunegala became an intersection point of Colombo Trinkomalee and Puttalam-Kandy road.

Governor "Worde" introduced several developments of railway network. Railway line, which comes from Colombo, divided in to two in Kandy and north the southern boundary of Kurunegala, which is "Polgahawela". After that north railway line was divided in to two at "Mahawa" northern boundary of Kurunegala district, to north and east railway line. North line goes to Mannar and Jaffna and east railway line goes to Trincomalee and Baticllo. There fore huge number of people used this facility through Kurunegala.

At the same time lots of public buildings were appearing. Police station, court complexes, post offices and several previous houses could be seen even today in the city limits. Those buildings express the architectural character of the period of those days. This is the period where present urbanization was started.

When considering the built area, road and railway network, it is easy to understand the manner of city planning. Athugala rock would gain an effect for this city planning.

In this period "Gamsabawa" district court was started. In 1888 they started to control road network and maintaining of public buildings.

hand due to location of the Kurunegala various foreign travel traders came to villagers by carts and they were known as "Setti".

Majority of the people engaged in the paddy cultivation and coconut plantation. In addition they were engaged in "kapu"(cotton) and iron industries.

After that shops and boutiques were emerged as permanent place for buying and selling. The collections of these shops were called "Kadamandiya". Gradually "kadamandiya" became a suburban township and then it became major town.

(Degammeda, S .1956p.22, 26,32,40)

3.2.3 City Development During Colonial Period.

Portuguese came to Sir Lanka in 1505 and during this period there was a thin population in the present town area. But existing village were there and those had minimum number of people .due to various external forces.

There was no specialty during the Dutch period. According to Saiman Casi Chetti 's records, in the 19th centaury Kurunegala area was known as "Sathkoraleaya".

In 1815 the British occupied Kandian Kingdom and they constituted general law for whole country. Governor was the head of the area and power started from the village headman (local authority).

1848 all the plantation of estates and all the lands were ruled under the government and normal people lost their lands. Due to that people had to work for a salary.

During the time "Angarika Dharmapala" came to Kurunegala and gave his speech in very painful voice to singhala people, about the lack of Buddhist school in the area. Few years later as a result of that speech "Madawala walauwa" became the "Maliyadewa" boy's school, which is situated on the Negambo Kurunegala road.

That meeting was held at the present bus stand premises. In those days this space was a lower ground without any building. There were few trees and bullock cart were parked under the trees. Bullock carts were the only means of transport system or general public.

In1922 the clock tower was build as a landmark in memory of soldiers to who died in the 1st world war at the main junction of the city. And in 1930 urban district council was lounged in Kurunegala.

Shopping and trade markets increased very rapidly along the main road and center part of the town according to the demand.

In 1939 to 1961 municipal council act was introduced. Under this town was constructed according to several rules. In this period busses came in to function and transport became easy. Buses were stopped at under the trees. In rainy seasons this became a pool of mud. Because of these 1960's according to Mr. D.B. Welagedara, Member of Parliament percent bus stand was built. There fore in this period Kurunegala many changers and new appearance to the town.

Roads (1814-1872) ————————

Rail way (1873-1890) - - - - - - - - -

Roads (1851-1872) . . . . . .

Rail way (1873-1890) ——— . ——— .

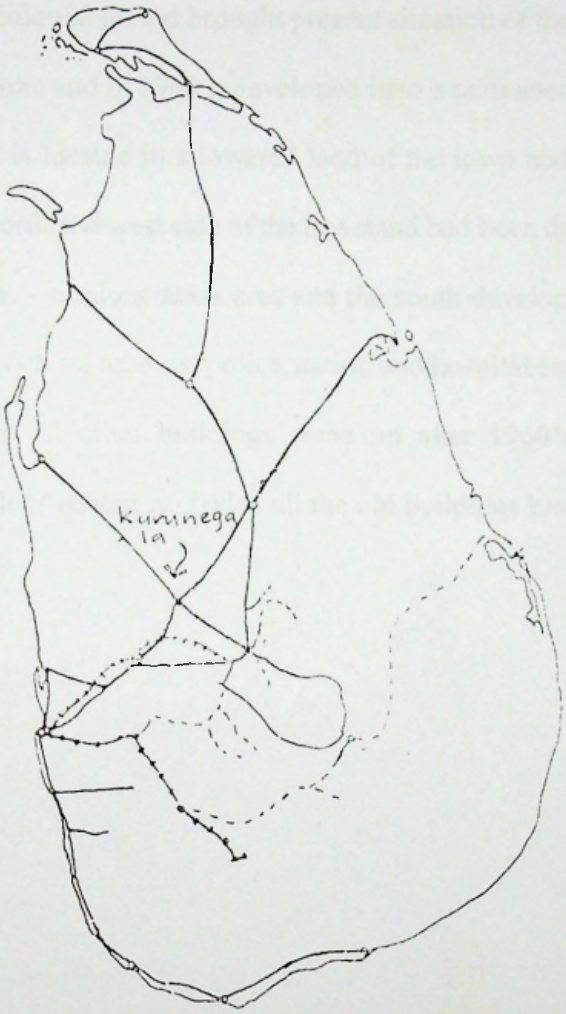


Fig.6: The map of road lay out of Kurunegala, which shows the connection with other deviations in Sri Lanka.

3.2.4 Postcolonial Period.

In 1949 kurunegala was declared as a municipality. After 1931 population increased very rapidly in this area. According to census department data population was 1,211,801 in 1981 and 1,425,369 in 2001.That means average annual growth rate was 0.9 in Kurunegala district. (Source-Department of Census and Statistics.)

The postcolonial period brought present situation of the city. Percent market was a temporary structure and in 1968 it developed in to a permanent building.

Bus stand is locatde in a lowered land of the town and by the side of the clock tower junction. North and west side of the bus stand had been developed as a commercial area, the east side - administration area and the south developed as the area which has public buildings such as, schools, police station and hospital etc.

In addition all other buildings came up after 1960's. In 1977 development doubled as a result of economy. Today all the old buildings have been converting to 3-4 storied.

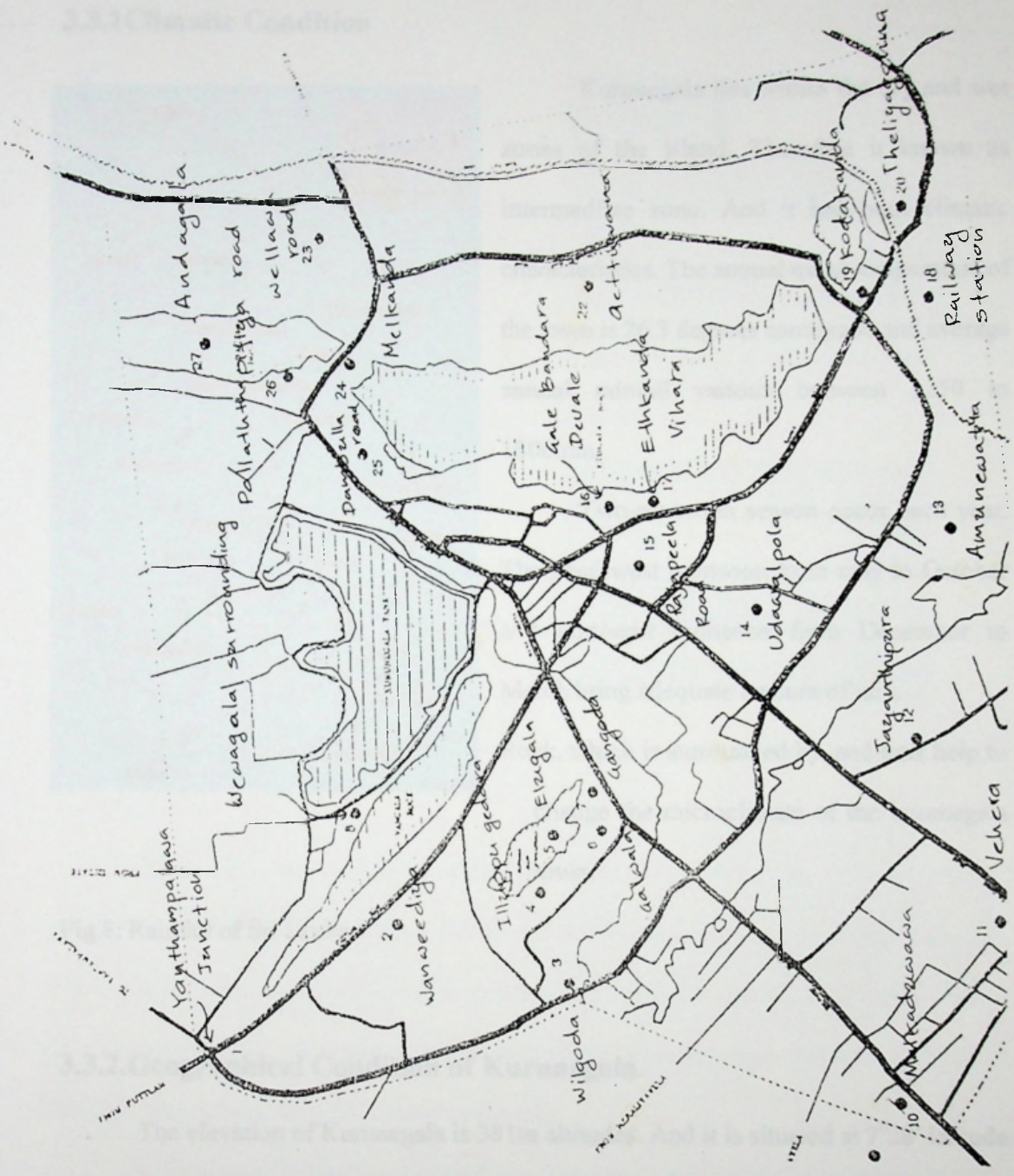
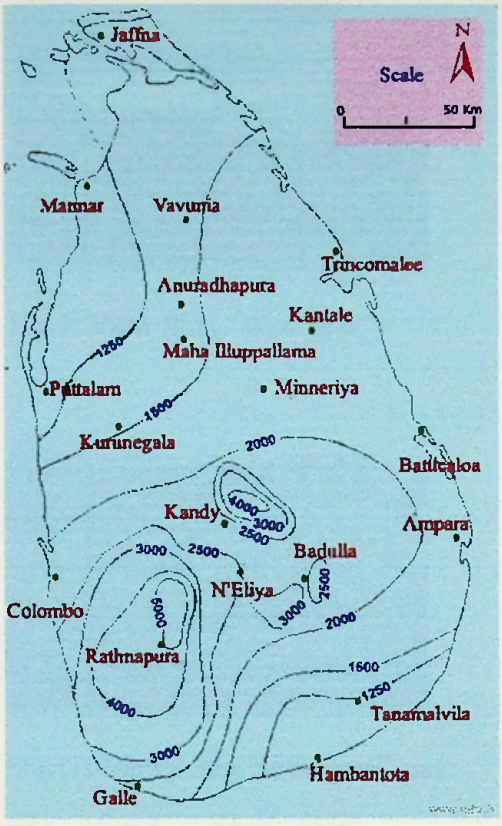


Fig.7: The map of Kurunegala town limit.

3.3 Urban Fabric Of Kurunegala City.

3.3.1Climatic Condition



Kurunegala lies within the dry and wet zones of the island. Therefore it known as intermediate zone. And it has both climatic characteristics. The annual mean temperature of the town is 26.3 degrees centigrade and average annual rainfall various between 1250 to 1800mm.

Two-monsoon season occur each year. The southwest monsoon from may to October and northeast monsoon from December to March bring adequate amount of rain.

Rock, which is surrounded by, and tank help to change the microclimate of the kurunegala town.

Fig.8: Rainfall of Sri Lanka

3.3.2.Geographical Condition of Kurunegala.

The elevation of Kurunegala is 381m altitudes. And it is situated at $7^{0}28'$ latitude to the North and $8^{0}22'$ longitude to the east.

3.3.3.General Character of the City.

3.3.3.1Lake

Fig.9: View from "Weu gala"

Fig.10: View of the "Maraluwawa Kanda"

Fig.11: View of the "Athugala" and "Ibbagala" from "Weu gala"

Fig.12: View of the "weu gala"

Kurunegala Lake is situated at the north of the city. From every side of the lake, range of mountains could be seen. Roads are running around the lake. North side has been used as the area for government quarters. To the south there is rock called "Weu gala". In addition to "Tampana" (another tank which is use to supply water to city) water fromthis lake is used to supply water to the city.

Water is supplied to Kurunegala Lake from the "Deduru Oya". Out flow of water again goes to"Deduru Oya". Forfounder of the lake is doubtful. But there are some

documents, which mention about the lake. According to public beliefs lake was built during the Buwanekabahu III

3.3.3.2 Rocks

Fig.13: "Puttalam" road directly focused to the "Athugala

Fig.14: "Athugala" and "Ibbagala" touching each other.

There are five rocks around the city

- Athugala
- Ibbagala
- Aadagala
- Elugala
- Weu gala

3.3.3.3.City

Fig.15: View of the bus stand

Fig.16: View of the Bo tree

Fig.17: Clock tower junction

Fig.18: "Parakumba" street.

- **Central Area of Kurunegala**

Mainly it has a core. Briefly as follows;

1. Core; the Kurunegala bus stand and its surrounding road network, Puttalam road and Colombo road.
2. Colombo road, "Rajapihila" road and "Kumaratunga Mawatha" surround the municipal market.
3. Kandy road Dambulla road and "Surathissa Mawatha" enclose the triangular area of court complex and lawyers library.
4. Seven-acre government block, which bounded by Puttalam road, Colombo road and "Mihidu Mawatha".
5. "Wan ela" is passing through Negambo road, and Puttalam road.

- **Bus Station.**

Due to intersection point of Puttalam-Kandy road and Colombo Trinkomalee road, kurunegala act as a major point for transportation. There fore larger no of people daily come to town to travel various directions and to fulfill their needs. Kurunegala is famous for vehicular parts, tuition and all the admin buildings are within the city limit.

CHAPTER FOUR

Methodology

4.1.Independent variables.

4.1.1. Land use maps.

Using the land use maps following areas could understand.

- Arrangement of the roads, streets, buildings.
- Street grids.
- Orientation of the buildings
- Natural features of the city.
- Category of the buildings and its locations.

4.1.2. CAD 3D Models

By studying the land use map of t Kurunegala city it is easy to understand the arrangement of the roads, buildings, water bodies and rocks of this area.

Façade studies would enable to do 3D models to kurunegala city. The heights of the buildings are escalating from rural to urban areas.

On the other hand could see the effects of development of the city by the surrounding rock and water bodies.

4.1.3. Façade study

By studying the façade could understand the street elevation .not the details of the façade but the height of the buildings trees, which are very important in this case.

Normally the heights of the buildings are escalating from rural to urban areas. This method shows the increasing or decreasing level of the building height and density could be analyzed.

Fig.19: Increasing of the Building Heights.

4.1.4. Photographic study

Plans, maps, elevation, sections and words could explain the spaces to some extend. But photograph could create real image and it helps to understand the 3D form and quality of the space. (Quality means landscape, topography, etc.)

4.2. Dependent variables

4.2.1.30-year climatic data

From the temperature (T°) and the relative humidity (RH) could analyze the climatic condition of the kurunegala area. That means from the data by using the following equation could calculate the THI value.

$$THI = (0.8*T°) + (RH*T°)/500$$

Where as;

THI=Temperature humidity ratio

RH = Relative Humidity

T° = Dry Bulb Temperature.

From the THI values comfortable level could be decided. That means,

THI < 21 -Comfortable

21 < THI < 24 -50% Comfortable

24<THI<26 -50% Uncomfortable

THI > 26 -100% Uncomfortable

30-year data collected like follows;

Maximum Temperature

YEAR	JA	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
1971												
1972												
1973												
1974												
1975												
1976												
2000												

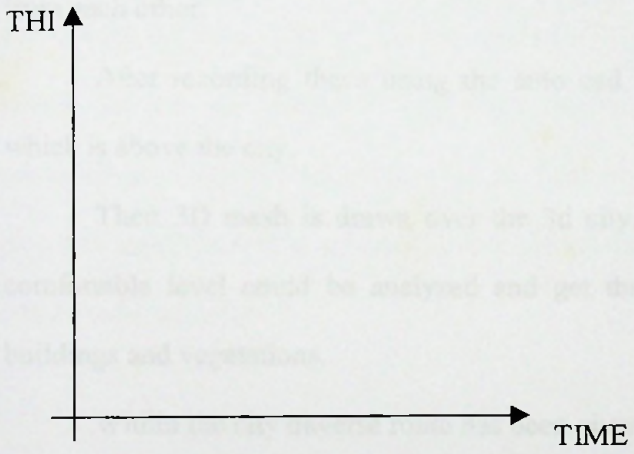
Likewise there should be 4 charts. They are,

- Maximum Temperature. (2.30p.m)
- Minimum Temperature. (5.30a.m)
- Maximum Relative Humidity. (8.30a.m)
- Minimum Relative Humidity. (5.30p.m)

From all these data could analyze values given below,

- THI variation during the last 30years.
- Average Temperature / RH / THI variation during the,
  - Day
  - Month
  - Year
- THI variation in Coldest / hottest months.

All these data enter to excel and draw the charts by using the same. Charts are drawn between the THI value and time.



4.2.2. City traverse

Research has been done within one day during day- time (12.30-2.30p.m) and night (8.30-9.30p.m). According to earliest researches it has been proved (day – night) gain the maximum point of the variation of temperature and relative humidity. In addition all the vehicles and humans gather to city and especially in tropical countries sun comes to the top point within this period in the noon. And in the night during 8.30-9.30

temperature and RH come to maximum point due to emit ion of heat, which store in the day time by the city surface.

Temperature and relative humidity is measured by using the **"Verlin hydrometer"** and **"Hobo"**. These two traverse readings should get in minute by minute. When readings are getting, the position also should be recorded.

In addition reference reading should be taken. That reading is used to gather knowledge about the THI variations within the research. This has to be done for both day and night.

Measurements obtain from several points should be converted as if taken simultaneously. If not THI values, which are getting from the research, are different from each other.

After recording these using the auto cad, from this data, could draw a mesh, which is above the city.

Then 3D mesh is drawn over the 3d city, along the roads. Differences of the comfortable level could be analyzed and get the influences from the water bodies, buildings and vegetations.

Within the city traverse route has been given in figure 21.

4.3 Analysis Techniques

4.3.1.Thermal comforts. Vs. section through city

4.3.2.Thermal comforts. Vs. land cover

4.3.3.Thermal comforts. Vs. 3D form

4.3.1.Thermal comforts. Vs. section through city

Section the 3d mesh along the road, which is mention above. And check what places are of comfortable or uncomfortable, and the reasons for the changers.

Relationship with the thermal comfortable variations along the Puttalam – Kandy road and Colombo – Dambulla road could be analyzed the section.

The sections along the roads THI and temperature variations according to the building height, density, green areas, and water bodies could read very easily and clearly.

4.3.2.Thermal comforts. Vs. land cover

Normally land cover means, features, which covers the earth. They may be a building, rock, tree water body, etc... The density of that specific could be analyzed by calculating the land cover as percentage. The THI vales and the temperature variation within the area are compared with these figures. Using percentage could reveal the relationship of the thermal comfort vs. land cover. In this study 100m-diameter circular area has been chosen in selected points. These circular areas should not overlap with nearby selected area.

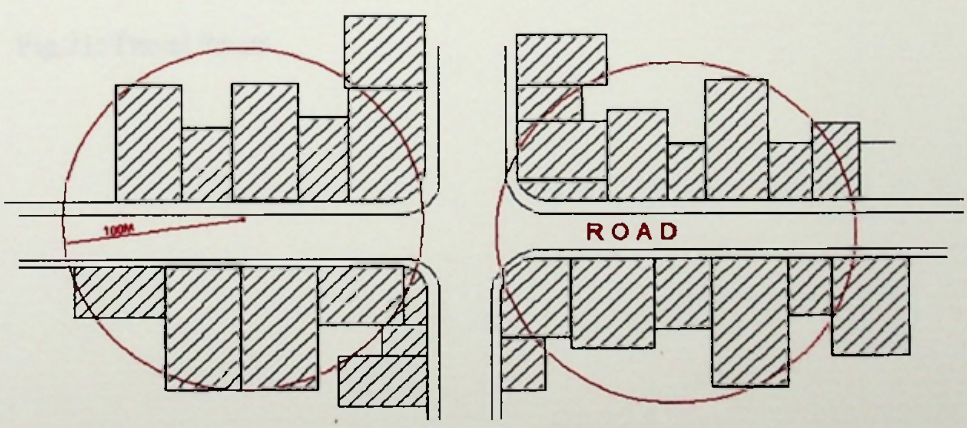


Fig.20 Method, how Could Measured the Land Cover?

4.3.3.Thermal comforts. Vs. 3D form

When studying the 3D form of the city, it helps to understand the relationship of thermal comfort with topography and landscape. Some times higher lands are more comfortable than lover lands. This is occurring due to the height differences.

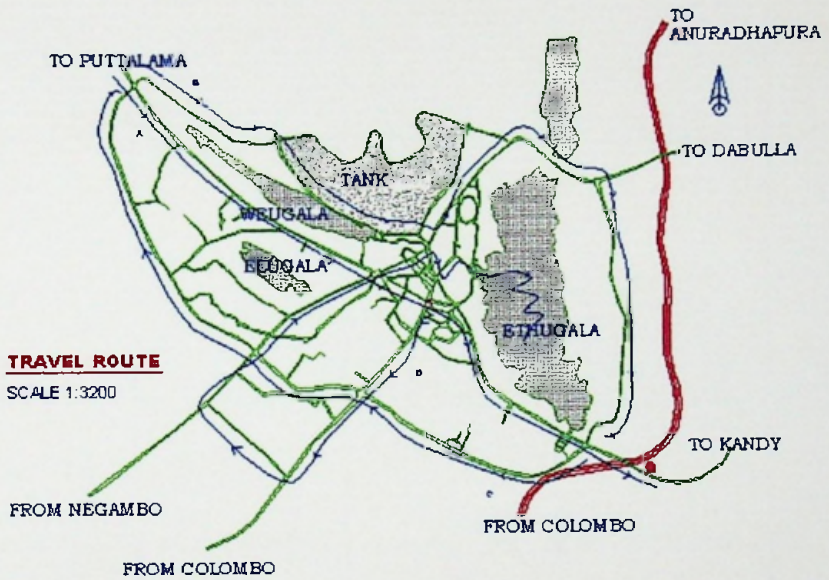


Fig.21: Travel Route

CHAPTER FIVE

Data and Analyzes

Land use maps

- Commercial area is along the roads and city center.
- Majority of the public buildings are within the city limit and concentrated to east side of the city which is close to the Athugala rock
- All the residential unites are away from the city.
-

3D models

- Increasing of building density in the center of the city can be analyzed in 3d form.
- From the fig.26, 27 this can be seen very clearly.

Façade study

- Heights of the buildings have been increased from rural areas to urban.
- Urban is more comfortable than rural.
- Rock areas are more comfortable than other areas during day time.(which covered by vegetation.)

Photographic study

- Spaces, which covered by tree canopies and have gloom, are the most comfortable places.
- Most of the roads have trees, along both sides. But due to wideness of the roads, large open spaces have been created.

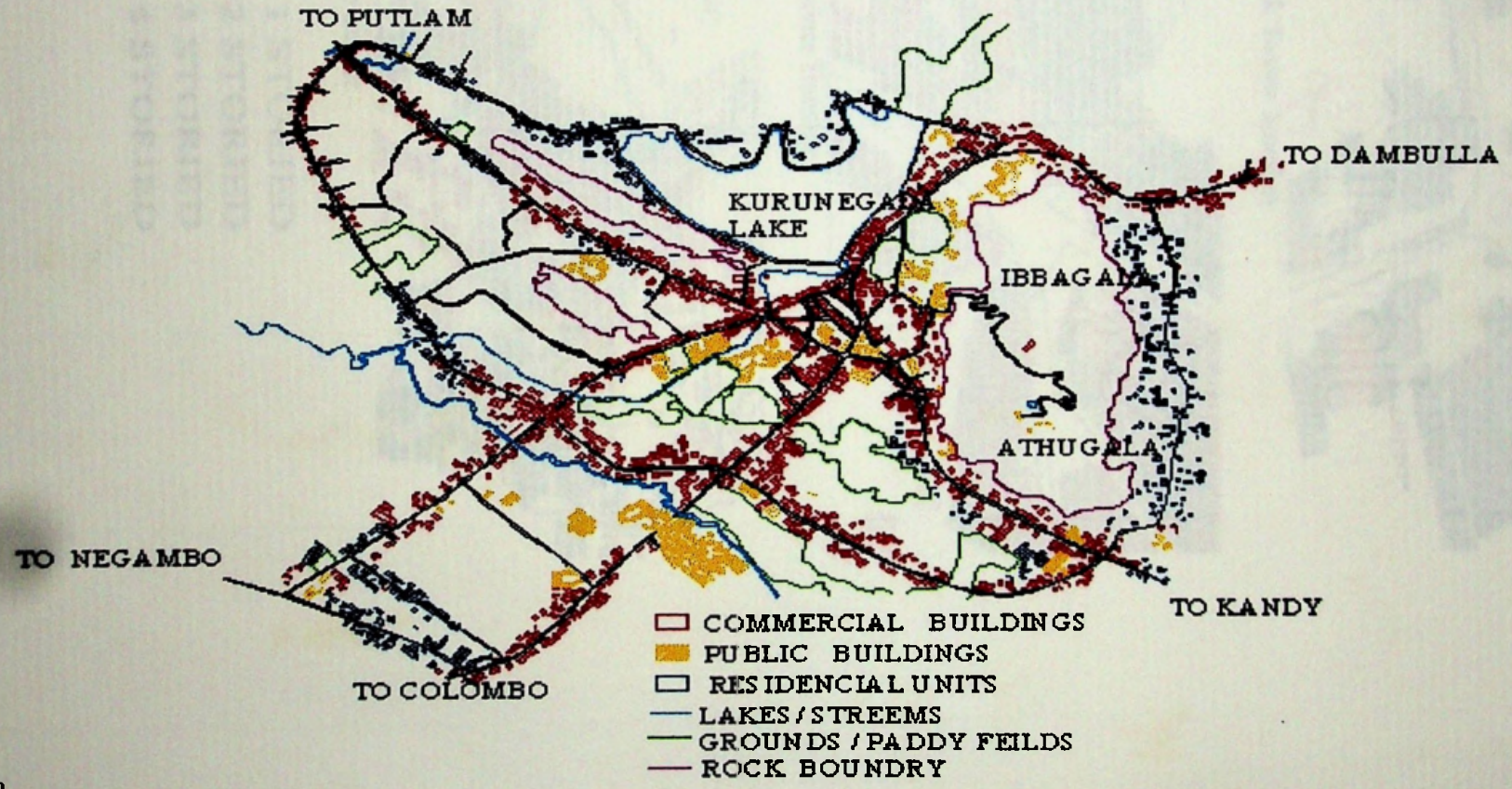


Fig.22: Land Use Map

Fig.23: Clock Tower Junction

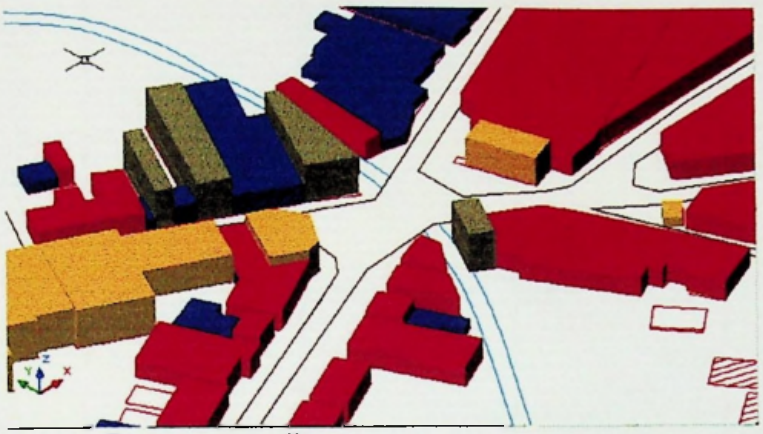


Fig.24: Puttalam Handiya


Fig.24: City Center

1 STORIED
2 STORIED
3 STORIED
4 STORIED

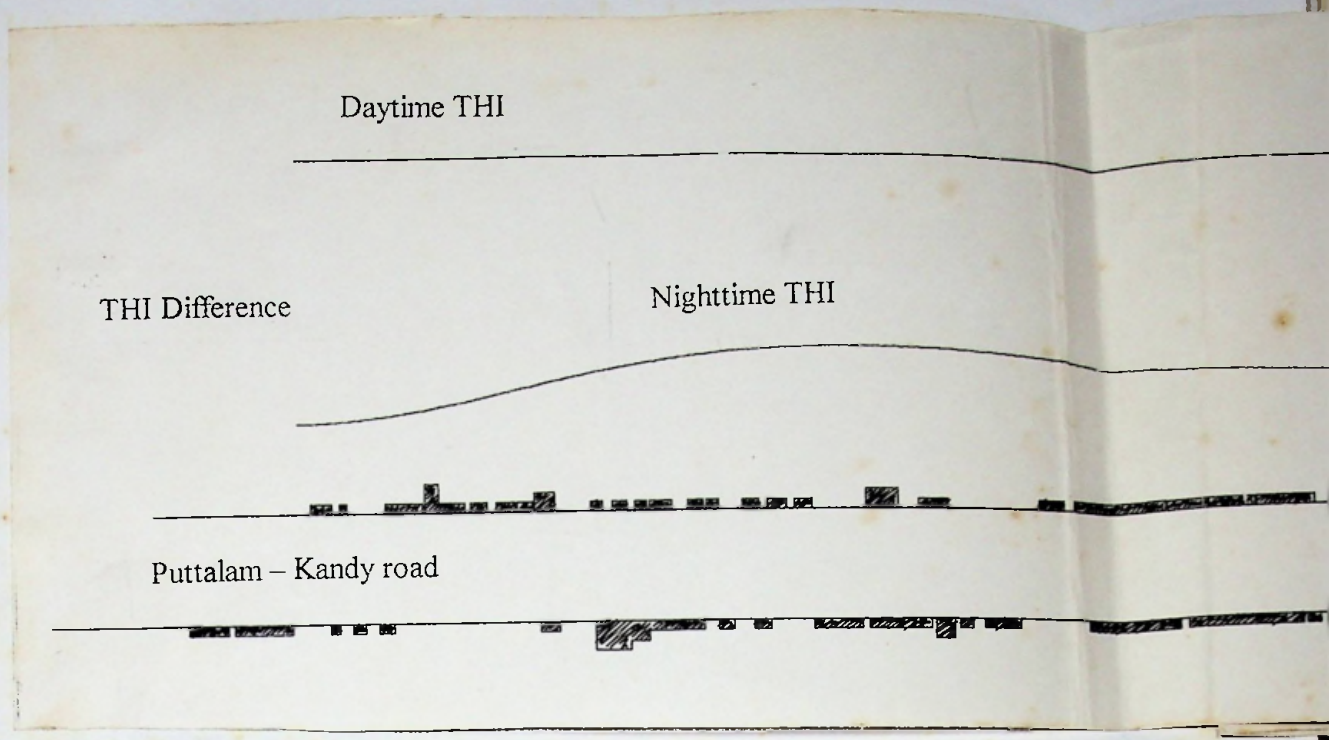


Fig.26: Façade Study – Puttalam - Kandy Road

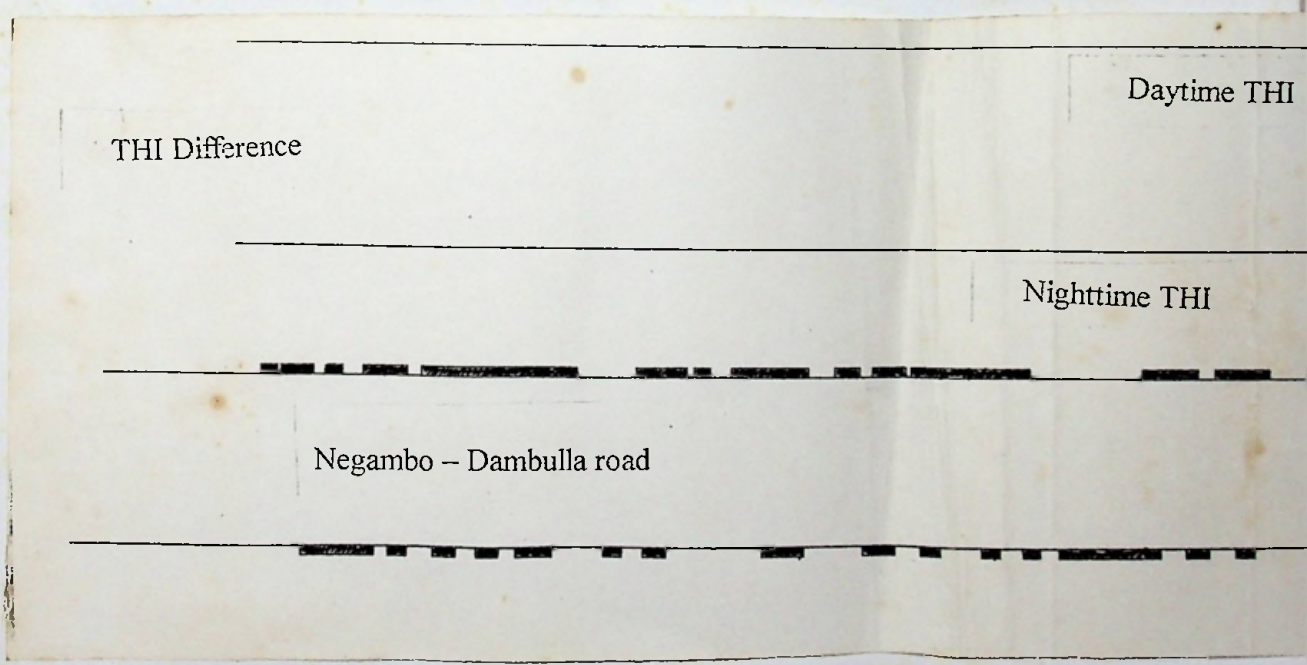


Fig.27: Façade Study – Negambo - Dambulla Road

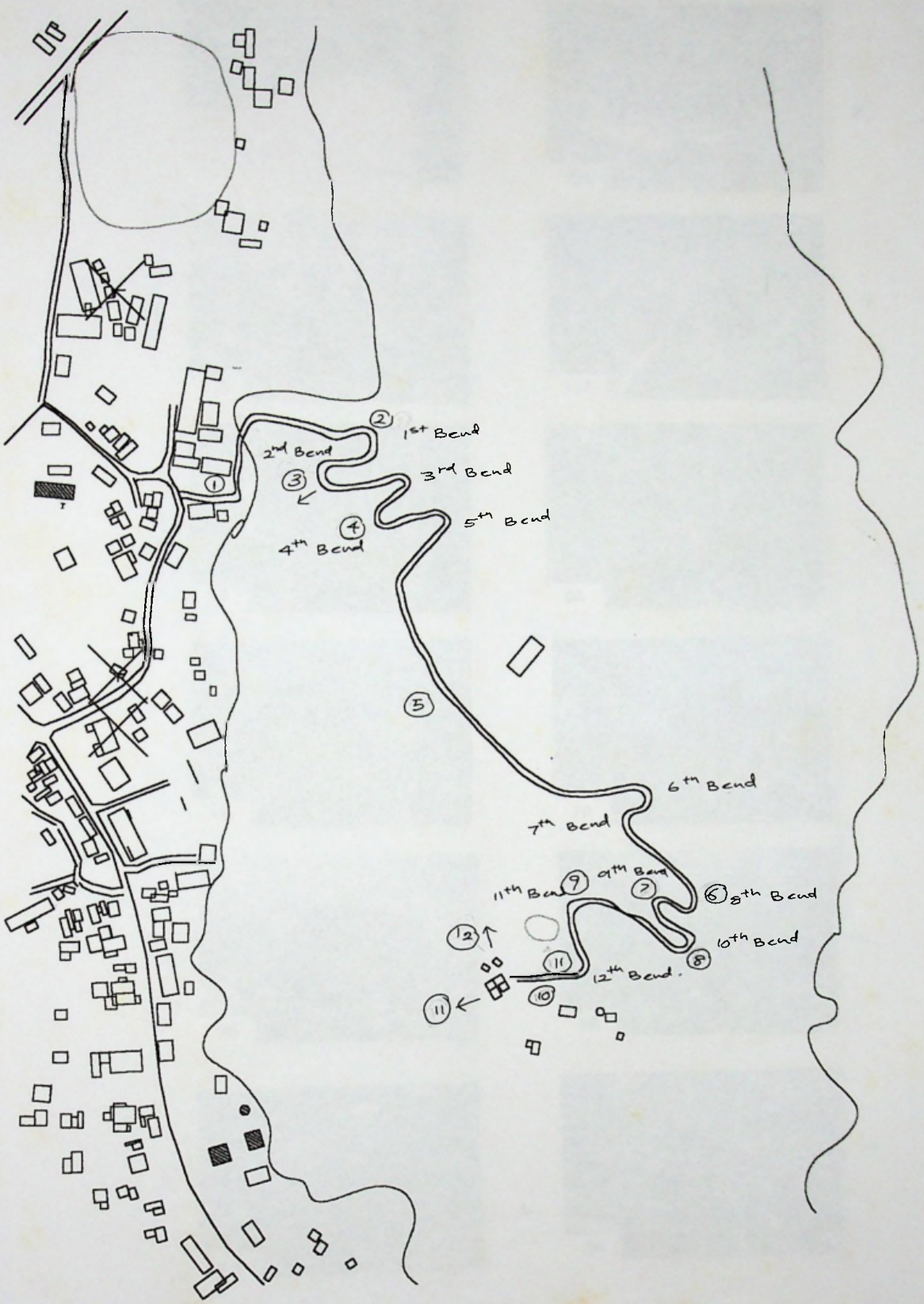


Fig.28: Photographic Study – Athugala

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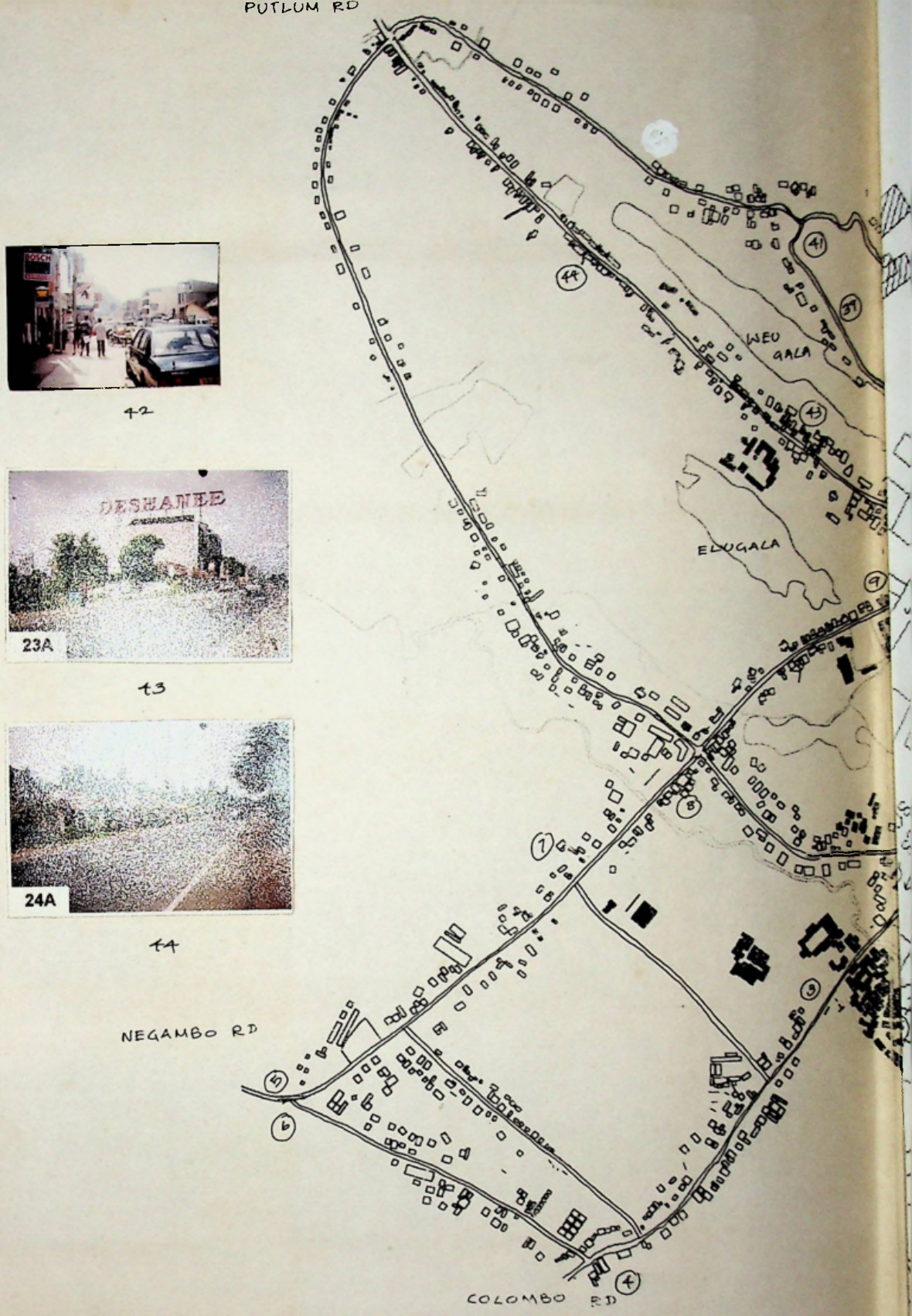

Fig. 29: Photographic Study – City

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30-Year Data

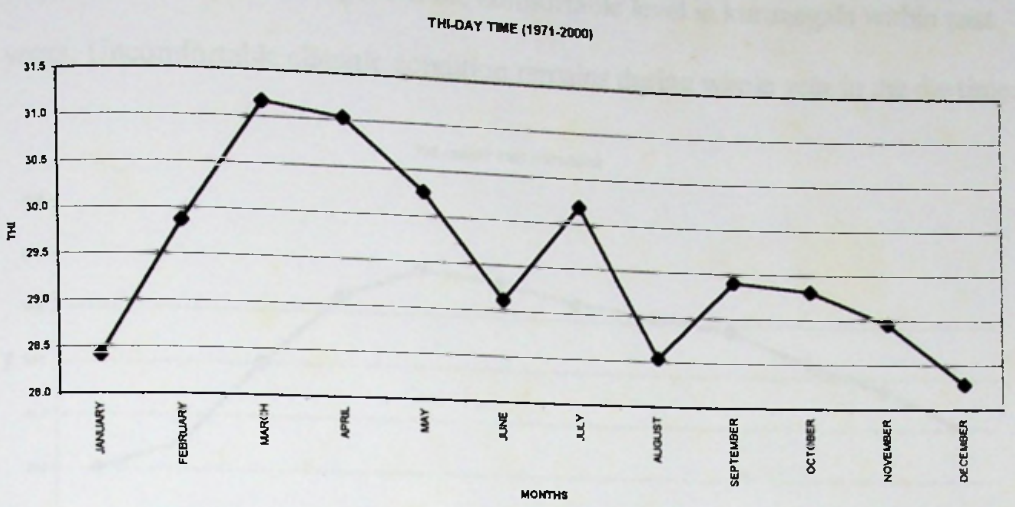


Fig.30: THI Vales-Day Time (1971-2000)

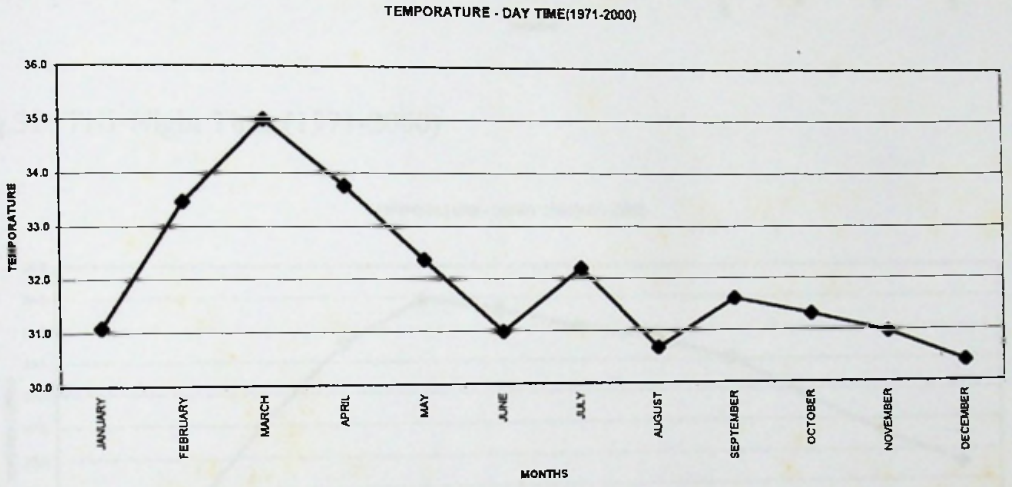


Fig.31: Temperature-Day Time (1971-2000)

According to the 30-year climatic data warmest and coolest months are March and December respectively. February, May, and July could be introduced as warmest months when comparing with other months. Other months are differing between 30.5 C^0 and 32.5 C^0 .31.6C is the average temperature in Kurunegala. Due to various factors temperature had been changed in city area. (EX-Urbanization, natural features etc.)

THI graph and temperature graph are same in shape. That means temperature is the powerful factor, which govern the comfortable level in kurunegala within past 30 years. Uncomfortable climatic condition remains during whole year in the daytime.

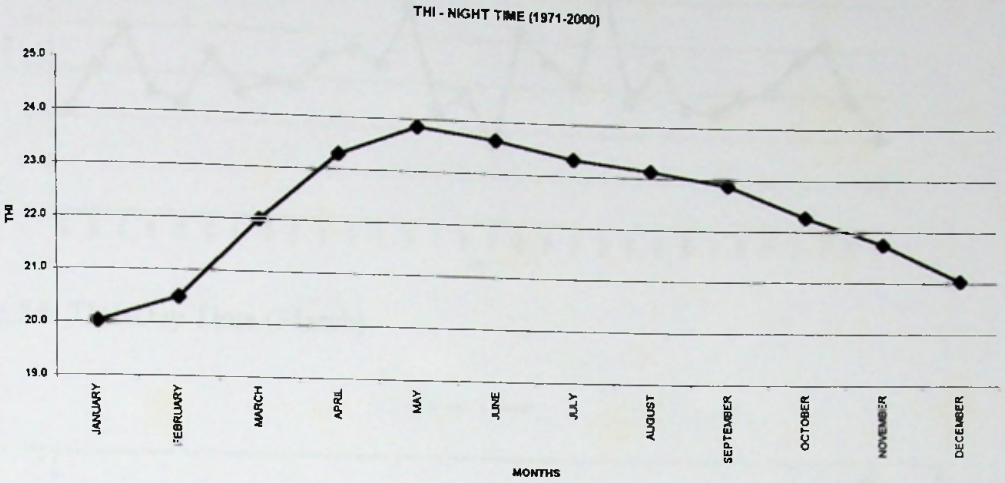


Fig.32: THI-Night Time (1971-2000)

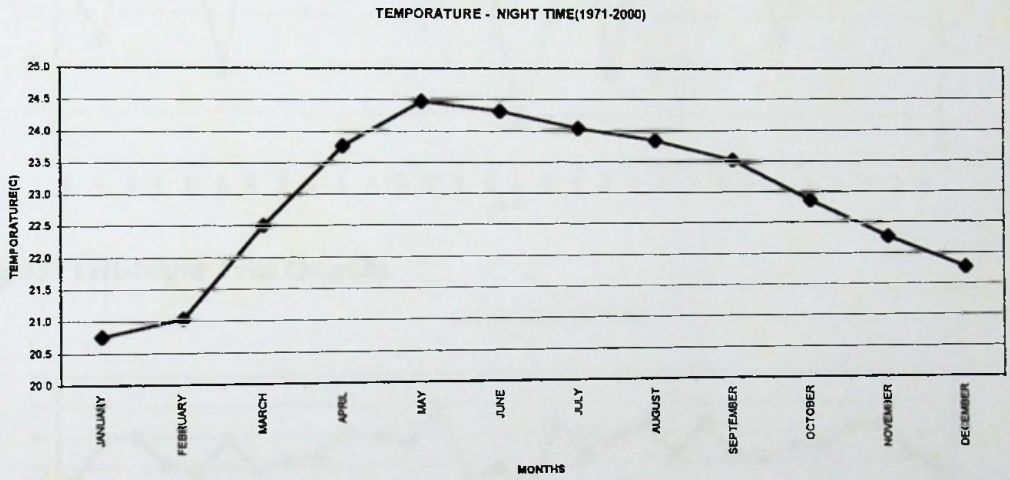


Fig.33: Temperature-Night Time (1971-2000)

The warmest and coolest months were May and December respectively in the nighttime. Except My all other months were 50% comfortable. May was 50%uncomfortable.

Warmest Month – March.

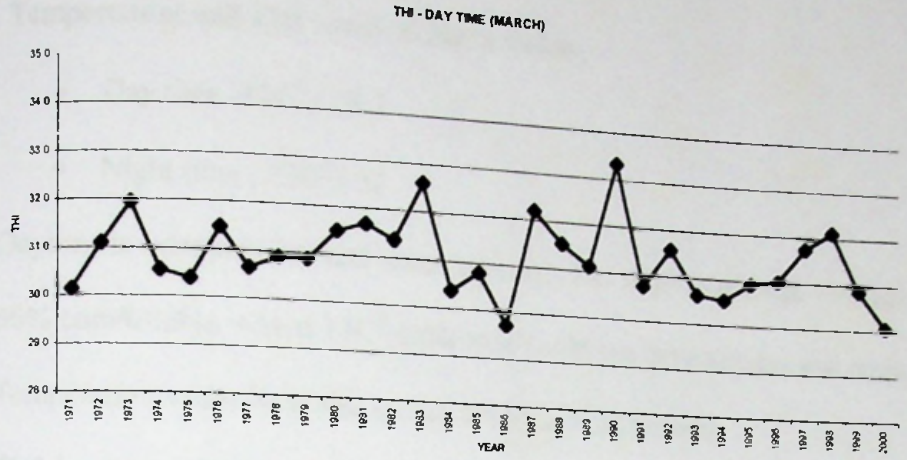


Fig.34: THI-Day Time (March)

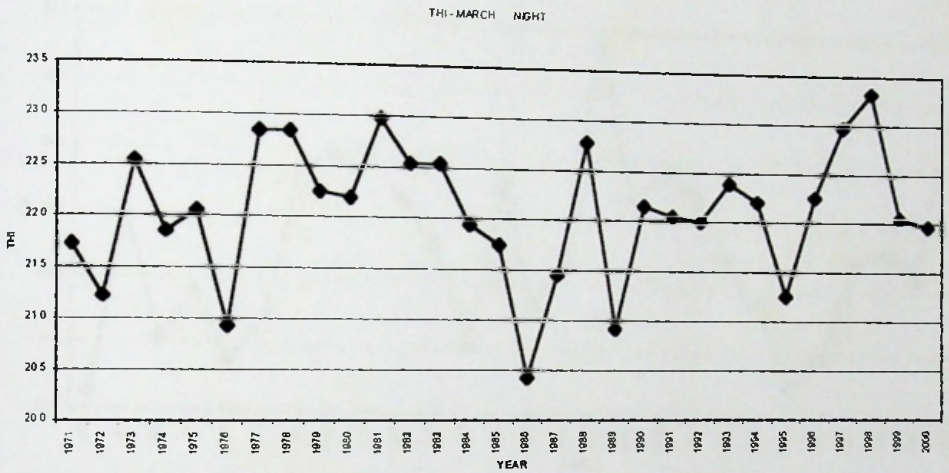


Fig.35: THI-Night Time (March)

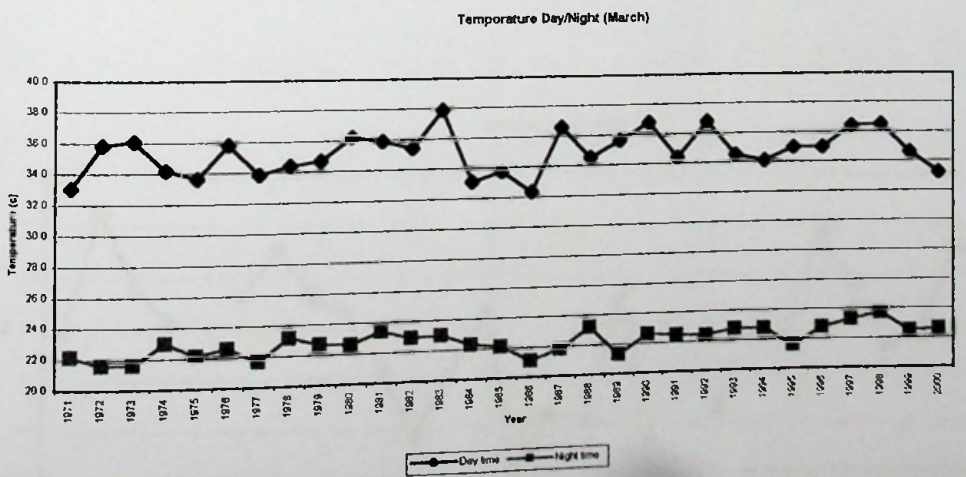


Fig.36: Temperature-Day and Night (March)

March is the warmest month in Kurunegala.

Temperatures and THI varies as are as below,

- Day time -35C^0 / 31.2
- Night time - 22C^0 / 22

Daytime is extremely hot and uncomfortable. But night is normal. Normal means, 50% comfortable. About 13C^0 difference could see between day and night.

Temperature varies from day by day about 2-3^0 of Celsius.

Coldest month - December

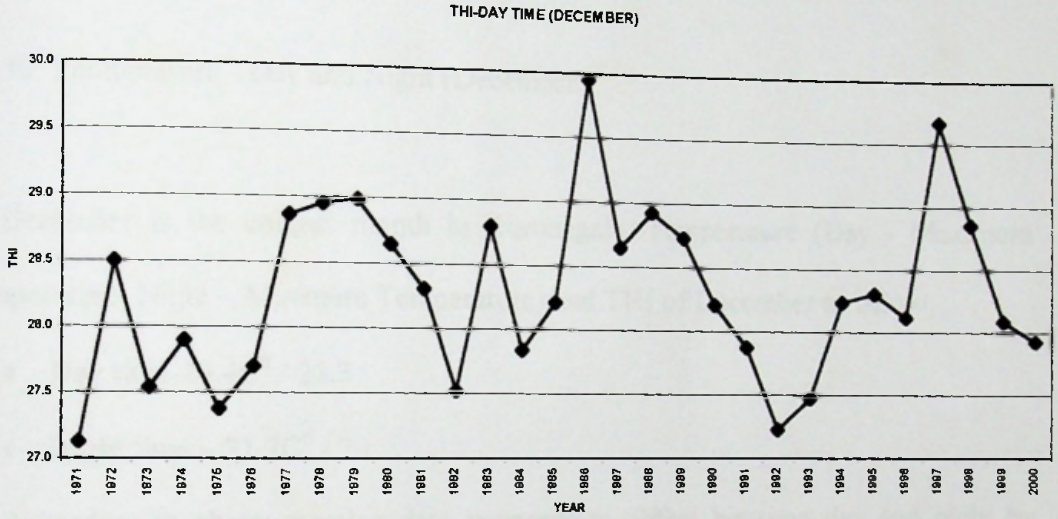


Fig.37: THI-Day Time (December)

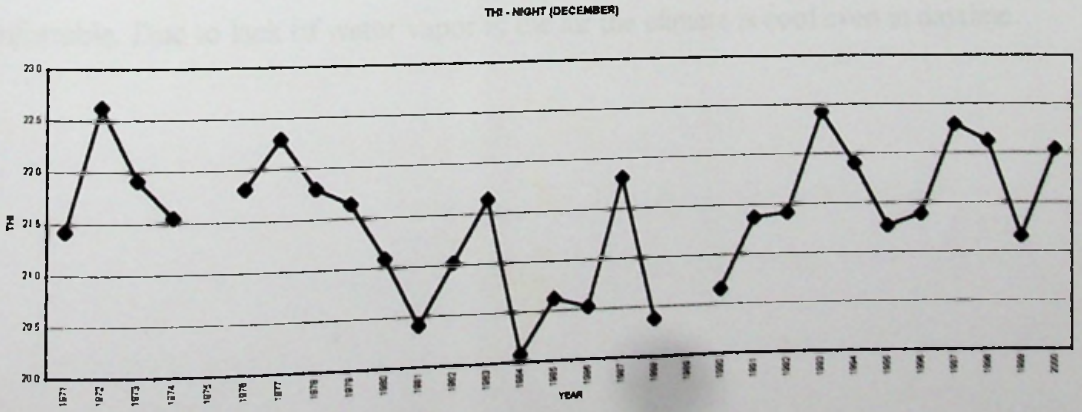


Fig.38: THI-Night Time (December)

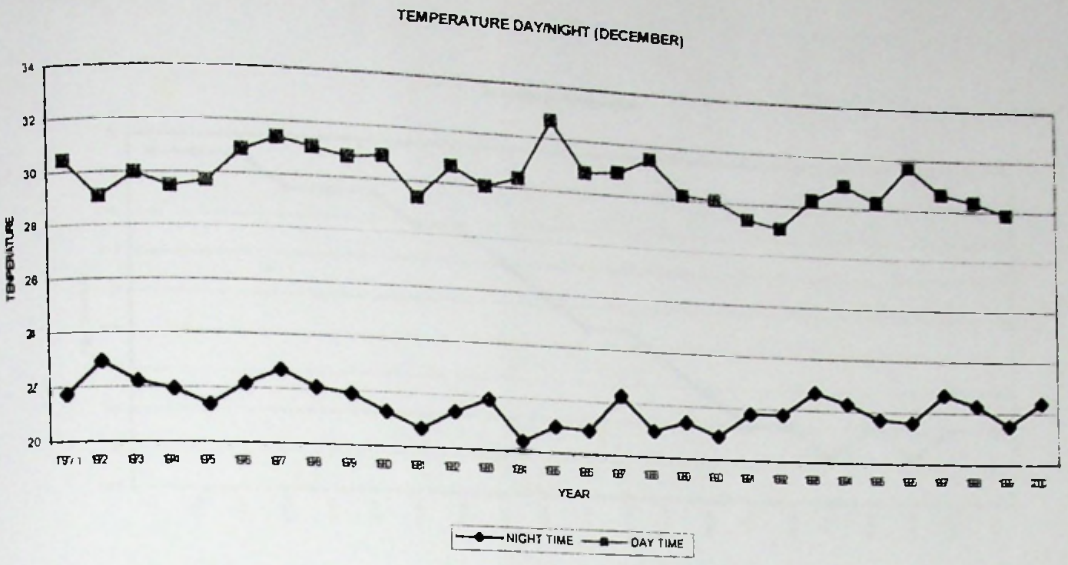


Fig.39: Temperature - Day and Night (December).

December is the coldest month in Kurunegala. Temperature (Day - Maximum Temperature, Night – Minimum Temperature) and THI of December as below;

- Day time-29.4C^0 / 28.3
- Night time – 21.7C^0 / 20

According to above mention data temperature differs between day and night by about 8C^0.Even daytime maximum temperature is 29.4C^0 climatic condition is uncomfortable. As result of nighttime temperature and relative humidity, climate is comfortable. Due to lack of water vapor in the air the climate is cool even in daytime.

City Traverse

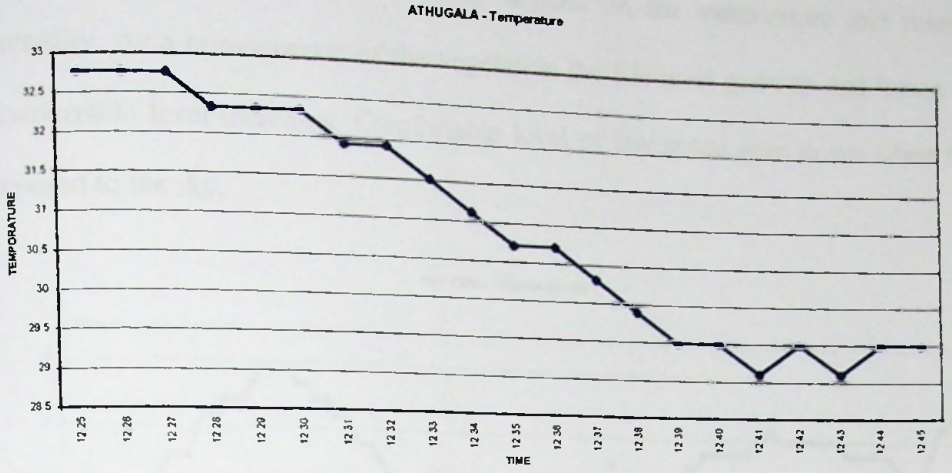


Fig.40: Temperature-"Athugala"

Fig.41: Travel Route of "Athugala"

"Athugala" and "Ibbagala" are touching each other. "Athugala" is the highest mountain, which are 350m in height. The access road to the "Athugala" goes though Ibbagala rock. Both sides of the road provide shade.

According to the graft THI vale and temperature had increased when height goes up. The maximum and the minimum vales were observed at the top and bottom respectively.

During 12:40p.m. to 12:44.p.m. THI vales have been changed according to zigzag pattern. The THI vales directly depend on the temperature and relative humidity. As a consequence of the vegetation the RH level goes up and hence the comfortable level increases. Comfortable level of any space goes down when it is exposed to the sky.

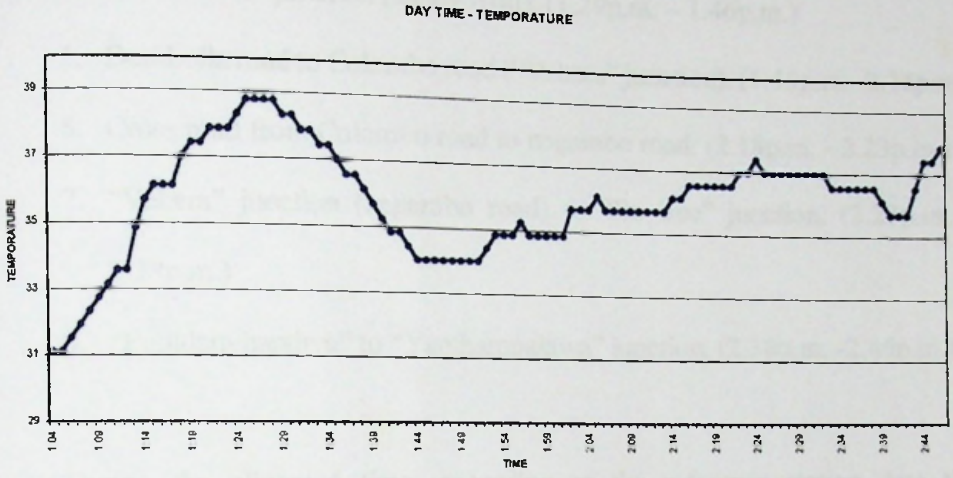


Fig.43: Temperature – Day Time (City Travers)

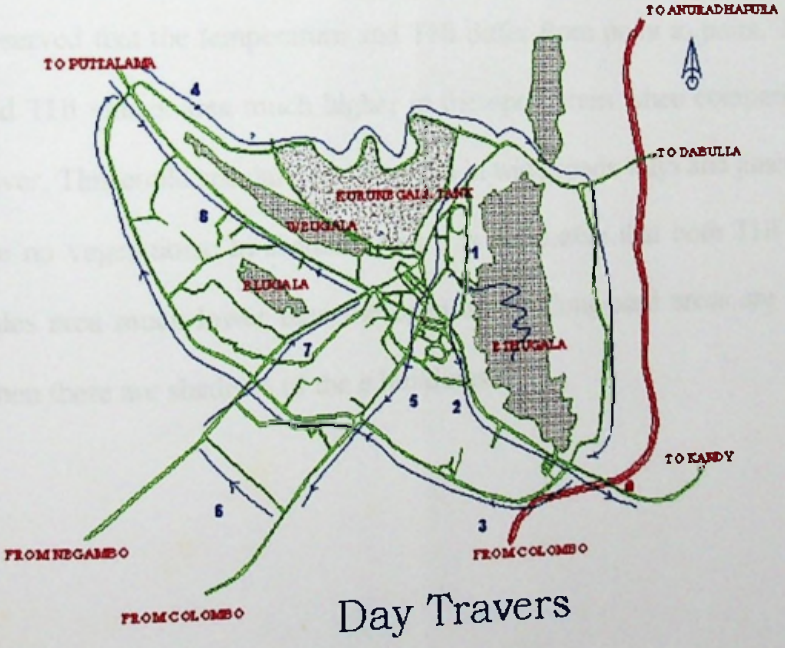


Fig.44: Travel Route - Daytime

1. Athugala (12.45 p.m. – 12.45 p.m.)
2. Kandy road. (1.04 p.m. -1.10 p.m.)
3. "Gettuwana" junction to "Puwakgashandiya", "Kadurugashandiya", "Yanthampalawa" junction. (1.01p.m. -1.29p.m.)
4. "Yanthampalawa" junction, tank circular road, Dambulla road to "Gettuwana" junction (kandy road). (1.29p.m. – 1.46p.m.)
5. Dambulla road to Colombo road ("Vehera" junction). (1.46p.m. -2.18p.m.)
6. Cross road from Colombo road to negambo road. (2.18p.m. - 2.23p.m.)
7. "Vehera" junction (negambo road) to "Bo tree" junction. (2.23p.m. - 2.38p.m.)
8. "Puttalam handiya" to "Yanthampalawa" junction. (2.38p.m. -2.46p.m.)

During the allocated time, according to the reference station data the temperature was constant in the surrounding area. But while doing city traverse it is observed that the temperature and THI differ from point to point. THE temperature and THI values area much higher in the open areas when comparing with the land cover. This could specially be observed in wide roads ways and junctions where there are no vegetations. In shaded areas it is noticeable that both THI and temperature vales area much lower than the open areas. Congested areas are also comfortable when there are shadows of the e buildings.

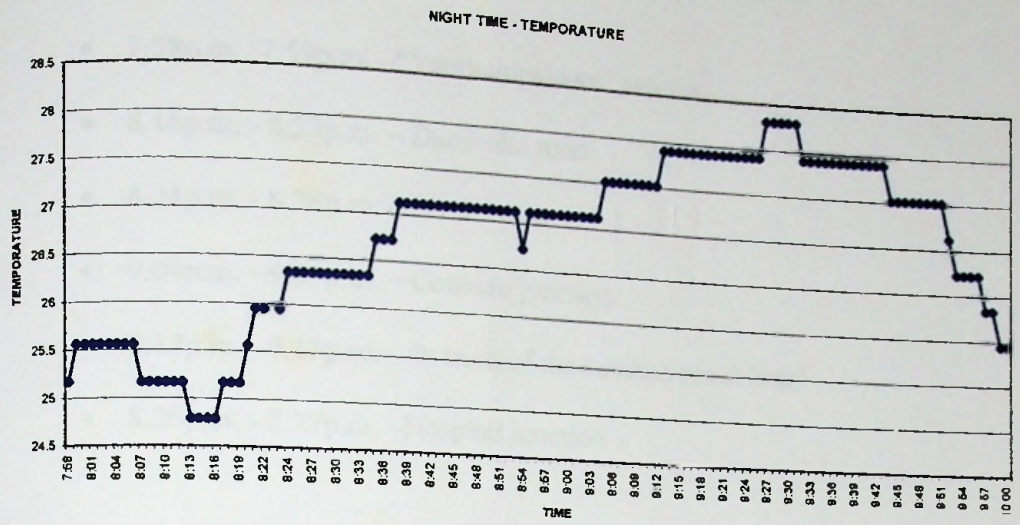


Fig.45: Temperature – Night Time (City Traverse)

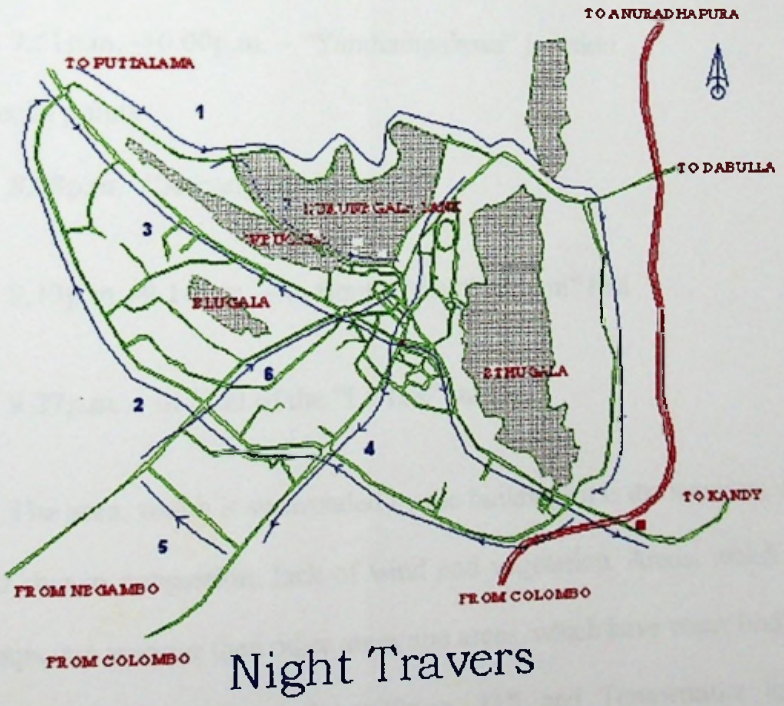


Fig .46:Travel Route – Night Time (City Traverse)

Increasing points

- 7.58p.m. -7.59p.m. –"Yanthampalawa" junction
- 8.16p.m. - 8.23p.m. – Dambulla road
- 8.34p.m. - 8.38p.m. – "Pola" road
- 9.04p.m. - 9.05p.m. – Convent junction
- 9.12p.m. - 9.13p.m. – In front of the kandian reach hotel
- 8.26p.m. - 8.27p.m. –Hospital junction

Decreasing points

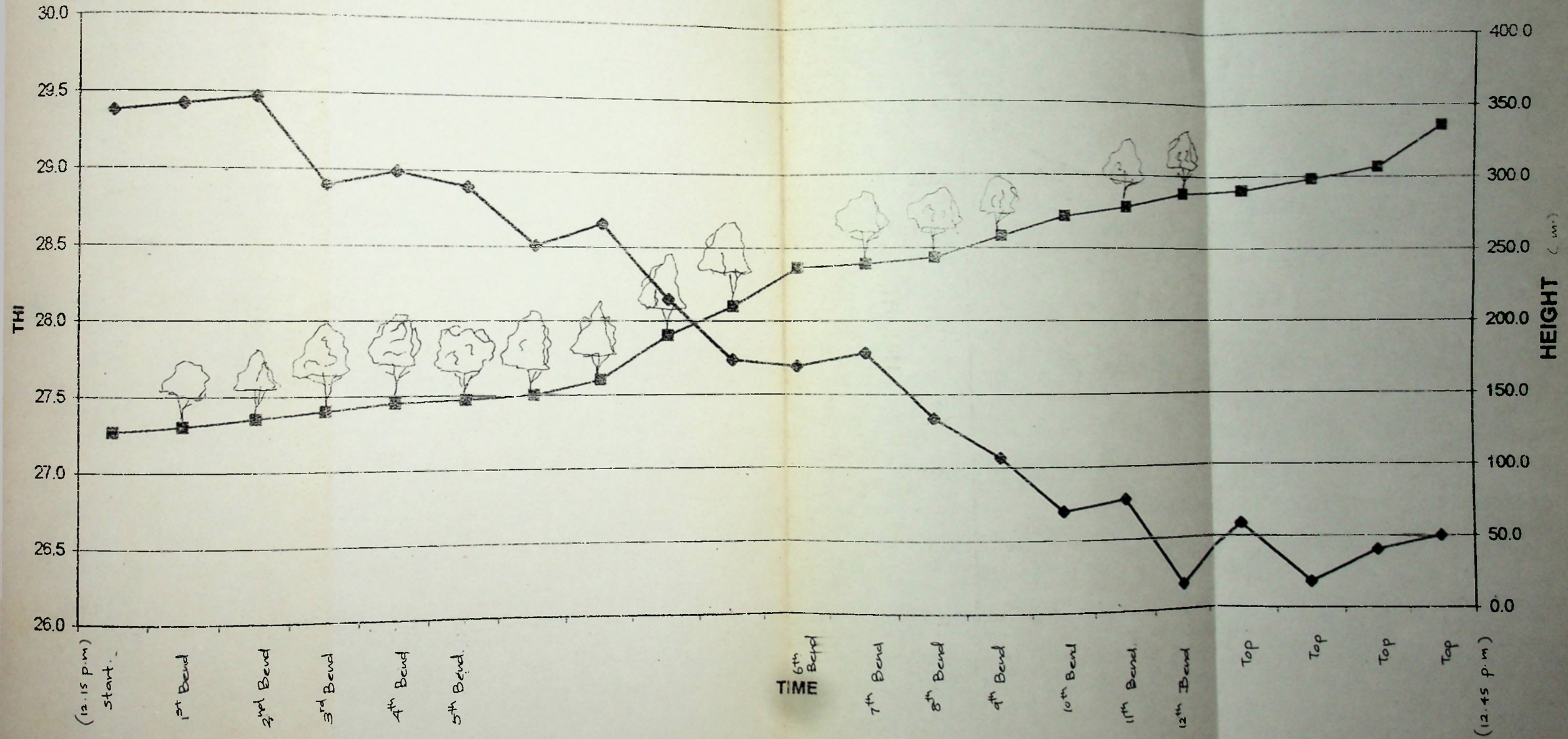
- 8.06p.m. -8.07p.m. - Circular road
- 8.12p.m. -8.13p.m. - Circular road
- 9.31p.m. -9.32p.m. - Gettuwana junction
- 9.43p.m. -9.44p.m. - "Kadurugas" handiya
- 9.51p.m. -10.00p.m. – "Yanthampalawa" junction

Special points

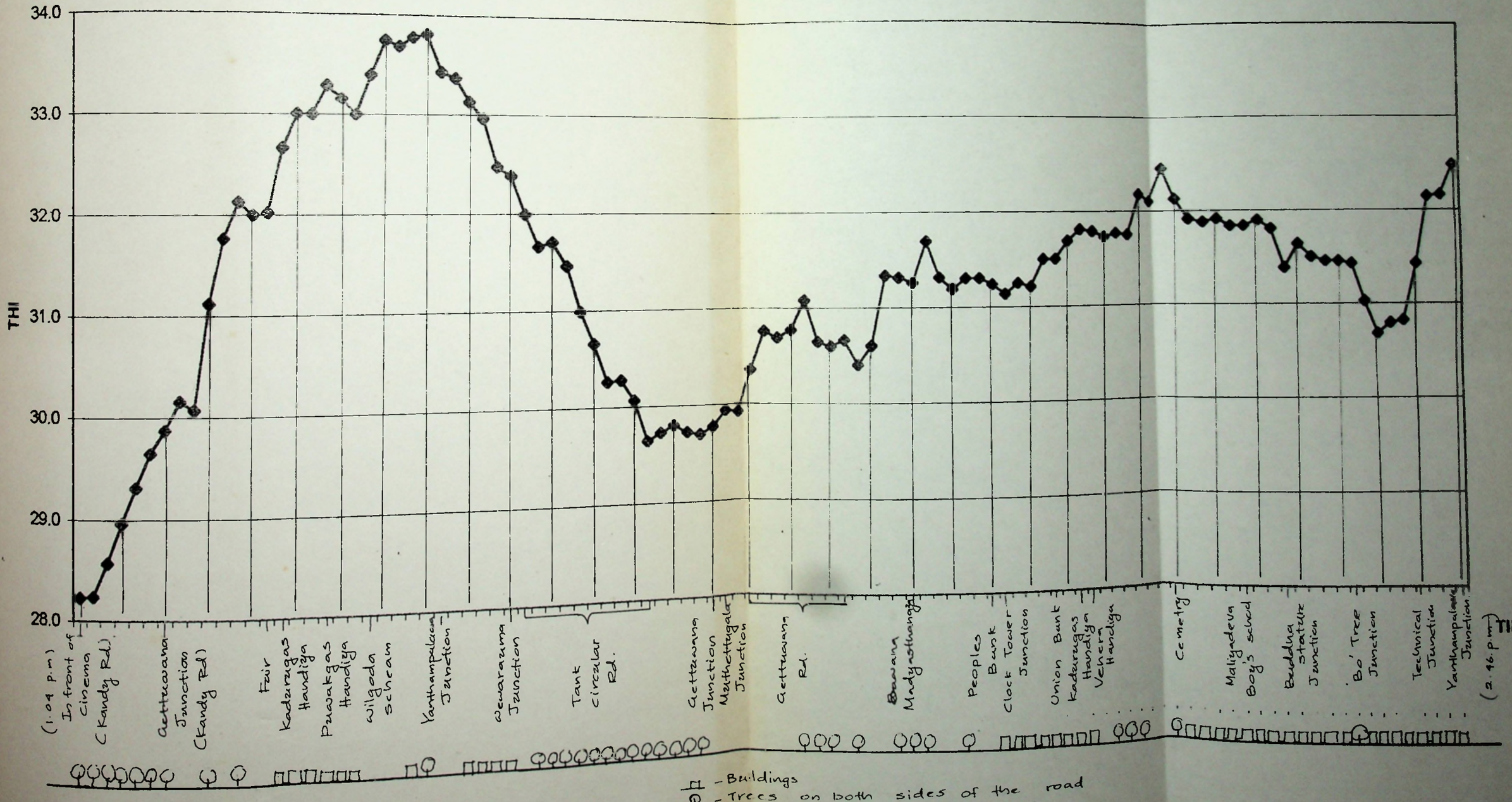
- 8.58p.m. –"Angangala" junction
- 9.13p.m. -9.14p.m. – In front of the "Wathimi" hall
- 9.27p.m. – In front of the "La-flas" station

The area, which is surrounded by the buildings it is the warmest. Junctions are warmer due to congestion, lack of wind and vegetation. Areas, which do not have wind gaps, are warmer than other areas and areas, which have water bodies, are more comfortable. From 7:30p.m. to 9:30p.m. THI and Temperature had gradually

ATHUGALA - DAY TIME

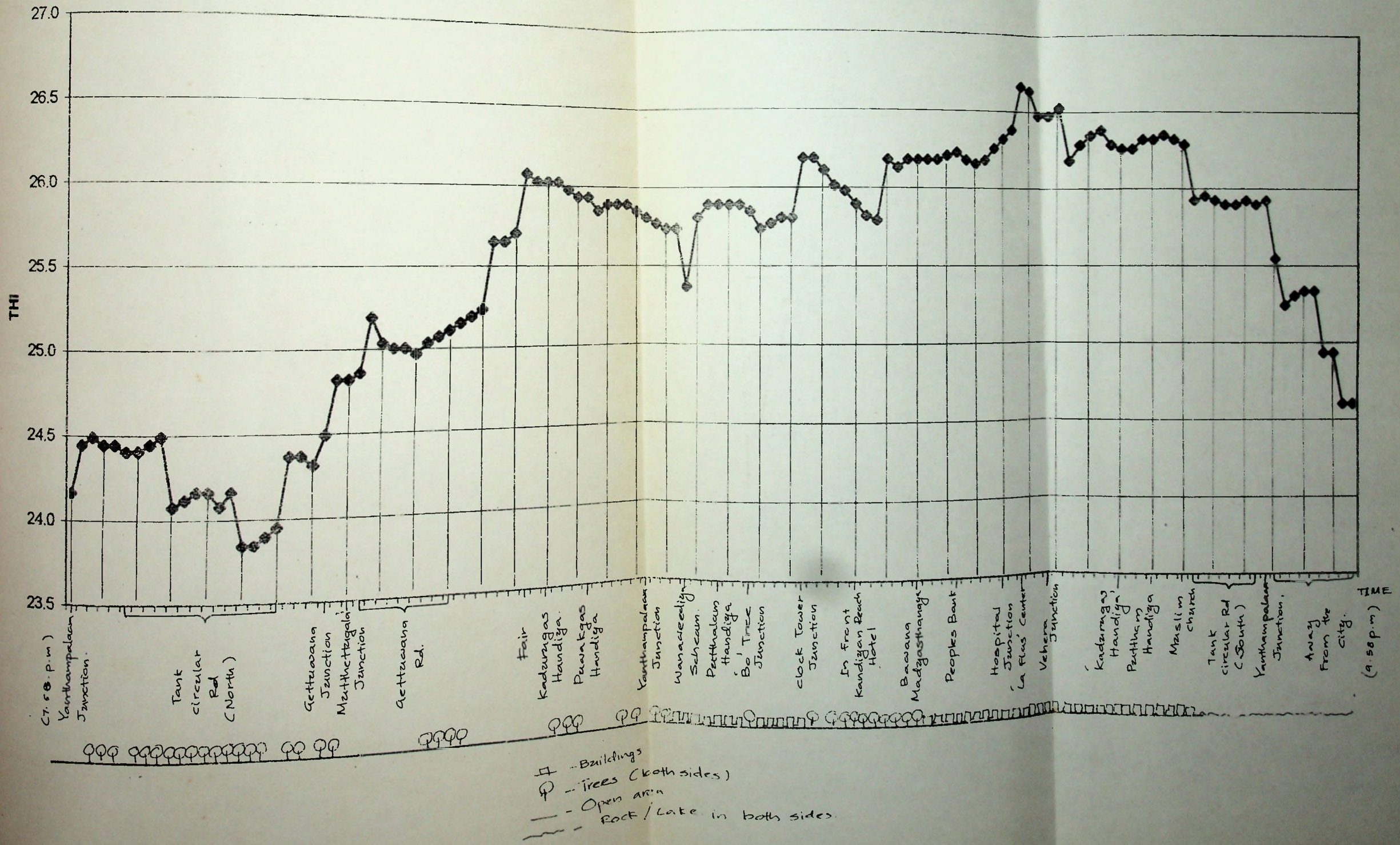


CITY TRAVERS - DAY TIME



- Buildings
- Trees on both sides of the road
- Open area.

CITY TRAVERS - NIGHT TIME



increased. But due to some kind of external forcers these two figures deviated. Some time this may be course to the presence of water body by the side of the road.

Reference Station Data

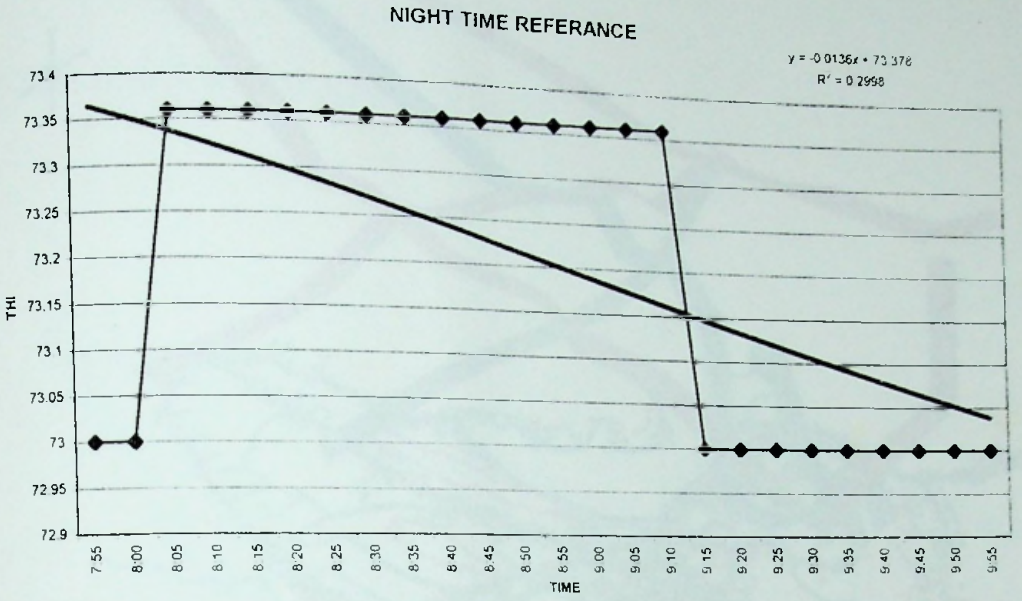


Fig.50: Reference Station Data - Night Time

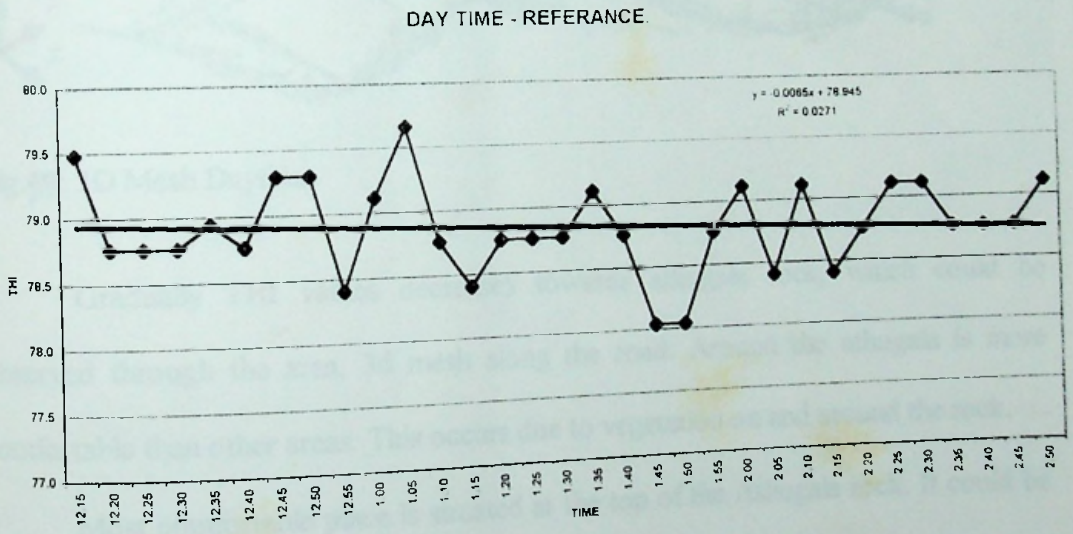


Fig.51: Reference Station Data - Day Time

Both day and night reference station data are constant. Due to that data's, which are gain from the city traverse, should not necessary to convert in to mid time.

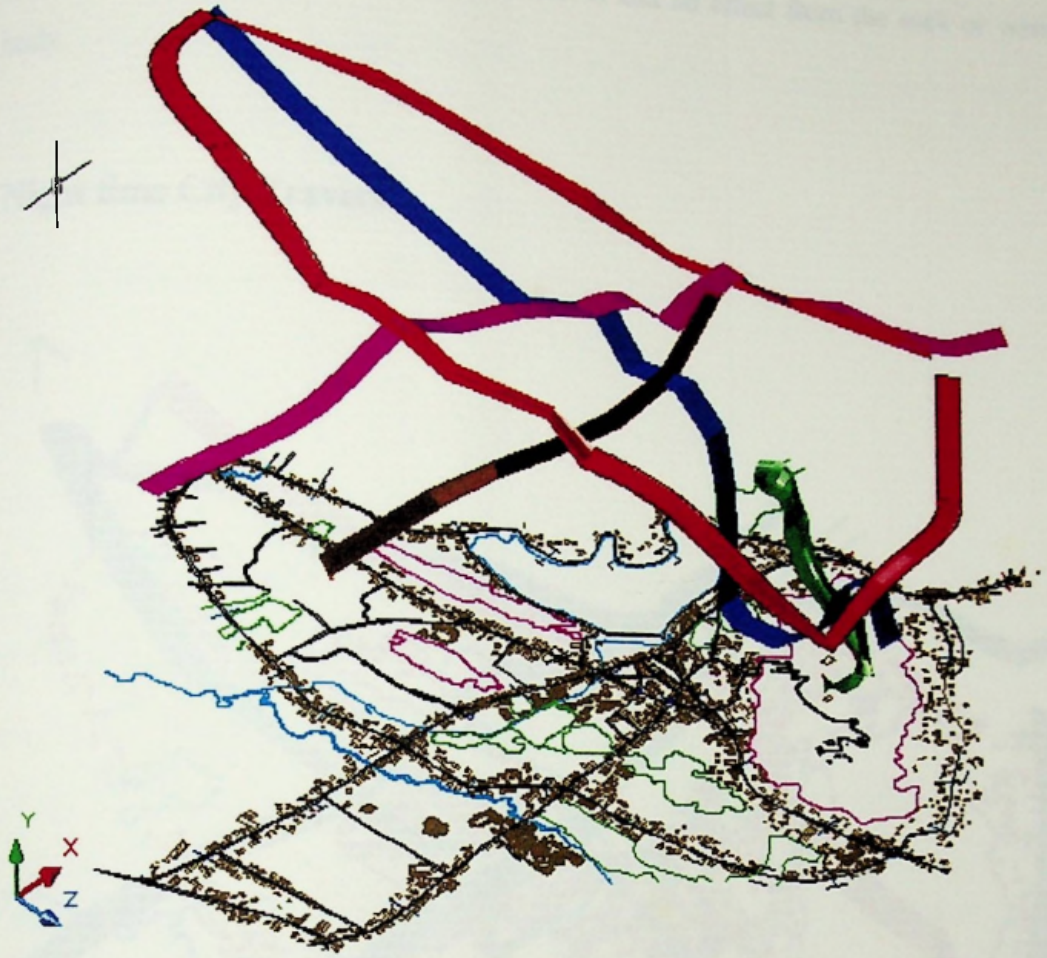


Fig.40: 3D Mesh Daytime

- Gradually THI values decreases towards athugala rock, which could be observed through the area, 3d mesh along the road. Around the athugala is more comfortable than other areas. This occurs due to vegetation on and around the rock.
- Most comfortable place is situated at the top of the Athugala rock. It could be seen from the above figure also
- According to earliest researchers there should be an **urban heat island effect.** But due to these rock boulders it has been obscured.
- The area which is in close proximity to the water body is more comfortable than others area in the city.

- The place, which is far away from the city, was the warmest .it could not be happen. But that point also urbanized place. It had no effect from the rock or water body.

Night time City Travers.

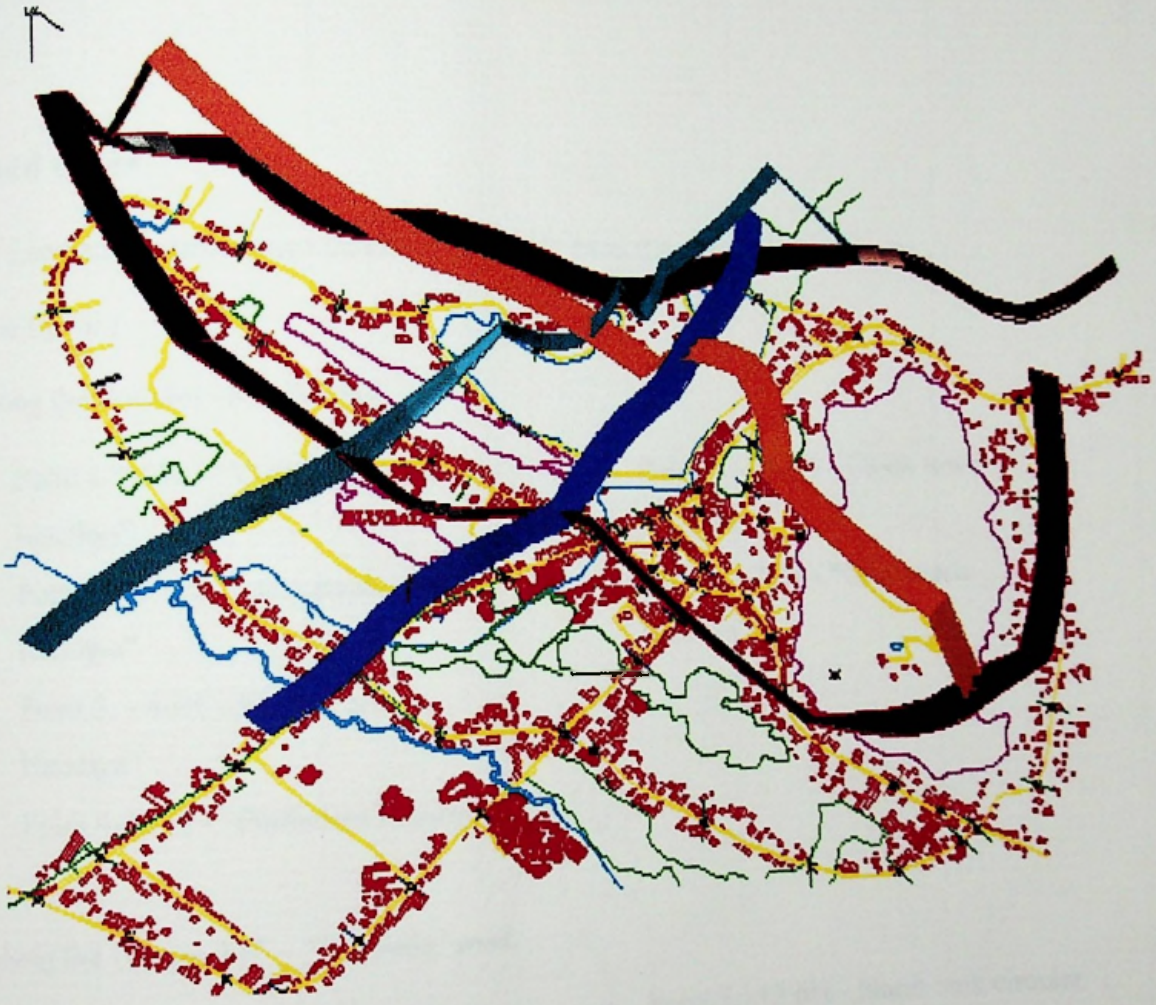


Fig.41: 3Dmesh Nighttime

- In the night time **urban heat island effect** could be observed to certain extend.

- Meshes, which are along the road, express the comfortable level through, difference in height levels.
- THI value is even high when the city is dead. City is uncomfortable than the area outside the city.
- Periphery of the city was uncomfortable.
- Water body helps to gain more comfort to the area.

Land cover

- Land cover: percentage increases gradually from the periphery to the city.

(See fig.54.)

Along the Puttalm –Kandy road:

- Point 1-7.9% - "Yanthampalawa junction"
- Point 2. -3.1% - "Angangala Handiya"
- Point 3. - 40% - Wewa Para Handiya"
- Point 4-40 % - "Putthalam Handiya"
- Point 5. -28.5% - Clock tower junction
- Point 6. –33% - "Gettuwana Handiya"

Along the "Negambo" – "Dabbulla" road:

- Point 1. -11% - "Wehera Handiya"
- Point 2. -26% - "Puwakgas Handiya"
- Point 3. -40% - "Putthalam Handira"
- Point 4. -44% - "Maha Veediya"
- Point 5. -12.6% - North tank circular road junction
- Point 6. -15.8% - "Gettuwana junction"

Fig .54: Land Cover –Measured Points

CHAPTER SIX

Conclusion

Chapter Six – Conclusion

Summary

Various rock based cities, could be seen in Sri Lankan history. Kurunegala is one of them. It has been developed among the rocks. All the surrounding historic villages have a rock base.

Most of the image houses and human settlements have been developed among the rocks since time immemorial. The reason for this might be the comfort. This study clearly indicates that rocks with vegetation are more comfortable to live in.

But uncovered or bare rocks cause several problems. Heat emissions as well as heat absorption ability of rocks are faster than other materials. Perhaps this occurs due to its dark color and rough texture. (In Sri Lankan context rocks are dark in colour and rough textured.)

"Athugala" and "IbbagalA", which are covered with vegetation, are situated east of the city center. This may be the cause why heat island effect could not be observed vividly in day time. As a result of the solar radiation, emitted heat from bear surface of Athugala, city becomes 100% uncomfortable in the day time. Due to emission of heat from the surrounding buildings night time also uncomfortable in the city center.

The essence of Kurunegala City is in the beauty of its rocks. The building s attains height overcome 4 stories this special view would be obliterated if the heights of the buildings exceed this level.

Present build up of the Kurunegala City could be considered satisfactory. But if there is visual and physical contact of the lake the situation could have been really marvelous.

Building facades, which are face to the east, should cover by adding lines of vegetations and all the buildings should be painted in light colour. By this method heat absorption could be minimized and in addition reflecting heat rays are being break out

Every building should have the canopies or shading device then these will be creating shady verandas. If Whole City connected by shady verandahs shopping is really a pleasure in a tropical city.

A wide road engenders large open spaces, which covered by bitumen. And it is clearly noted by this research that the situation is really uncomfortable. . Hence to minimize this ill effect tree lines on either side of tie road and in the middle too should be planted.

Conclusion of back ground study.

All design should be done paying consideration to the site .specially climate of the area. Climate depends on topography, vegetation and building forms nearby.

Specially in tropical countries solar radiation is a major problem. To deviate from this various design techniques should be used. By orientating the building in to correct direction and by using suitable materials, design could be converting in to environment friendly design. Orientation, shape and form should differ for zone to zone.

Only by using the shade and cool breeze any space could be formed in to comfortable space. Shade and cool breeze could increase the convertible level of the city.

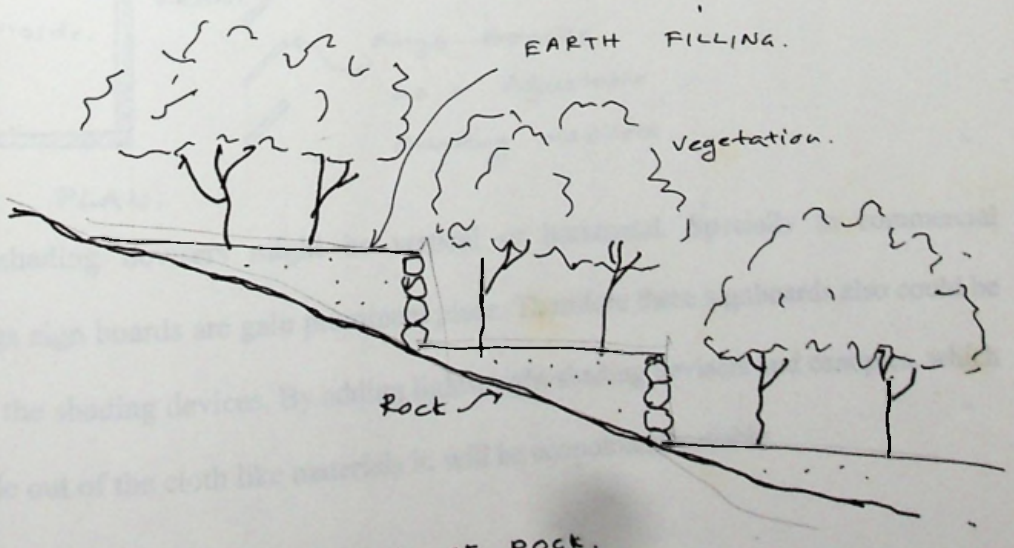
Design variables in architectural expression depend on shape, building facades, fenestration and ventilation. By catering to all these automatically could generate comfortable design.

Summery of findings,

- The most comfortable place is on top of "Athugala"
- The lake surroundings are all so comfortable from other area.
- Roads, which are bounded by 3-4, storied buildings on both side of the road and wide-open spaces are really uncomfortable.
- Tree canopies are more comfortable than open spaces during whole day.
- Even in rock areas with vegetation is comfortable than open area in the rock.

6.1. Strategies

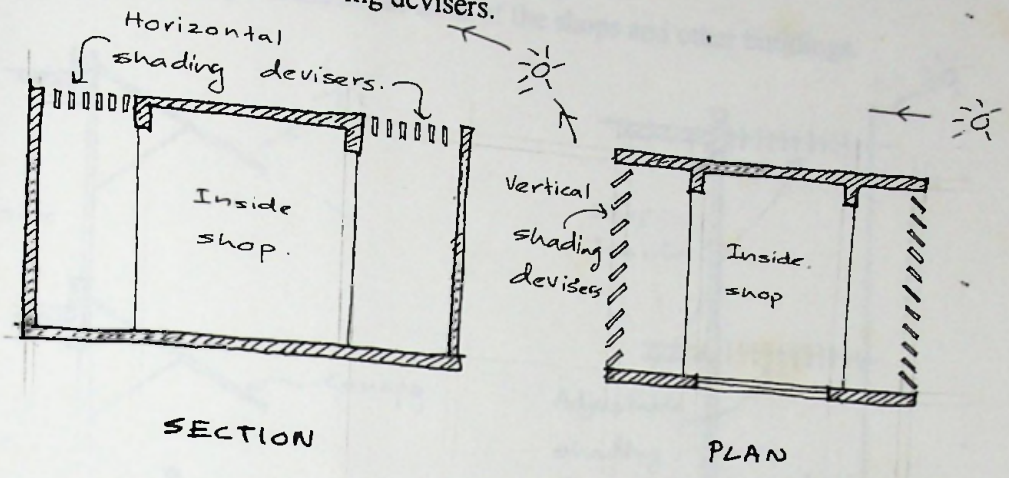
By terracing the floor of the rocks using earth could be convert into comfortable living areas (ex-"Weu gala" and "Ellugala" in the kurunegala.)

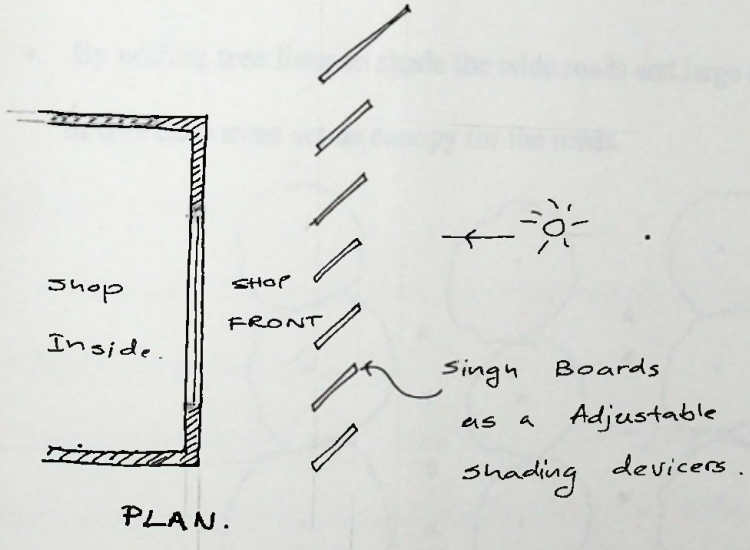


SECTION OF ROCK.

Most of the buildings are orientated to east and west and hence they face major problem due solar radiation. To overcome this problem the following design techniques could be followed.

- By adding adjustable shading devisers.

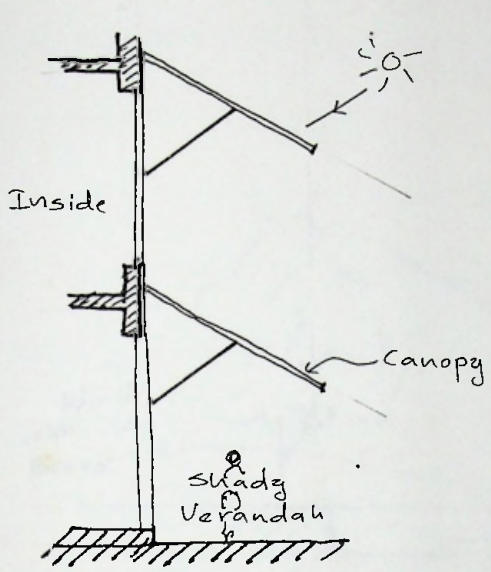


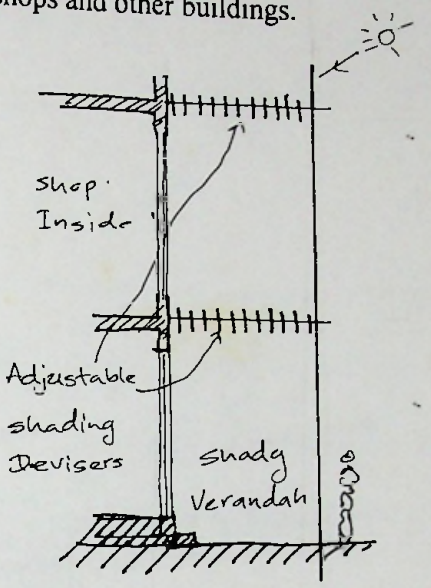


These shading devisers might be vertical or horizontal. Specially in commercial buildings sign boards are gain prominent place. Therefore these signboards also could be used as the shading devices. By adding lightweight shading devisers and canopies, which are made out of the cloth like materials it, will be economically viable.

Shade and the vegetation can be used as major factors for a climate sensitive city in tropical country. Comfortable city could be formed in according to following techniques:

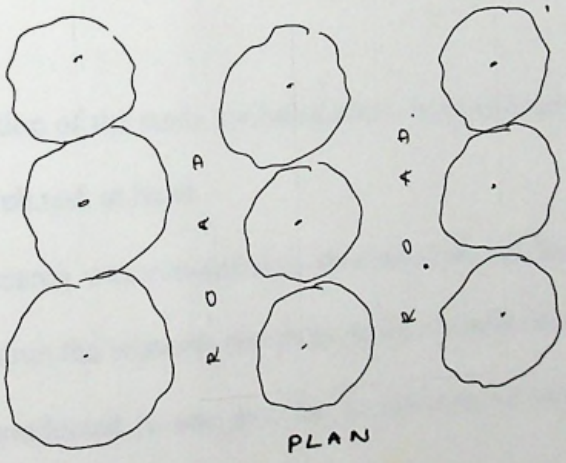
- By creating shady verandahs in front of the shops and other buildings.

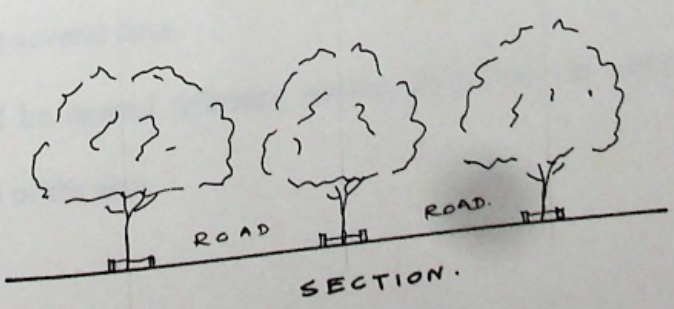




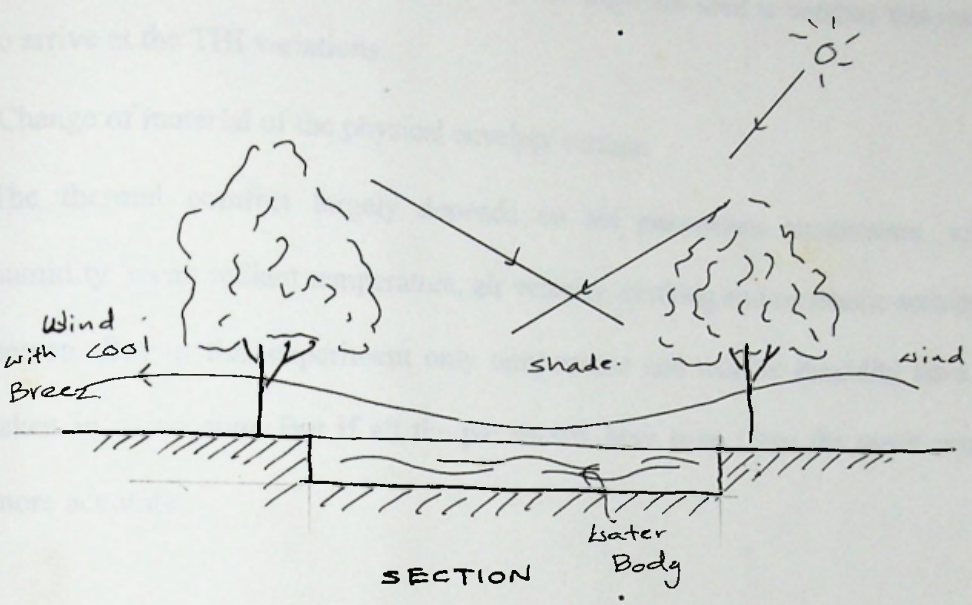
- By adding tree lines to shade the wide roads and large open spaces.

  In this case trees act as canopy for the roads.





Water bodies are being used to wash out the heat from the urban settings. This theory also could apply, when designing the cities.



6.2. Limitations

The envision limitation of the study are listed below in consideration of the scope and the limitation the research task at hand.

- Though this research was conducted in December the coldest month, it should have been done in March the warmest month to obtain a beneficial result.
- This research conducted in one day, but to maintain accuracy it should have been done utilizing several days.
- There should be several reference stations, around the city derive accuracy in the comfort level of the area.

- Accuracy and applicability of data collection.
  - Depends on factors of clouds, position of data points.
  - Human errors (unexplainable results)

- Only two specific periods during the day and night are used to conduct this research to arrive at the THI variations.
- Change of material of the physical envelop/ surface.
- The thermal comfort largely depends on six parameters temperature, relative humidity, mean radiant temperature, air velocity, clothing and metabolic activity of a person. But in this experiment only temperature and relative humidity have been taken in to account. But if all the parameters have been taken the result could be more accurate.

6.3. Areas for Future study.

When considering the Kurunegala city most comfortable place, was on top of the Athugala. There were no trees and open. Perhaps this occurs due to the height. Ground of that space is rock. Therefore there is special thing to study. Studying topic might be as follows:

- **Rock as a building material** (Tiles, Insulation etc.)

Spaces, which are comfortable than other spaces had relationship with the factor, mentioned below.

- Shade of tree or building.
- Water body.

Therefore below mentioned topics may be useful for future studies.

- **Scale of water body, which could add to one building or city.**
- **Type of vegetation, which reduce the air temperature in city, and inside the buildings.**

In addition by studying the,

- **Types and scale of the canopies and shading devisers which could apply in front of the shop fronts** could do good designs for tropical cities.

Construction adhering to the climate, aesthetic and user requirement provides comfort and beauty to the city. When all these are designed using architectural theories a comfortable country could be formed. If all the countries in globe follows this pattern of modern design theories to suite the individual characteristics to suet the nature of the habitat, this world could be wonderful place to live in. In well designed building all these qualities (Eco - friendly, user friendly, etc) are included. These give relaxation to the mind and create musical ideas from the bottom of the heart. And make man closer to spiritual attainment.

Places where, covered rock floors with soil and have vegetation are the most comfortable places in daytime. In addition shady areas with cool breeze are more comfortable in day and night. Ratio between width of the road and height of the trees and buildings govern the comfortable level of the roads.

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"Heat," *Microsoft® Encarta® Encyclopedia 2000.* © 1993-1999 Microsoft Corporation.

"Climate and Terrestrial Biomes," *Microsoft® Encarta® Encyclopedia 2000.* © 1993-1999 Microsoft Corporation.

Appendix

- "**Heat**, in physics, energy transferred from one part of a substance to another or from one body to another, by virtue of a difference in temperature. Heat is energy in transit; it flows from a substance at a higher temperature that is placed in contact with a substance at a lower temperature, raising the temperature of the latter and lowering that of the former, provided the volume of the bodies remains constant. Heat does not flow from a lower to a higher temperature unless work is done."

- **Temperature**

  "The sensation of warmth or coldness on contact with a substance is determined by temperature, by the ability of the substance to conduct heat, and by other factors. Although it is possible, with care, to compare the relative temperatures of two substances by the sense of touch, it is impossible to evaluate the absolute magnitude of the temperatures by subjective reactions."

"Climate and Terrestrial Biomes," *Microsoft® Encarta® Encyclopedia 2000.* © 1993-1999 Microsoft Corporation.

➢ Temperature scales

Several different temperature scales are in use today; they include

1.The Celsius scale,

Known also as the centigrade scale, freezing point, 0° C and a boiling point is 100° C. Most often this is use for scientific works

2.The Fahrenheit scale,

In the Fahrenheit scale, used for scientific work and based on the mercury thermometer, the freezing point of water is defined as 32° F and the boiling point as 212° F.

3.The Kelvin scale,

The most commonly used thermodynamic temperature scale, zero is defined as the absolute zero of temperature that is, -273.15° C, or -459.67° F.

4.The Rankine scale,

Another scale employing absolute zero as its lowest point is the Rankine scale, in which each degree of temperature is equal to one degree on the Fahrenheit scale. The freezing point of water on the Rankine scale is 492° R, and the boiling point is 672° R.

5.The international thermodynamic temperature scale

- **Temperature and precipitation scales**

  Temperature is an important aspect of climate and can be used to grade climatic zones on a scale of five:

(1) Tropical, with annual and monthly averages above 20° C (68° F).

(2) Subtropical, with 4 to 11 months above 20° C, and the balance between 10° and 20° C (50° to 68° F).

(3) Temperate, with 4 to 12 months at 10° to 20° C, and the rest cooler.

(4) Cold, with 1 to 4 months at 10° to 20° C, and the rest cooler.

(5) Polar, with 12 months below 10° C.

Within each hemisphere, eight basic climatologically zones can also be recognized in terms of precipitation:

(1) Equatorial: rain in all seasons.

(2) Tropical: summer rain with winters dry.

(3) Semi-arid Tropical: slight summer rain.

(4) Arid: dry in all seasons.

(5) Dry Mediterranean: slight winter rain.

(6) Mediterranean: winter rain, summers dry.

(7) Temperate: precipitation in all seasons.

(8) Polar: precipitation sparse in all seasons. .

Tables of 30-Year Climatic Data

THI - DAY TIME (1971-2000)

Time	RH	TEMPERATURE	THI
JANUARY	57.2	31.1	28.4
FEBRUARY	46.3	33.5	29.9
MARCH	45.3	35.0	31.2
APRIL	59.6	33.8	31.0
MAY	67.5	32.4	30.3
JUNE	69.8	31.0	29.1
JULY	68.9	32.2	30.2
AUGUST	65.3	30.7	28.5
SEPTEMBER	65.0	31.6	29.4
OCTOBER	68.2	31.3	29.3
NOVEMBER	67.5	31.0	29.0
DECEMBER	65.3	30.4	28.3

THI - NIGHT TIME (1971-2000)

Time	RH	Temperature	THI
JANUARY	82.3	20.8	20.0
FEBRUARY	87.0	21.0	20.5
MARCH	88.5	22.5	22.0
APRIL	90.0	23.8	23.3
MAY	87.4	24.5	23.9
JUNE	86.2	24.3	23.6
JULY	85.2	24.0	23.3
AUGUST	85.1	23.8	23.1
SEPTEMBER	86.4	23.5	22.9
OCTOBER	86.8	22.9	22.3
NOVEMBER	88.3	22.3	21.7
DECEMBER	83.1	21.8	21.0

➢ Data Tables of City Traverse

CITY TRAVERS - "ATHUGALA"DAY TIME (12.12.2002)

Time	Time	Temperature (*C) (1)	RH (%) (1,2)	Dew Point (*C) (1,2)	Temperature (*C) (*4)	THI	Height
12:25	25:00.0	32.76	48.3	20.65	33.05	29.4	126.8
12:26	26:00.0	32.76	49	20.86	33.44	29.4	130.0
12:27	27:00.0	32.76	49.7	21.08	33.44	29.5	135.0
12:28	28:00.0	32.34	46.8	19.79	33.25	28.9	140.0
12:29	29:00.0	32.34	48.2	20.26	31.7	29.0	145.0
12:30	30:00.0	32.34	46.7	19.74	31.32	28.9	147.0
12:31	31:00.0	31.93	46.4	19.3	31.13	28.5	150.0
12:32	32:00.0	31.93	48.7	20.03	30.94	28.7	160.0
12:33	33:00.0	31.52	46.5	18.98	30.37	28.1	190.0
12:34	34:00.0	31.12	45.6	18.3	30.94	27.7	210.0
12:35	35:00.0	30.71	50.8	19.62	31.51	27.7	236.2
12:36	36:00.0	30.71	52.3	20.05	31.13	27.8	239.0
12:37	37:00.0	30.31	50.9	19.29	30.56	27.3	243.3
12:38	38:00.0	29.9	52.6	19.44	29.81	27.1	258.0
12:39	39:00.0	29.5	52.5	19.05	29.25	26.7	271.5
12:40	40:00.0	29.5	53.8	19.43	29.44	26.8	278.0
12:41	41:00.0	29.1	49.7	17.84	29.62	26.2	287.5
12:42	42:00.0	29.5	50.6	18.47	30.56	26.6	290.0
12:43	43:00.0	29.1	49.8	17.89	30.18	26.2	298.0
12:44	44:00.0	29.5	47.5	17.51	31.13	26.4	306.6
12:45	45:00.0	29.5	49.1	18.01	32.47	26.5	335.5

CITY TRAVERS - DAY TIME (12.12.2002)

Date Time	Date Time	Temperature (*C) (1)	RH (%) (1,2)	Dew Point (*C) (1,2)	Temperature (*C) (*4)	THI
1:04	04:00.0	31.12	53.5	20.78	31.13	28.2
1:05	05:00.0	31.12	53.7	20.84	32.28	28.2
1:06	06:00.0	31.52	53.2	21.06	33.25	28.6
1:07	07:00.0	31.93	53.5	21.52	32.86	29.0
1:08	08:00.0	32.34	53.2	21.81	33.44	29.3
1:09	09:00.0	32.76	52.5	21.98	32.66	29.6
1:10	10:00.0	33.17	50.4	21.7	32.28	29.9
1:11	11:00.0	33.59	48.9	21.6	32.08	30.2
1:12	12:00.0	33.59	47.6	21.16	31.7	30.1
1:13	13:00.0	34.85	46.5	21.91	32.66	31.1
1:14	14:00.0	35.7	44.9	22.1	32.86	31.8
1:15	15:00.0	36.13	44.6	22.39	33.64	32.1
1:16	16:00.0	36.13	42.8	21.72	32.47	32.0
1:17	17:00.0	36.13	43.1	21.83	31.89	32.0

1:19	19:00.0	37.44	40.8	22.11	33.25	33.0
1:22	22:00.0	37.88	37.6	21.17	32.47	33.2
1:23	23:00.0	37.88	35.6	20.31	32.86	33.0
1:24	24:00.0	38.32	35.8	20.77	33.64	33.4
1:25	25:00.0	38.77	35.2	20.89	35.04	33.7
1:26	26:00.0	38.77	34.4	20.53	34.04	33.7
1:27	27:00.0	38.77	35.6	21.1	34.63	33.8
1:28	28:00.0	38.77	36	21.24	35.24	33.8
1:29	29:00.0	38.32	36.2	20.98	35.64	33.4
1:30	30:00.0	38.32	35.4	20.63	35.44	33.4
1:31	31:00.0	37.88	37.3	21.04	35.44	33.1
1:32	32:00.0	37.88	35.1	20.1	34.63	33.0
1:33	33:00.0	37.44	33.7	19.11	33.64	32.5
1:34	34:00.0	37.44	32.5	18.56	33.25	32.4
1:35	35:00.0	37	32.3	18.08	33.25	32.0
1:36	36:00.0	36.57	32.9	18.02	32.47	31.7
1:37	37:00.0	36.57	33.5	18.25	32.47	31.7
1:38	38:00.0	36.13	35.4	18.75	31.7	31.5
1:39	39:00.0	35.7	34	17.78	31.13	31.0
1:40	40:00.0	35.27	34.6	17.69	31.32	30.7
1:41	41:00.0	34.85	34.2	17.17	31.32	30.3
1:42	42:00.0	34.85	34.4	17.24	30.75	30.3
1:43	43:00.0	34.43	36.6	17.82	30.56	30.1
1:44	44:00.0	34.01	35.8	17.12	30.75	29.6
1:45	45:00.0	34.01	37	17.64	31.89	29.7
1:46	46:00.0	34.01	38.1	18.08	32.08	29.8
1:47	47:00.0	34.01	37	17.64	32.66	29.7
1:48	48:00.0	34.01	36.6	17.45	32.08	29.7
1:49	49:00.0	34.01	37.7	17.89	31.89	29.8
1:50	50:00.0	34.01	40.1	18.84	32.47	29.9
1:51	51:00.0	34.01	39.9	18.78	33.05	29.9
1:52	52:00.0	34.43	40.9	19.5	33.05	30.4
1:53	53:00.0	34.85	41.3	20.05	32.28	30.8
1:54	54:00.0	34.85	40.3	19.66	32.86	30.7
1:55	55:00.0	34.85	41.5	20.11	32.28	30.8
1:56	56:00.0	35.27	40.6	20.15	31.7	31.1
1:57	57:00.0	34.85	39.7	19.42	31.89	30.6
1:58	58:00.0	34.85	39	19.13	31.51	30.6
1:59	59:00.0	34.85	39.9	19.48	30.94	30.7
2:00	00:00.0	34.85	36.2	18.01	32.08	30.4
2:01	01:00.0	34.85	39.1	19.19	33.44	30.6
2:02	02:00.0	35.7	38.9	19.84	33.25	31.3
2:04	04:00.0	35.7	37.8	19.41	33.05	31.3
2:05	05:00.0	36.13	38.6	20.1	32.28	31.7
2:06	06:00.0	35.7	38.6	19.72	31.7	31.3

2:07	07:00.0	35.7	36.8	18.97	32.86	31.2
2:08	08:00.0	35.7	38.4	19.66	33.05	31.3
2:09	09:00.0	35.7	38.4	19.66	33.25	31.3
2:10	10:00.0	35.7	37.5	19.28	32.86	31.2
2:11	11:00.0	35.7	36.1	18.7	33.25	31.1
2:12	12:00.0	35.7	37.7	19.35	33.64	31.3
2:13	13:00.0	35.7	37.1	19.09	33.84	31.2
2:14	14:00.0	36.13	35.9	18.95	33.44	31.5
2:15	15:00.0	36.13	35.9	18.95	34.04	31.5
2:16	16:00.0	36.57	33.3	18.17	33.84	31.7
2:17	17:00.0	36.57	34.9	18.92	33.25	31.8
2:18	18:00.0	36.57	34.6	18.78	33.05	31.8
2:19	19:00.0	36.57	33.8	18.41	32.86	31.7
2:20	20:00.0	36.57	34.3	18.63	33.44	31.8
2:21	21:00.0	36.57	34.1	18.56	32.86	31.8
2:22	22:00.0	37	34.8	19.24	32.28	32.2
2:23	23:00.0	37	33.8	18.8	32.66	32.1
2:24	24:00.0	37.44	33.4	18.96	32.28	32.5
2:25	25:00.0	37	34.2	18.95	34.23	32.1
2:26	26:00.0	37	31.2	17.55	34.63	31.9
2:27	27:00.0	37	30.8	17.37	34.63	31.9
2:28	28:00.0	37	31.2	17.55	35.64	31.9
2:29	29:00.0	37	30.2	17.07	35.44	31.8
2:30	30:00.0	37	30.2	17.07	35.04	31.8
2:31	31:00.0	37	31	17.46	35.85	31.9
2:32	32:00.0	37	29.8	16.87	36.05	31.8
2:33	33:00.0	36.57	29.1	16.14	36.88	31.4
2:34	34:00.0	36.57	32.6	17.85	37.5	31.6
2:35	35:00.0	36.57	30.7	16.97	37.08	31.5
2:36	36:00.0	36.57	30.1	16.67	36.88	31.5
2:37	37:00.0	36.57	30.1	16.67	36.67	31.5
2:38	38:00.0	36.57	29.7	16.47	37.08	31.4
2:39	39:00.0	36.13	29.4	15.95	36.05	31.0
2:40	40:00.0	35.7	29.7	15.76	36.05	30.7
2:41	41:00.0	35.7	31.3	16.55	36.88	30.8
2:42	42:00.0	35.7	31.7	16.73	36.88	30.8
2:43	43:00.0	36.57	29.7	16.47	34.43	31.4
2:44	44:00.0	37.44	29.3	16.96	34.04	32.1
2:45	45:00.0	37.44	29.5	17.07	33.64	32.2
2:46	46:00.0	37.88	28.7	17.05	34.04	32.5

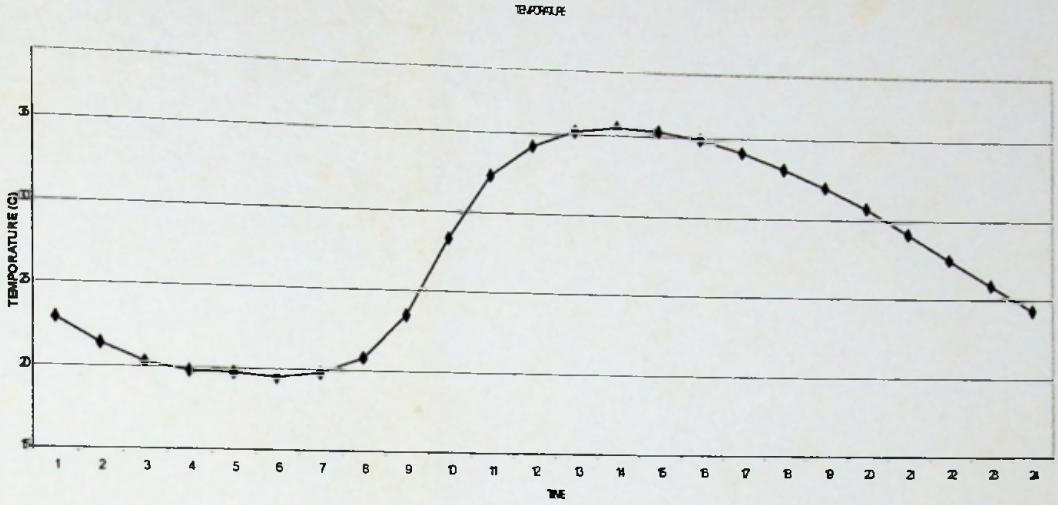
CITY TRAVERS - "ATHUGALA"DAY TIME (12.12.2002)

Date Time	Date Time	Temperature (*C) (1)	RH (%) (1,2)	Dew Point (*C) (1,2)	Temperature (*C) (*4)	THI
7:58	58:00.0	25.17	80	21.63	25.8	24.2
7:59	59:00.0	25.56	78.2	21.65	25.98	24.4
8:00	00:00.0	25.56	79.1	21.82	25.62	24.5
8:01	01:00.0	25.56	78.2	21.65	25.09	24.4
8:02	02:00.0	25.56	78.2	21.65	24.38	24.4
8:03	03:00.0	25.56	77.4	21.49	24.38	24.4
8:04	04:00.0	25.56	77.4	21.49	24.38	24.4
8:05	05:00.0	25.56	78.2	21.65	24.38	24.4
8:06	06:00.0	25.56	79.1	21.82	23.86	24.5
8:07	07:00.0	25.17	78.3	21.29	23.86	24.1
8:08	08:00.0	25.17	79.1	21.46	24.03	24.1
8:09	09:00.0	25.17	80	21.63	24.03	24.2
8:10	10:00.0	25.17	80	21.63	23.86	24.2
8:11	11:00.0	25.17	78.3	21.29	23.86	24.1
8:12	12:00.0	25.17	80	21.63	23.86	24.2
8:13	13:00.0	24.79	80.9	21.46	24.21	23.8
8:14	14:00.0	24.79	80.9	21.46	24.38	23.8
8:15	15:00.0	24.79	81.9	21.65	24.74	23.9
8:16	16:00.0	24.79	83	21.85	24.91	23.9
8:17	17:00.0	25.17	84.1	22.44	24.56	24.4
8:18	18:00.0	25.17	84.1	22.44	24.74	24.4
8:19	19:00.0	25.17	83	22.22	24.91	24.3
8:20	20:00.0	25.56	79.1	21.82	24.91	24.5
8:21	21:00.0	25.95	78.2	22.01	25.09	24.8
8:22	22:00.0	25.95	78.2	22.01	25.27	24.8
8:23	23:00.0	25.95	79	22.18	25.09	24.9
8:24	24:00.0	26.34	78.2	22.38	24.91	25.2
8:25	25:00.0	26.34	75.2	21.76	24.03	25.0
8:26	26:00.0	26.34	74.6	21.63	24.03	25.0
8:27	27:00.0	26.34	74.6	21.63	23.86	25.0
8:28	28:00.0	26.34	73.9	21.49	23.86	25.0
8:29	29:00.0	26.34	75.2	21.76	24.03	25.0
8:30	30:00.0	26.34	75.9	21.91	24.21	25.1
8:31	31:00.0	26.34	76.6	22.06	24.21	25.1
8:32	32:00.0	26.34	77.4	22.21	24.56	25.1
8:33	33:00.0	26.34	78.2	22.38	24.74	25.2
8:34	34:00.0	26.34	79	22.55	24.74	25.2
8:35	35:00.0	26.73	79.8	23.09	25.09	25.7
8:36	36:00.0	26.73	79.8	23.09	24.91	25.7
8:37	37:00.0	26.73	80.8	23.28	24.91	25.7
8:38	38:00.0	27.12	80.7	23.65	24.91	26.1
8:39	39:00.0	27.12	79.8	23.46	25.09	26.0

8:40	40:00.0	27.12	79.8	23.46	25.62	26.0
8:41	41:00.0	27.12	79.8	23.46	25.62	26.0
8:42	42:00.0	27.12	78.9	23.28	25.44	26.0
8:43	43:00.0	27.12	78.1	23.1	25.27	25.9
8:44	44:00.0	27.12	78.1	23.1	25.09	25.9
8:45	45:00.0	27.12	76.5	22.78	25.27	25.8
8:46	46:00.0	27.12	77.3	22.94	25.09	25.9
8:47	47:00.0	27.12	77.3	22.94	24.91	25.9
8:48	48:00.0	27.12	77.3	22.94	24.74	25.9
8:49	49:00.0	27.12	76.5	22.78	24.74	25.8
8:50	50:00.0	27.12	75.8	22.63	24.91	25.8
8:51	51:00.0	27.12	75.1	22.48	24.91	25.8
8:52	52:00.0	27.12	74.5	22.34	24.74	25.7
8:53	53:00.0	27.12	74.5	22.34	24.74	25.7
8:54	54:00.0	26.73	74.5	21.98	24.74	25.4
8:55	55:00.0	27.12	75.8	22.63	25.09	25.8
8:56	56:00.0	27.12	77.3	22.94	25.44	25.9
8:57	57:00.0	27.12	77.3	22.94	25.98	25.9
8:58	58:00.0	27.12	77.3	22.94	25.8	25.9
8:59	59:00.0	27.12	77.3	22.94	25.98	25.9
9:00	00:00.0	27.12	76.5	22.78	26.16	25.8
9:01	01:00.0	27.12	74.5	22.34	26.16	25.7
9:02	02:00.0	27.12	75.1	22.48	25.98	25.8
9:03	03:00.0	27.12	75.8	22.63	26.34	25.8
9:04	04:00.0	27.12	75.8	22.63	25.98	25.8
9:05	05:00.0	27.52	75.8	22.99	25.98	26.2
9:06	06:00.0	27.52	75.8	22.99	25.98	26.2
9:07	07:00.0	27.52	74.4	22.71	25.8	26.1
9:08	08:00.0	27.52	72.6	22.31	25.62	26.0
9:09	09:00.0	27.52	72	22.19	25.44	26.0
9:10	10:00.0	27.52	70.5	21.84	25.09	25.9
9:11	11:00.0	27.52	69.1	21.52	24.91	25.8
9:12	12:00.0	27.52	68.6	21.41	24.91	25.8
9:13	13:00.0	27.91	69	21.87	24.91	26.2
9:14	14:00.0	27.91	68.1	21.67	24.91	26.1
9:15	15:00.0	27.91	69	21.87	24.74	26.2
9:16	16:00.0	27.91	69	21.87	24.74	26.2
9:17	17:00.0	27.91	69	21.87	24.91	26.2
9:18	18:00.0	27.91	69	21.87	24.74	26.2
9:19	19:00.0	27.91	69.5	21.98	24.56	26.2
9:20	20:00.0	27.91	69.9	22.08	24.56	26.2
9:21	21:00.0	27.91	69	21.87	24.56	26.2
9:22	22:00.0	27.91	68.6	21.77	24.91	26.2
9:23	23:00.0	27.91	69	21.87	25.09	26.2

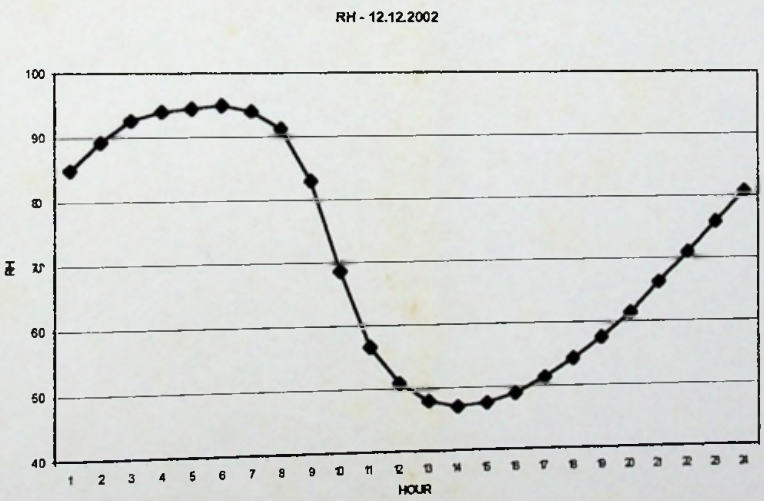
9:24	24:00.0	27.91	70.4	22.19	25.09	26.3
9:25	25:00.0	27.91	71.5	22.43	25.27	26.3
9:26	26:00.0	27.91	72.6	22.67	25.44	26.4
9:27	27:00.0	28.31	70.9	22.67	25.09	26.7
9:28	28:00.0	28.31	70.4	22.55	25.09	26.6
9:29	29:00.0	28.31	67.6	21.92	24.91	26.5
9:30	30:00.0	28.31	67.6	21.92	24.74	26.5
9:31	31:00.0	28.31	68.5	22.12	24.38	26.5
9:32	32:00.0	27.91	69	21.87	24.03	26.2
9:33	33:00.0	27.91	70.9	22.31	24.03	26.3
9:34	34:00.0	27.91	72	22.55	23.86	26.3
9:35	35:00.0	27.91	72.6	22.67	24.03	26.4
9:36	36:00.0	27.91	70.9	22.31	24.38	26.3
9:37	37:00.0	27.91	70.4	22.19	24.21	26.3
9:38	38:00.0	27.91	70.4	22.19	24.21	26.3
9:39	39:00.0	27.91	71.5	22.43	24.21	26.3
9:40	40:00.0	27.91	71.5	22.43	24.56	26.3
9:41	41:00.0	27.91	72	22.55	24.91	26.3
9:42	42:00.0	27.91	71.5	22.43	25.27	26.3
9:43	43:00.0	27.91	70.9	22.31	25.27	26.3
9:44	44:00.0	27.52	71	21.95	25.27	25.9
9:45	45:00.0	27.52	71.5	22.07	24.91	26.0
9:46	46:00.0	27.52	71	21.95	24.74	25.9
9:47	47:00.0	27.52	70.5	21.84	24.56	25.9
9:48	48:00.0	27.52	70.5	21.84	24.56	25.9
9:49	49:00.0	27.52	71	21.95	24.03	25.9
9:50	50:00.0	27.52	70.5	21.84	23.51	25.9
9:51	51:00.0	27.52	71	21.95	23.33	25.9
9:52	52:00.0	27.12	71	21.59	23.51	25.5
9:53	53:00.0	26.73	72.2	21.47	23.33	25.2
9:54	54:00.0	26.73	73.3	21.72	23.16	25.3
9:55	55:00.0	26.73	73.9	21.85	22.81	25.3
9:56	56:00.0	26.73	73.9	21.85	22.64	25.3
9:57	57:00.0	26.34	73.3	21.36	22.81	24.9
9:58	58:00.0	26.34	73.3	21.36	22.98	24.9
9:59	59:00.0	25.95	74	21.14	22.98	24.6
10:00	00:00.0	25.95	74	21.14	23.33	24.6

- **Temperature And RH Variation During 24 Hours - Charts (12.12.2002).**



Temperature variation within 12.12.2002

(Source-



Relative humidity variation within 12.12.2002

(Source-

KURUNEGALA M.C. AREA

Prepared By :

Dy. Director :

Director Planning :

Scale 1:17500

URBAN DEVELOPMENT AUTHORITY
SUB OFFICE, KURUNEGALA

Date :