_ 2
PRE_PLANNING

"... the environmental crisis is a design crisis. It is a consequence of how things are made, buildings are constructed and landscapes are used..."

[Guy 2002:228]

2.1 CARBON AND A CHANGING CLIMATE

Climate change is a complex problem that has a series of consequences on the living and built environment. In the last few years the relationship between climate change and carbon has become more important. As indicated in the Graph 2-01 the rate at which the global average temperature has risen has increased at the same rate the greenhouse gases in our atmosphere.

With the increase in greenhouse gasses in the earth's troposphere, more heat is trapped within the earth's atmosphere.
This leads to an increase in energy content in the atmosphere causing long term weather pattern changes and extreme weather events [Walker & King 2008:49]. This inturn leads to rising sea levels, food and water shortages, effects the human health and a loss in global biodiversity [Discussed in detail in section 2.1.5].

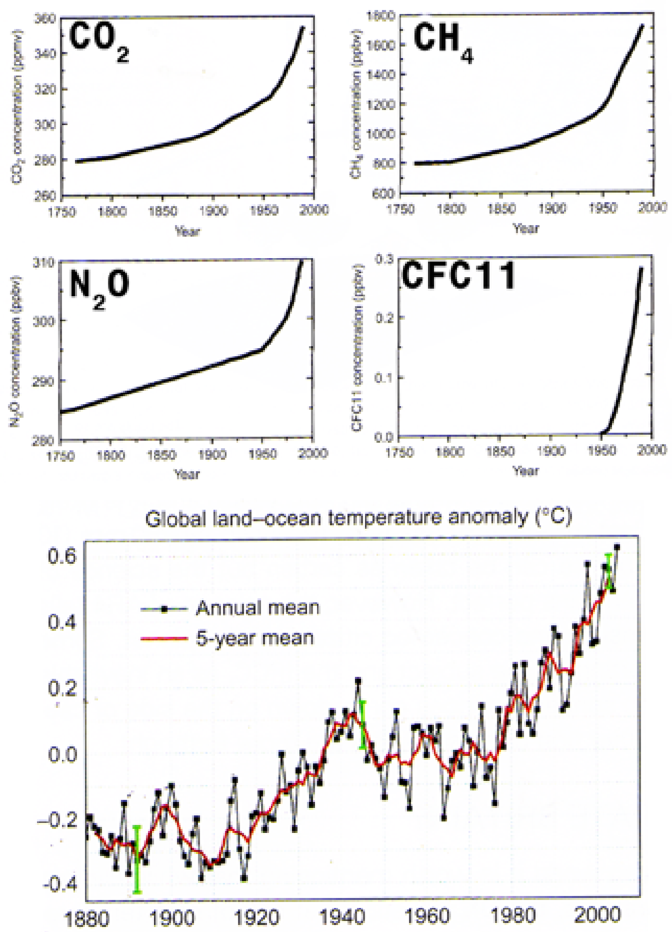
One of the sectors that plays a big part in this is the built environment.
When designing buildings in the urban context in a climate that is changing the designer needs to address the following two issues:

a) How does one adapt the existing structures or new structures to accommodate the change in climate patterns in the next 30 years?
b) How does one mitigate climate change through architecture?

Understanding climate change and its consequences for Tshwane equips the designer to design robust buildings with a longer life cycle in a climate that is changing

2.1.1 Changing into a global problem

For many years the existence and impact of climate change was debated by many scientists around the world. The possible impact of global climate change was first discussed in the 1968 at the first meeting of the Club of Rome [Roaf et al 2009:7]. Yet only in the mid 1980's did scientific simulations shown clear evidence of what is happening, after which the Intergovernmental Panel on Climate Change [IPPC] was founded in 1988 [Freed 2008:220].



Graph 2-01: The increase in greenhouse gasses from 1880-2000
[Source: Roaf et al, p 4 &52]

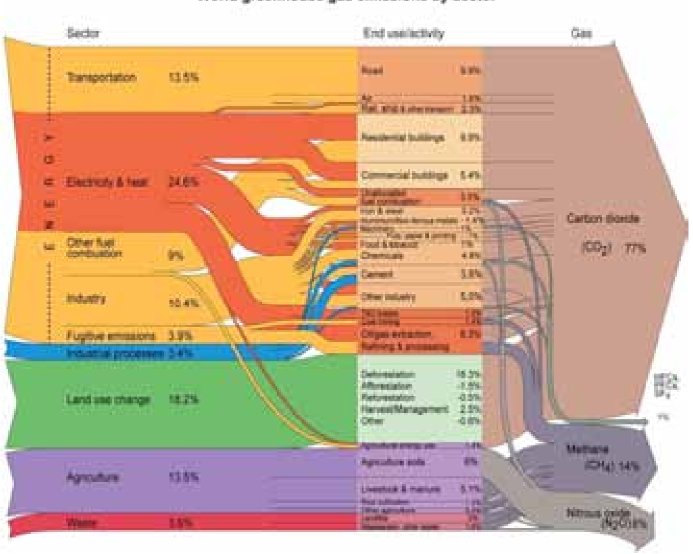


Figure 2-05: Diagram indicating the sources of greenhouse gasses
[Source: IPPC website accessed 26 Feb 2010]

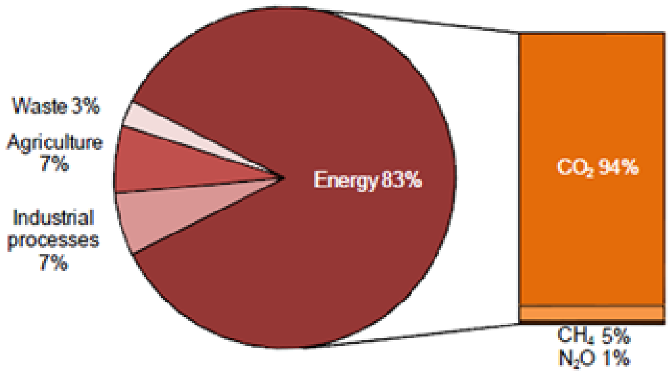


Figure 2-06: The sectors causing in GHG emissions [Source: IEC 2009 p 8]

For a long period the true cause and impact of climate change wasn't clear and **only in 2007 did the IPCC state that it is 90% sure that climate change is indeed manmade and will "...continue for centuries"** [Freed 2008:221; King& Walker 2008:13].

In 1997 the Kyoto Protocol was adopted, requiring developed countries to cut down their greenhouse gas emissions to 5% below 1990 figure by 2012. In 2005 the protocol came into force and was ratified by 184 nations [UNFCCC homepage 2010]. It was not aimed at solving the problem but at starting the mitigation process [Bennet 2003:116 & Miller 2004:295].

In December 2009 the COP 15 was held in Copenhagen, yet little progress has been made regarding the acceptance of legislation or taking definitive action to mitigate the effects of climate change [Walsh 2009:01]. Hopes that countries will recommit themselves to the Kyoto protocol were dashed, leaving the global community yet again without a focussed direction to reducing global greenhouse gasses.

2.1.2 Greenhouse gasses

Even though greenhouse gasses make up only a fraction of the earth's atmosphere, the "...heat trapping ability..." of these gasses keeps the earth's temperature in check [Bennet et al 2003:111]. Greenhouse gasses are transparent to short waves but opaque to long waves which allow the heat rays of the sun to penetrate the earth's atmosphere but not to reflect heat back into space.

The problem arises when the quantities of greenhouse gasses increases beyond the natural balance that promotes life on earth.

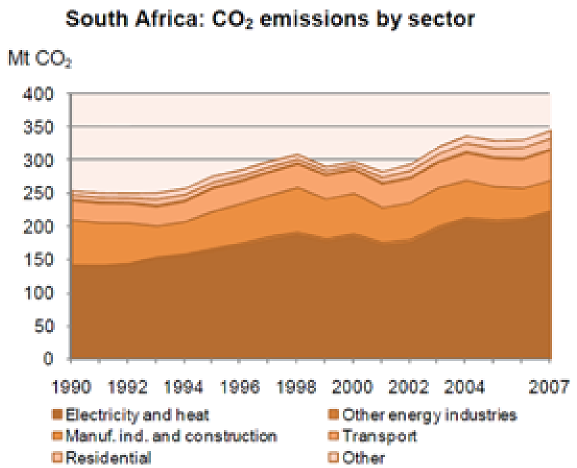
Greenhouse gasses are a collective name for the following gasses: carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Water vapour (H_20) and Halocarbons (CFC-11 and CFC-12) [Bennet et al 2003:112]. To this list one could add hydroflurocarbons as well as carbon tetrachloride [Miller 2004:282].
These different gasses are all produced by human practices such as energy production, consumption, industrial and agricultural as well as ecological processes
[Awuor et al 2008:231].

The Kyoto Protocol employs a system of equating the different greenhouse gasses and their effects. This is called the GWP 100 values. As shown in Table 01 the warming effect [up to 100 years after its emission] of a gas is equated to a single CO_2 equivalent [Sekiyo & Okamoto 2010:364]. These CO_2 eq are used to assess life cycle assessment [LCA] and life cycle climate performance [LCCP].

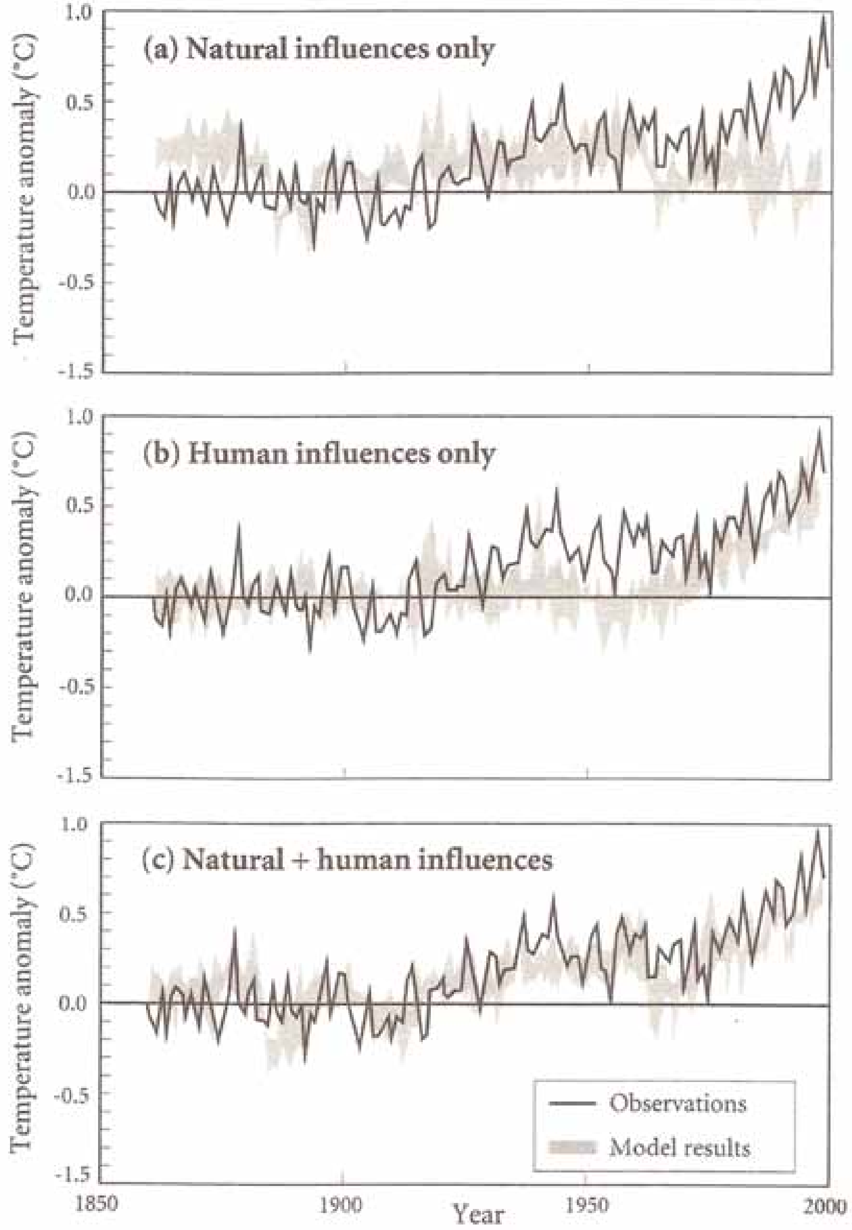
In South Africa the main contributor to greenhouse gasses is the burning of fossil fuels for energy generation as well as other forms of combustible energy sources [Du Plessis et al 2003:244]. South Africa is among the top 20 green house gas emitting countries and contributes 2% of the global CO_2 eq emissions. This amounts to 41% of Africa's total greenhouse gas emissions [Du Plessis et al 2003:244].

COMMON NAME	CHEMICAL FORMULA	LIFETIME [time in toposphere]	Human Sources	Relative warming potential [compared to CO_2]
Carbon dioxide	CO_2	-	Burning of fossil fuels, deforestations	1
Methane	CH_4	12 years	Agriculture, cattle herd, landfill sites , natural gasses	23
Nitrous Oxide	N_2O	114-120	Burning of fossil fuels, fertilizers, life stock waste	296
Chlorofluorocarbons	CFC's	11 - 20	Air conditioners, refrigerators, plastic foams	900-8300
Hydrofluorocarbons	HCFC's	9-390	Air conditioners, refrigerators, plastic foams	470-2 000
Hydroflurocarbons	HFC's	15-390	Air conditioners, refrigerators, plastic foams	130-12 700
Halons		65	Fire extinguishers	5 500
Carbon Tetraclhoride		42	Cleaning agent	1400

Table 2-01: Carbon equivalent values [Source: Miller, p 282]



Graph 2-02: Graph indicating the sectoral contribution to GHG emissions [Source: IEC 2009:21]



Graph 2-03: Graphs indicating the increase temperature and the influences [Source: Walker & King, p 22].

The quantities of greenhouse gasses in the atmosphere has fluctuated over millions of years. It is measured in parts per million [PPM] and is related to a CO_2 eq number. During the ice age the CO_2 eq in the atmosphere was 180-190 PPM CO_2 eq. During the warmer periods during the preindustrial age it ranged around 290 PPM CO_2.

At the turn of the 20th century the CO_2 levels ranged between 260-290 ppm. The change in the atmosphere can be attributed to the development of the Industrial Revolution [Walker & King 2008:22] though no significant increase was measured.

In 2007 the measured value of CO_2 levels ranged at 383 ppm CO_2 eq which is 40% higher than at the start of the 20th century, yet Walker & King [2008:22] states that because of the presence of methane and the rate at which CFC's destroy the ozone, it would be more accurate to state that the levels are closer to 430 ppm CO_2 eq.

In Graph 2-03 the increase in greenhouse gasses in the earth's atmosphere and the temperature increase are clearly shown. It was found that globally there has been an average increase of 0.6 °C [Engelbrecht 2010].

2.1.3 PREDICTED CLIMATE CHANGE IN AFRICA AND SOUTHERN AFRICA

According to the fourth IPCC assessment on climate change [2007] the following can be expected in South Africa and Southern Africa:

If the emission rates are kept at a level of high to medium **the average air temperature increase for Africa could be expected to be between 3-4 °C [period 2080-2099].** Yet the average temperature rise in Southern Africa could be expected to be 3.7 °C in summer. What is alarming though is that for the period 2070-2099 between September to November an average temperature increase of 7 °C can be expected [IPCC 2007].

The increase of vegetation in these warmer conditions will help to cool the average temperature, by up to 0.8 °C [IPPC 2007]. Yet in an urban environment this lowering in temperature cannot be expected as the heat island effect will increase the average temperature.

The IPCC assessment on climate change [2007] states that the whole of Africa will experience a decline in rainfall, with a likely decrease in the Mediterranean, North Sahara, West coast and Southern Africa. In the western parts of Southern Africa a 40% decrease in precipitation is predicted.

In contrast, significant regional climate changes will occur, with the central and eastern plateau and Drakensberg regions possibly experiencing higher summer rainfalls [IPCC 2007]. Yet according to Meadow & Hoffmann [2003:177] the increase in rainfall will not necessarily mean a higher moisture content in the soil, as a lot of the moisture would be lost to evo-transpiration due to higher average air temperatures.

An increase in humidity can be expected in the central plateau of South Africa [Mason et al 2003:254] but this will not mean an increase in groundwater. One issue of concern though is the fact that the number of rainfall days during the summer will decrease, yet increase in its intensity [IPPC 2007 & Mason et al 2003:254].

Water resources will decline significantly and become increasingly vulnerable.

NOTE: The following information regarding the figures predictions for Southern Africa and South Africa might change as the IPCC [2007] states that there is a lack of computational facilities as well as a lack in human resources to process information and collect data in Africa.

2.1.4 The impact of climate change

Climate change has a series of effects each with dangerous global consequences:

Loss of biodiversity
Global biodiversity is at serious risk with 30-50% of all biodiversity on earth bound to be lost by the end of the century [Walker & King 2008:41]. This can be attributed to changing weather patterns occurring , too fast for species to migrate or adapt, as noted by Rutherford et al [1999:11]. Fire frequencies will also increase, causing the degradation of the leftover green environment. With the expected hot and humid climates the reproduction of diseases will increase significantly, causing an increase in their transmittance [Rutherford et al 1999:7 & Walker & King 2008: 41].

Droughts
Africa, especially east Africa, will experience severe droughts, because of the cooling of the Northern Atlantic [Walker & King 2008:47]. **This will lead to increasing pressure on water resources, by 2020 up to 250 million people could be exposed to water shortages.** Much shorter planting periods would cause a shortage of food with rain fed agriculture dropping by up to 50% [Ramos & Kahla 2009:262].

Extreme weather patterns
The Research Centre on the Epidemiology of Disasters has noted that there has been **a major increase in climate related natural disasters** [Sherbinin et al 2001:40]. This can be related to the increase in heat and energy in the earth atmosphere, especially the surface temperature of the ocean [Walker & King 2008:49]. Though this will not necessarily increase the frequency of extreme weather events; the intensity and duration of these events are noted to have increased [Sherbinin et al 2007:40].

Heat waves.
The increase in the frequency and intensity of heat waves [Kovats &Akhtar 2008:170]can be linked to the fact that the earth's ambient temperature has increased, making the odd spike in temperature all the more dangerous. **The warmer, dryer summers in many cities will contribute significantly to the occurrence of heat waves** [Walker & King 2008:50&55].

Rising sea levels and flooding
As noted by Sherbinin et al [2007:39] by 2015 5% of the world's population [more than 400 million] will be living in megacities ,two thirds of which are coastal cities.

With rising sea levels many coastal cities are at risk. It is estimated that three billion humans live in coastal cities. **The rising sea levels will lead to excessive erosion and loss of top soil and place severe stress on the living (available) space with in these cities** [Walker & King 2008:56].

Food supply and sources

While food production is predicted to be on the increase on the middle to higher latitudes, it is Africa that is going to suffer the most severely in terms of food shortages [Walker & King 2008:56]. In the central latitudes the average temperature will increase significantly, making it too warm for most existing plant types to be grown [ibid]. Ramos and Kalha [2009:262] also reports that **food production will drop significantly with rain-fed agriculture dropping by 50%.**

In Africa the following changes can be expected:

- **a)75-250 million people in Africa will face water shortages**
- **b)A drop of up to a 50% in agriculture production will occur**
- **c)Malaria range to decrease in Southern Africa, but will extend into the Eastern Highlands**
- **d)Large coastal cities such as Lagos and Alexandria will be at risk**
- **e)The occurrence of heat waves will increase**

[Walker & King 2008:60-61]

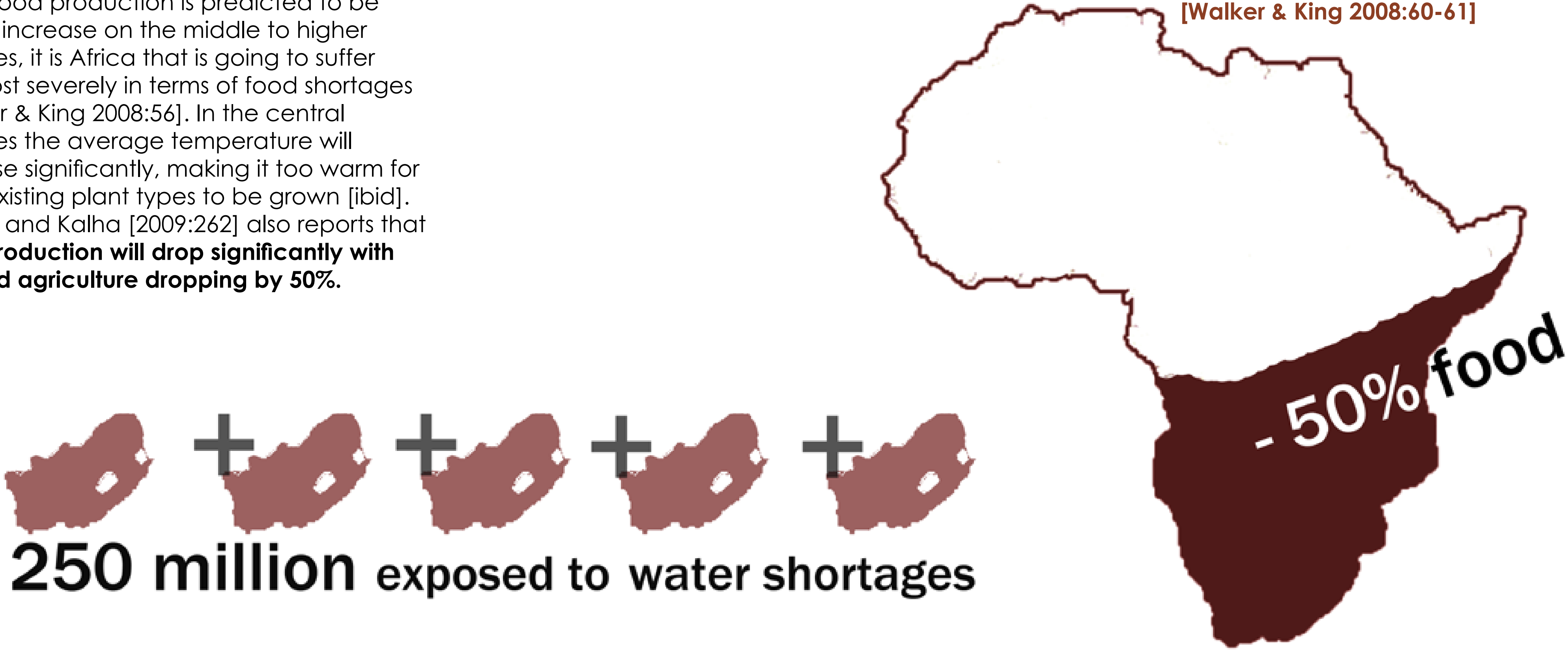


Figure 2-07: Predicted food and water shortages caused by climate change [Source: Author]

2.1.5 Climate change and the urban environment

The effect of climate change on the urban environment will be even more severe due to an increase in emissive sources and density of inhabitants. As stated by Awuor et al [2008:232] one can expect an increase in energy, food and water consumption, all of which will exacerbate the other impacts of climate change.

The current global trend indicates that urbanization is occurring at an increased rate. In 2007, 50% of the world's population was urbanised, which will increase to 75% by 2050 [Burdett & Rode 2007:9]. Large parts of the population will be at risk; the majority of the affected population will be poor and unable to prepare for or adapt to the shocks of extreme weather conditions [Sherbinin et al 2007:40].

There is a series of health risks that will affect urban populations, ranging from illnesses caused by the increased distribution of infectious diseases, to deaths caused by heat waves, floods, storms, fires and droughts [Awuor 2008:232]. Water-/ food-borne diseases will escalate along with the increase in severity of storms and drought conditions leading to low levels of flowing water and bad water quality [Kovats & Akhtar 2008:16].

Most structures will not be comfortable or liveable within 30 years from now, as climate change will increase the ambient heat significantly [Chow et al 2002:233]. Bennet et al [2003:113] state that **the heat island effect in urban areas can contribute to climate change temperature increases of up to 10 °C more than in nearby rural areas .** The problem of heat island effects within the urban environment will have to be mitigated in order to achieve thermally comfortable buildings.

With solar irradiance increasing, building materials must be used that will withstand the heat as well as insulate more efficiently [Chow et al 2002:231].

Walker and King [2008:55] warn that the dryer, warmer summers will lead to more severe heat waves. With the increase in temperature comes an increase in fires in urban environments, as was experienced on Greece's mainland in 2007 with widespread fires during the high summer period. Buildings and urban open spaces will have to be adapted to deal with higher temperatures and the possibility of fire exposure.

The heat island effect will cause extreme climatic conditions which will result in increased rainfall over shorter time periods, intensified thunderstorms [electrical storms] and an the increase in hail storms and their intensity [Kovats & Akhtar 2008:161].

Even though there will be an increase in the severity of precipitation, Kovats & Akhtar [2008:166] state that the IPCC has predicted that water sources will become more vulnerable. Most water will be lost to storm water runoff as the intensity of rain storms increases. The access to and quantity of fresh water resources will decrease severely [Awuor 2008:235], prompting city dwellers to start recycling water and harvest rainwater.

Awuor [2008:242] calls for early warning systems ranging from highly technical meteorological sensors to low-tech human reaction groups. In Bangladesh groups of cyclists with whistles convey information regarding impending storms to the public in the street [Walker & King 2008:67]. The use of soft and hard engineering to adapt cities to possible threats, as well as the protection and reuse of resources such as water, is also important to ensure survival [Awuor 2008:239 -240].

2.1.6 Climate change conclusions

Climate change leads to a series of adverse effects, causing changes to global weather patterns as well as micro climates in the urban environment. It is clear that the safety of city dwellers will become increasingly important to address.

At the same time natural resources will become even more vulnerable and scarce, demanding that society will have to become more responsible with how these resources are used and preserved.

In order to respond to these changes one must first understand the local urban context and the local effects of climate change, so that the necessary precautions can be taken.

Figure 2-08: Heatwaves and increasing affect of fire ["The great Chicago Fire" - [http://contentloco.com/travel/top-things-you-should-know-about-chicago.aspx]

2.2 CLIMATE CHANGE AND CARBON IN TSHWANE

"Cities are the defining ecological phenomenon of the twenty-first century."

[Newman & Jennings 2008:02]

Cities are areas where massive changes can be made that would either cause or mitigate climate change. Globally cities have recognised the importance of sustainable development. Since 1994 Seattle has implemented a comprehensive sustainability plan with emphasis on the following:

1. Linking and integration of sectors and areas
2. Inclusion of all stakeholders
3. Long-term visions and goals [thinking past annual budgets]
4. Quality and diversity of interventions

[Ruano1999:152]

Tshwane should plan its sustainable interventions and mitigation strategies with the same intension. **Large interventions with long term visions are needed in this city.** These must aim to empower and integrate all sectors of the local population. The aim must be on developing high quality systems within the city that addresses the very quality of life.

In Bogotá, Columbia, the BRT transport system was integrated with green belts, cycle lanes, car-free days and road restrictions [Newman & Jenning 2008:142]. All these strategies and interventions were implemented to promote a more pedestrian friendly and humane city.

2.2.1 Tshwane, seperation and transport system

Tshwane is a typical South African city that was changed significantly during the Apartheid era [Du Plessis et al 2003:243]. It developed as a centralised, dense city contained within its natural boundaries [Holm 1998:60].

In 1923, under the Group Areas Act of the Apartheid era,**the city was fragmented into segregated racial zones** [Chipkin 1998:160], resulting in a city with isolated and dislocated suburbs where the poorest of the population were forced to stay the furthest from the city centre [Du Plessis et al 2003:243].

In 2000, six years after the establishment of a free democracy, these segregated urban areas were integrated into one city. The municipal area of Pretoria changed its name to the City of Tshwane, effectively doubling the urban area but remaining as a fragmented low-density metropolis [Berstein & Mcharthy s.a:1].

The low-density nature of this metropolis has led to an unsustainable and energy inefficient public transport system
[Du Plessis et al 2003:252].

The first phase of the BRT system aims to connect the northern suburbs of Tshwane with the city centre [Advanced Logistics Group 2008:4]. This will encourage corridor development as well as improve the lives of the population staying in area
[Pienaar et al 2007:426].

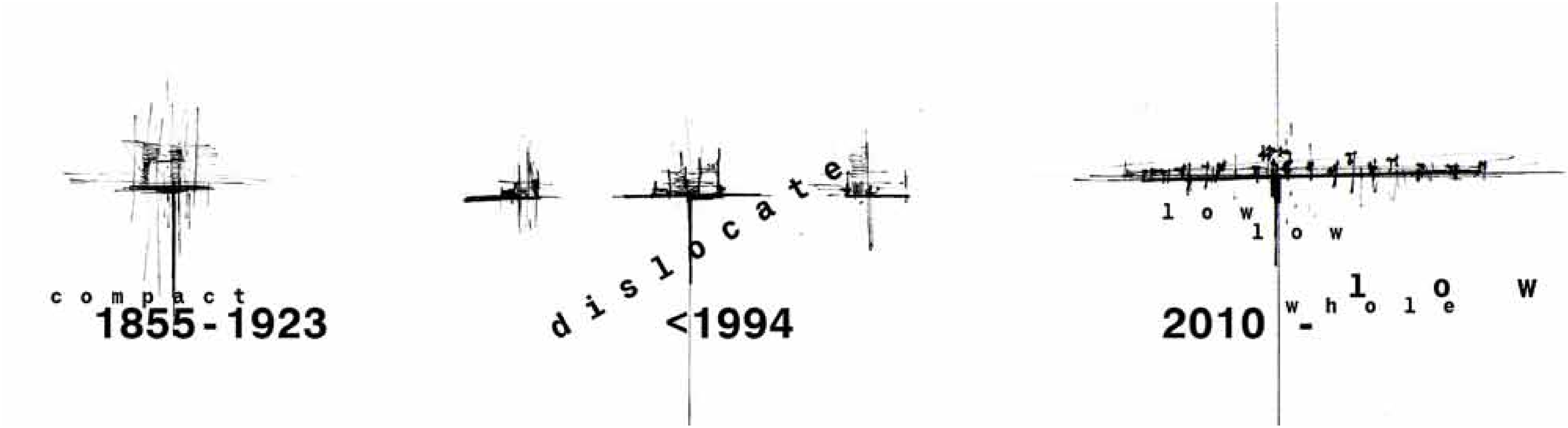


Figure 2-09: From Pretoria to Tshwane – compact to low density [Source: Author]

2.2.2 Tshwane and climate change today

Climate change has global effects that can be measured and predicted, yet regionally these changes can be very different from each other and very difficult to predict. These predictions are, according to F Engelbrecht [Principal Researcher Atmospheric Modelling at the CSIR], only broad indication and not necessarily accurate.

In research done to assess the global temperature increase and compare it to Southern Africa's climate, it was found that globally there has been an average increase of 0.6 °C, while during the same period in the central area of South Africa there has been a temperature increase of 1.4-1.6 °C. This can be attributed to the high pressure system that forms over this area and drives moisture and clouds away, making this area extremely susceptible to temperature increases [Engelbrecht 2010].

This means that in the event of a CO_2 eq increase to 560ppm by 2060, **an average temperature increase of 4°C in summer and 6°C in winter can be expected for Tshwane.** This is double the global average temperature increase in winter [Engelbrecht 2010]. It could lead to a need for less in winter yet cooling of indoor environments in summer will become vital.

In winter the subtropical belt will be enhanced, leading to a generally dryer Southern Africa, with especially dry areas in the Western Cape. On the whole South Africa will be dryer, yet the central regions will experience a small increase in rainfall [Engelbrecht 2009:1032]. **The rainfall in Tshwane might be a little more in the next 60 years. Unfortunately the intensity of the rainfall will increase while fewer rainy days are to be expected [section 2.1.4]. Great volumes of valuable water will be lost in the process due to unmanaged stormwater runoff [Engelbrech 2010].**

Very little research has been done with respect to climate change in Africa [Engelbrecht 2009:1013], thus information regarding relative humidity and wind patterns has not been analysed or researched. According to Engelbrech [2010] one can expect a lower humidity during the winter period in spite of an increase in air temperature

2.2.3 Responding to climate change in the urban environment

“[E]xposed, vulnerable, energy-profligate buildings” [Roaf et al 2008:344] are still being designed, even though the problems and effects of sustainability and climate change are well known to our 21st century society. To ensure the sustainability of buildings designers must design new structures to adapt to the climate changes that can be expected in the future.

By adapting to these forecasts the energy efficiency of structures will increase, in the process mitigating climate change.

Within the urban context, buildings and street materials must be designed to reflect as much heat as possible. This can be achieved by **adding vegetation to streetscapes as well as using lighter, reflective building materials** [Haselbach 2008:68].

Adequate shading and drinking fountains must be provided in public spaces [Roaf et al 2009:60]. This will **protect vulnerable inhabitants from excessive shocks to their health during heatwaves.**

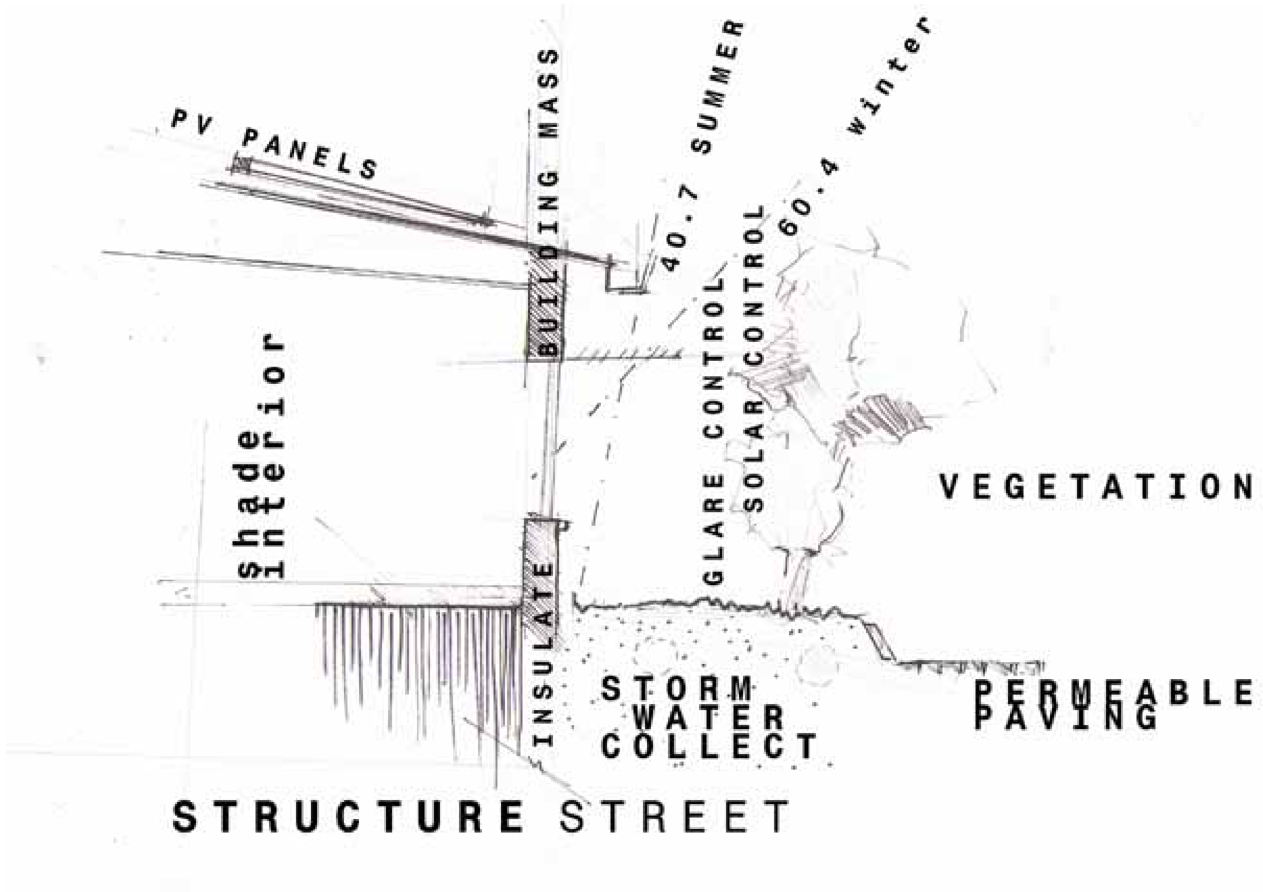


Figure 2-10: Adapting buildings for climate change
[Source: Author]

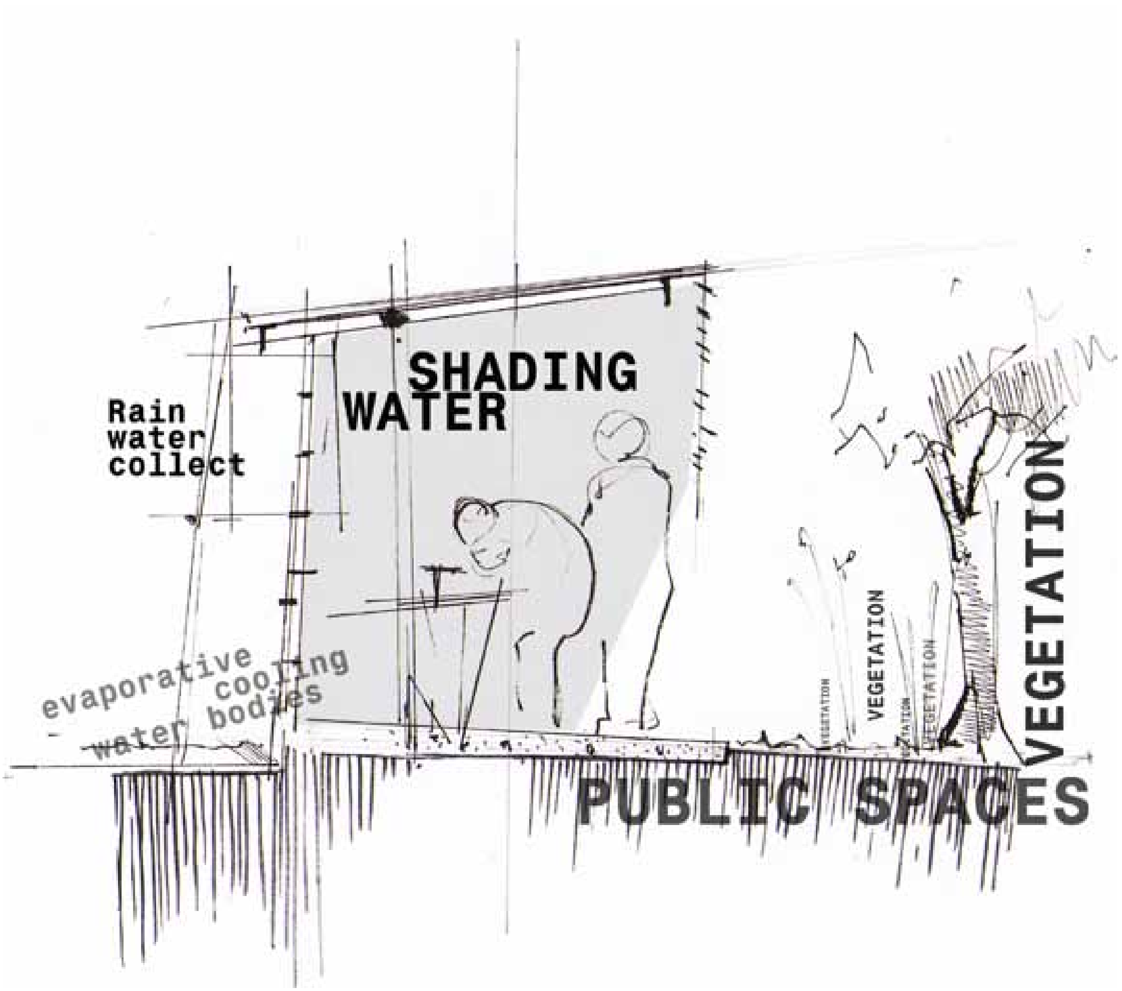


Table 2-02: Shading in public spaces [Source: Author]

With the increase in solar irradiance the thresholds between interior spaces and outdoor spaces must be considered. By making use of a series of screens the glare and discomfort experienced upon exiting buildings can be lessened.

Less cloud cover is to be expected in the winter. **The solar shading must protect the occupant from unnecessary glare,** especially on work surfaces.

As the temperature in Tshwane is expected to increase it will be important to ensure that the heat capacity of building materials is addressed. Buildings must be designed to insulate against increased air temperature, while shading of the building facade in the summer is important. It will become very important to **shade western facades to ensure cool evening temperature in buildings** [Roaf et al 2009:55].

Ventilation during the summer period will become very important. **As Tshwane is going to become less humid evaporative cooling will become a very effective and efficient ventilation method.**

Fortunately warmer winters will lead to warmer indoor temperatures, leading to less heating being required. The designer must take advantage of this by using passive solar heating methods to heat structures in the colder months.

During storms, or in the rainy season, the management and reuse of storm water must be an important priority for all sites and buildings. **The gutter systems and rain water harvesting systems should also be adapted to accommodate higher quantities of water.** The harvesting of rain water will be of increasing importance -as discussed in section 2.1.5.

The generation of photovoltaic solar energy will become more efficient, especially during the dry winter months when little cloud cover is expected.

With the increase in heat waves in Tshwane, the designer must ensure that the structure is adequately protected in the event of a fire. This means adhering to fire regulations and, most importantly, ensuring safe escape route and safety measures for the users of the building

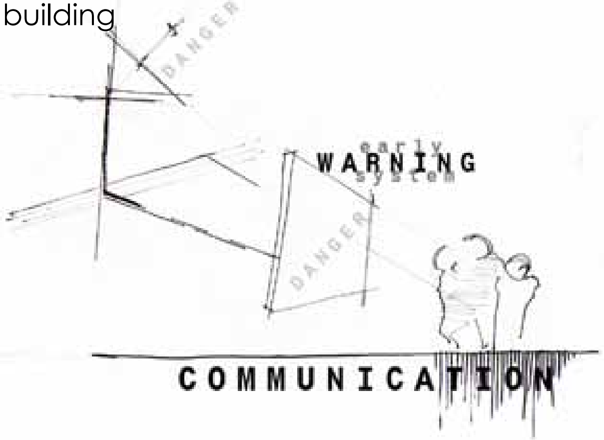


Figure 2-11: Warning systems in buildings [Source: Author]

Buildings can also start to incorporate warning systems to warn the public about possible extreme weather events and as well as in the event of a disaster. This can be include public awareness programs to mitigate climate change.

Responsive and robust structures will be needed to ensure comfortable buildings in the near future.

2.2.5 Mitigation options and focus

Adapting and designing buildings to respond to the changes in climate are important to ensure sustainable cities and societies. Yet adopting methods of mitigating climate change are even more important.

The Stern report states according to Roaf et al [2009:18] that **it will cost 20% of the GDP to continue with the "business as usual" approach and a general denial from the public if temperatures rise by 5.8 ° C globally, though it will only cost 1 % GDP to reduce greenhouse gasses and stabilising it at a maximum level of 350 CO_2 ppm.**

In this study the focus is on more sustainable modes of public transport and low carbon architecture.

2.3 TRANSPORT- A BUS RAPID TRANSIT SYSTEM IN TSHWANE

Figure 2-12: Energy consumed by transport increase with 40% [1990 - 2007]
[Source: Author]

The energy & heating and the transport sectors generate up to two thirds of the global greenhouse gas emissions worldwide. These are also the fastest growing sectors in terms of greenhouse gas emissions and have increased with 60% and 45% respectively between 1990 -2007 [IEC 2009:13]. In 2007 the global CO_2 emission for transport was 6 632.5 million tons.

In developing countries the greenhouse gas emissions linked to transport are predicted to increase with 60% by the year 2020 [IEC 2002:20]. To ensure a sustainable future, developing countries will have to adapt and develop public transport systems.

Public transport systems have positive environmental impacts, by displacing single occupant vehicle usage [Wright & Hook 2007:85]. In a scenario analysis for a "large developing-nation city" [according to the author the size of Curitiba, Bogota], **a 1% reduction in private vehicle use and shift to public transport use has a 1 million tonnes CO_2 reduction over a 20 year period**[Wright & Fulton 2005:710]. Integrating this with pedestrian and cycling routes to promote sustainable movement patterns increases the reduction in CO_2 substantially [*ibid* 2005:711].

In South Africa the vision of developing a Bus Rapid Transit [BRT] system for Tshwane is to develop a more sustainable, efficient and accessible system. This will contribute to the mitigation of climate change in South Africa, as 20% of all energy used in the country is spent on transport [Winkler et al 2006:24]. In the year 2007 it was found that South Africa produced 345.8 million tonnes of CO_2 [IEC 2009:45]. According to the Graph 2-02 [p.19] and the statement that 24% of global greenhouse gas emissions is produced by the transport sector [IEC 2009:21 ; Wright & Hook 2007:701]. South Africa's transport sector would have produced roughly 82.995 million tons of CO_2 in 2007.

Research done in Bogota found that the air quality improved significantly after the implementation of a BRT system. There has been a reduction of 44% in sulphur dioxide, 7% nitrogen dioxide and 24% particle matter [Wright & Hook 2007:699]. This can be credited to the BRT busses that use of cleaner fuels and has more efficient engine technologies, [Wright & Hook 2007:702-705].

Implementing a BRT system in Tshwane will contribute as a climate change mitigation strategy while at the same time improving the living standards of the inhabitant of the city.

2.3.1 The Bus Rapid Transit system

The Bus Rapid Transit system is a "road based public transport system" [Advanced Logistics Group 2008:2] which can easily provide highly efficient transport for high numbers of commuters over a short time period. **The BRT is a very flexible and adaptable system** [Levinson et al 2003:4], that can adapt to future changes and fluctuation without compromising the initial phases [Advanced Logistics Group 2008:8].

It is a safe affordable transport system that creates an environment for social interaction and the interaction of people of different income groups [Wright & Hooker 2007:86].

2.3.2 The BRT system in Tshwane

In the 1970's urbanisation occurred at a very fast rate in South America. In order to address the shortage and increasing strain on the existing public transport systems the BRT system was developed [Wright 2001:1]. The system is a series of right-of-way bus lanes that are integrated into the existing road networks. It is a very fast, efficient and cost-effective method to provide transport [Wright 2001:1].

The BRT system aims to link the isolated suburbs of Pretoria with the city centre, while at the same time increasing the western and eastern movement of commuters [Advanced Logistics Group 2008:4]. The different routes are planned to provide the most coverage in Paul Kruger Street and the heart of the city as recommended by Advanced Logistics Group [2008:05].

As stated by Pienaar et al [2007:426] the BRT system will promote the current corridor development, as experienced in Curitiba [Wright & Hook 2007:87],while improving the daily lives of the inhabitants living on the periphery of Tshwane through densification and providing an easier, safer and quicker means of travelling. It is proposed to be a legible and user friendly system, accommodating the tourists and locals alike [Advanced Logistics Group 2008:15].

2.3.3 The whole BRT system

According to a BRT presentation [Olivier 2009:04] 6 priority corridors were identified within Tshwane which will be developed as BRT routes or enhanced bus routes. These routes together with their feeder zones will provide much needed coverage across Tshwane to improve public transport.

Stage 1 includes two trunk lines and two enhanced bus routes. The aim is to accommodate movement from the northern suburbs as well as east-west movement though the city
[Advance Logistics Group 2008:5].

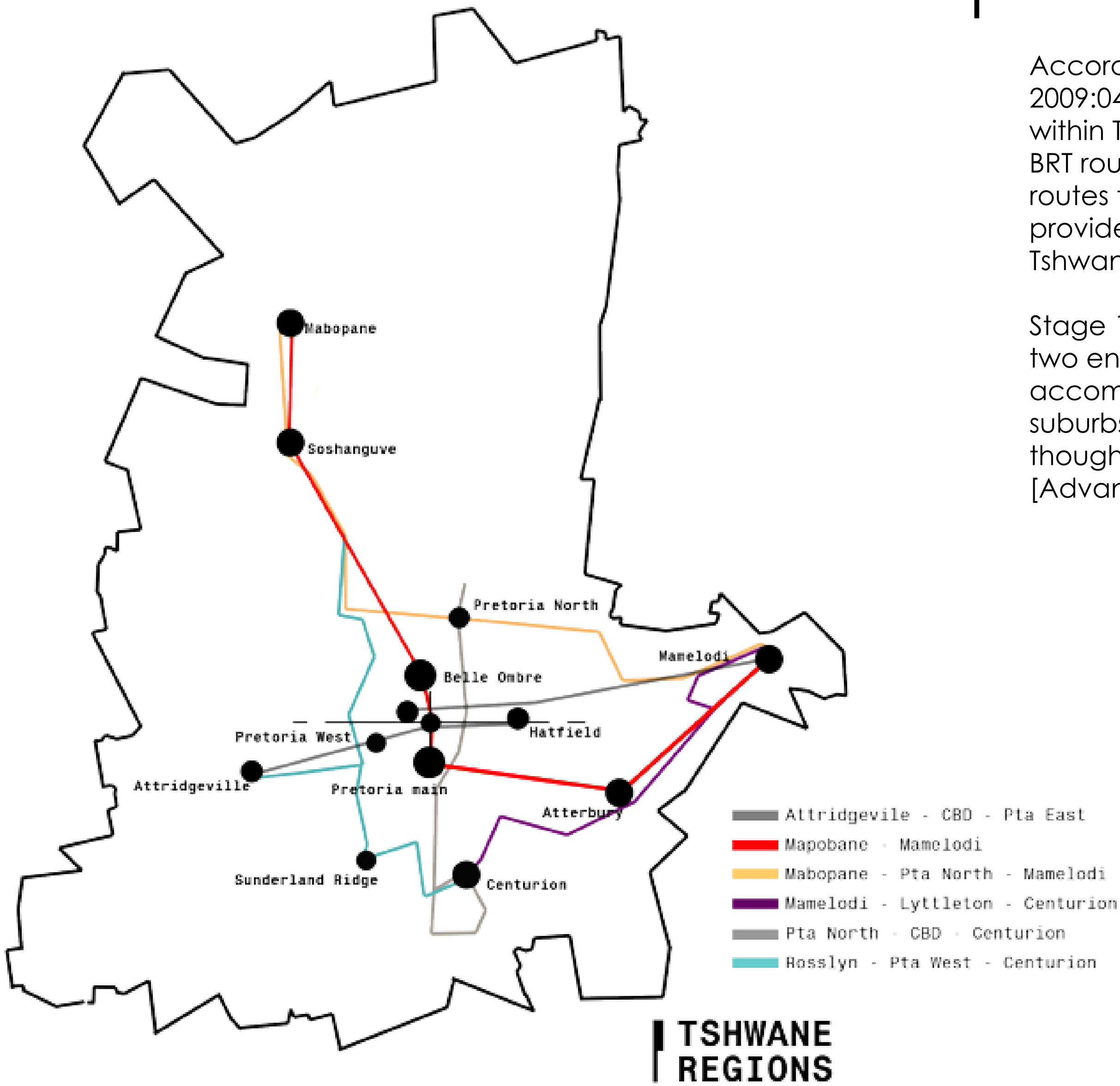


Figure 2-13: Six priority corridors in Tshwane [Source: Author]

2.3.4 Routes and BRT in Tshwane [STAGE 1]

Two BRT lines are proposed for Stage 1 of the BRT development, as indicated in Figure 12:
Line 1 _ Mabopane - Pretoria Main Station
Line 2_ Mamelodi - Belle Ombre Station
[Advanced Logisitics Group 2008:69]

These two lines aim to facilitate and improve the connection between the northern and north eastern suburbs and the city centre. Line 1 and 2 will be trunk lines with dedicated bus lanes [Advange Logistics Group 2008:06].

Each will have two services, being a normal line stopping at each station and an express line stopping only at selected stations and at the terminals [Olivier 2009:21].

The terminals for these two lines will be at

1. **Mabopane Station**
2. **Belle Ombre Station**
3. **Pretoria Main Station**
4. **Mamelodi ***

The BRT lines 1 & 2 are focussed on giving as much public transportation coverage as possible in Paul Kruger Street [Advanced Logistics Group 2008:5]. This will lead to an increased frequency of public transport along this street, reducing private vehicle use. In the process a more pedestrian orientated route will be created with lower speeds and narrower lane widths for vehicles [Advanced Logistics Group 2008:47].

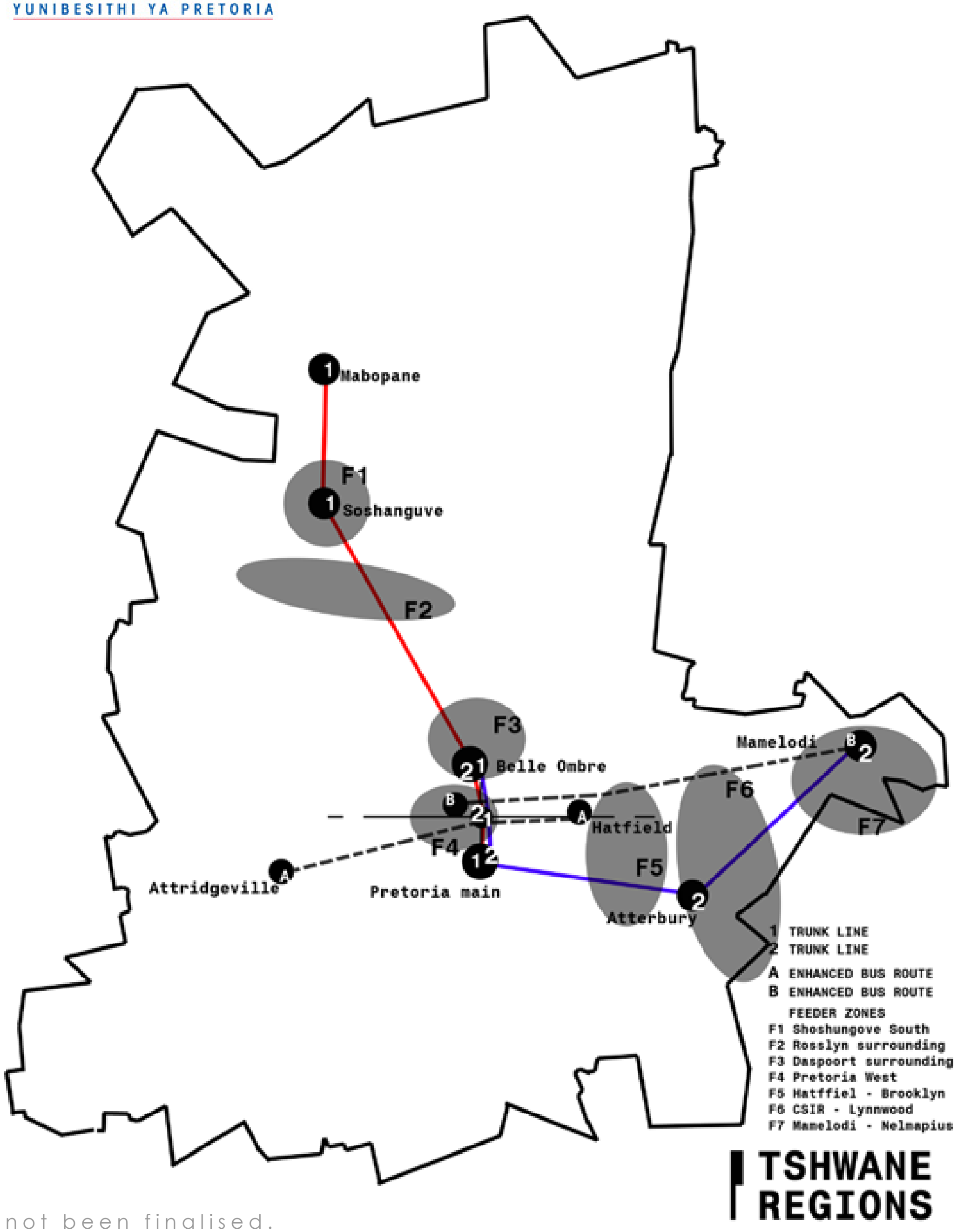


Figure 2-14: Routes and Feeder Zones in Tshwane [Source: Author]

*At the time of the study the planning for the BRT line 2 has not been finalised.

The anticipated number of commuters using the BRT during peak times will be

6 400 people per hour
[Line 1 Mabopane]
6 400 people per hour
[Line 2 Mamelodi] *

Peak period is normally from 5 am to 8 am [Advance Logistics Group 2007:76].

The Advanced Logistics Group [2008:5] also proposes an east-west access route that will connect Attridgeville with Hatfield and Mamelodi with a second route to the city centre. With these lines overlapping the most coverage is given to the city centre, improving the frequency of available transport [Advanced Logistics Group 2008:5].

The enhanced bus corridors will use normal low floor busses [refer to section 2.3.8 for BRT bus specifications] , travel in mixed traffic routes and have curb-side stations. The system will have express lines and a formalised timetable while free transfer between these lines and the BRT station will be accommodated [Advanced Logistics Group 2008:49].

Feeder Zones are also proposed to ensure that the BRT Routes will be accessible; these feeder zones are to be serviced with smaller vehicles [The Advanced Logistics 2008:53]. By making use of feeder zones an adaptable and accommodating system can be provided, instead of a more expensive trunk lines to service the whole area.

The project proposes the use of the existing taxi/minibus infrastructure to act a feeder system for the BRT. The city of Tshwane has engaged in talks with taxi associations with the aim of achieving a partnership between taxi owners and the BRT system [Laubser 2010].

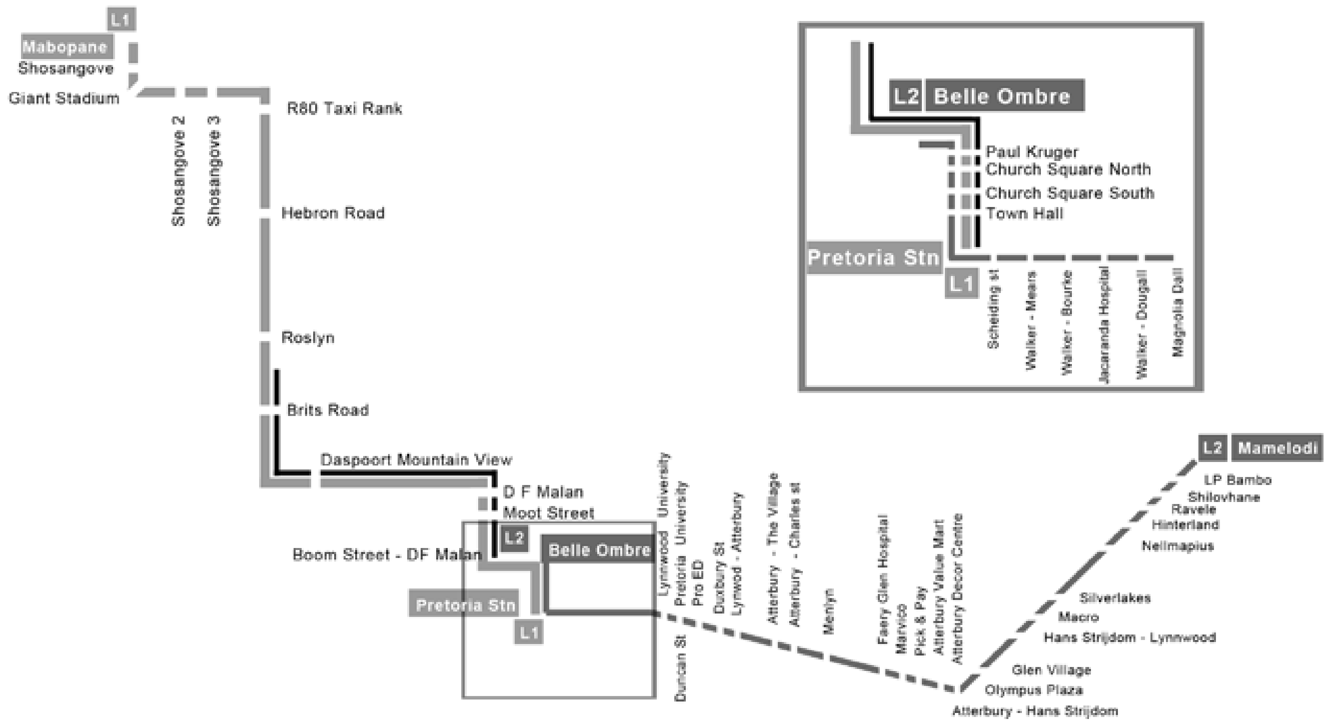


Figure 2-15: Schematic layout of Two BRT lines [Source Tshwane Bus Rapid Transit
* Note: For predicted users and station info refer to table 13-30, pg 307.

2.3.5 BRT Terminal layout at the Pretoria Main Station

The site for one of the BRT terminals is the Pretoria Main Station. The station building was constructed in 1912 and is one of the first public buildings designed by Sir Herbert Baker [Lindeque 2001:04]. The building itself has historic architectural value, while the Station Square was constructed between 1912-25, has experienced many changes throughout its history. The World War I and World War II memorial and original walls on the square are still intact.

This is culturally and historically a very sensitive site. Unfortunately development on this site has been uncoordinated and has led to an illegible and fragmented site [Seabrook 2009:38].

Two propos[...]y SSI and KM Architects and the other by KWP architects, that aim to renovate the forecourt of the Pretoria Main Station [Figure 14 -17].

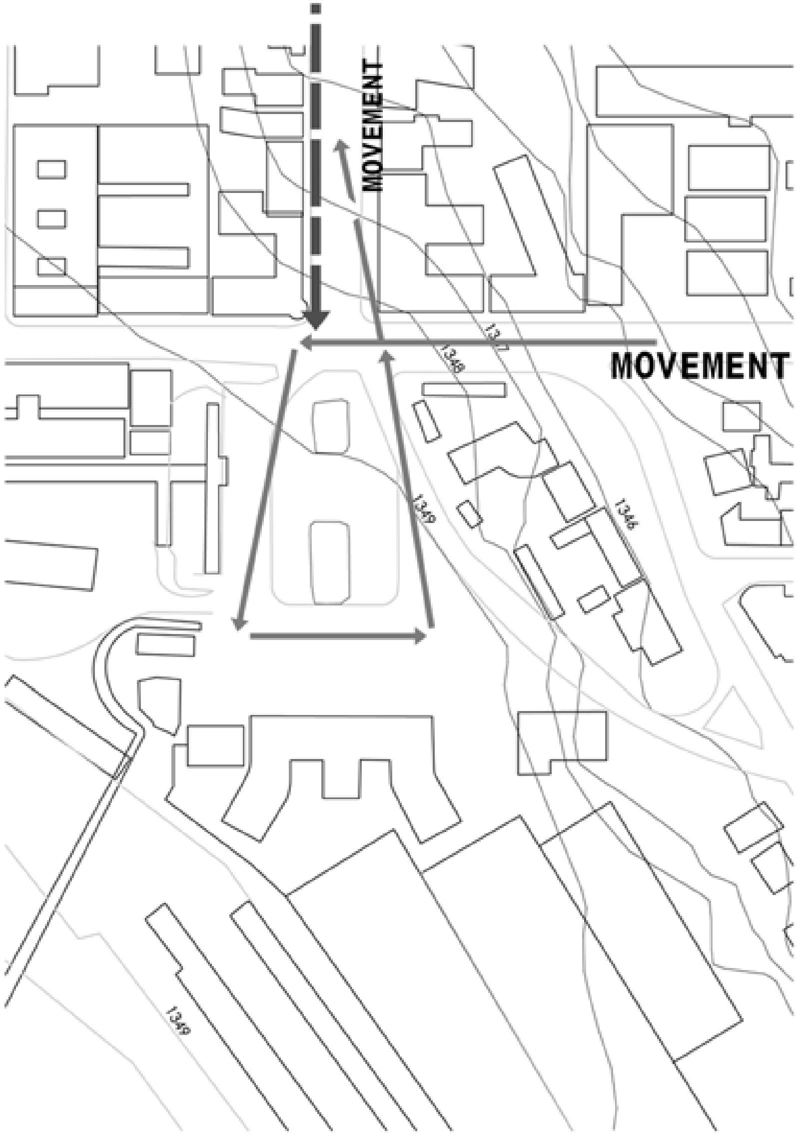
The proposals all have very different intentions especially in relation to the station square garden and forecourt. The KWP plan aims to repair the existing stone walls while keeping most of the historical forecourt intact.

The plans by SSI and KM architects are more extensive, as they suggest a redesign of the whole station precinct. The proposal links Salvokop with the station by covering the railway platforms behind it. A parking garage is proposed on top of the railway track, with an over-scaled glass-domed mall/terminal building rising behind the station building.

The forecourt is changed altogether, with a pedestrian underpass constructed where the Station Square is currently situated. Buildings are proposed on the eastern and western edge of the station forecourt which would mean the closure of Railway Road on the eastern edge [Figure 16 & 17]. The BRT stations are situated in the forecourt, with 2 options proposed for the western edge or on either side of the garden.

The proposal aims to change the scattered illegible nature of the station into a coherent whole. The pedestrian underpass is insensitive to the heritage fabric on site, while the proposed mall behind the station is over-scaled. The glass dome will also be an energy inefficient and unsustainable structure. The two options for the BRT stations are sensible and will be explored in the conceptual phase of the design.

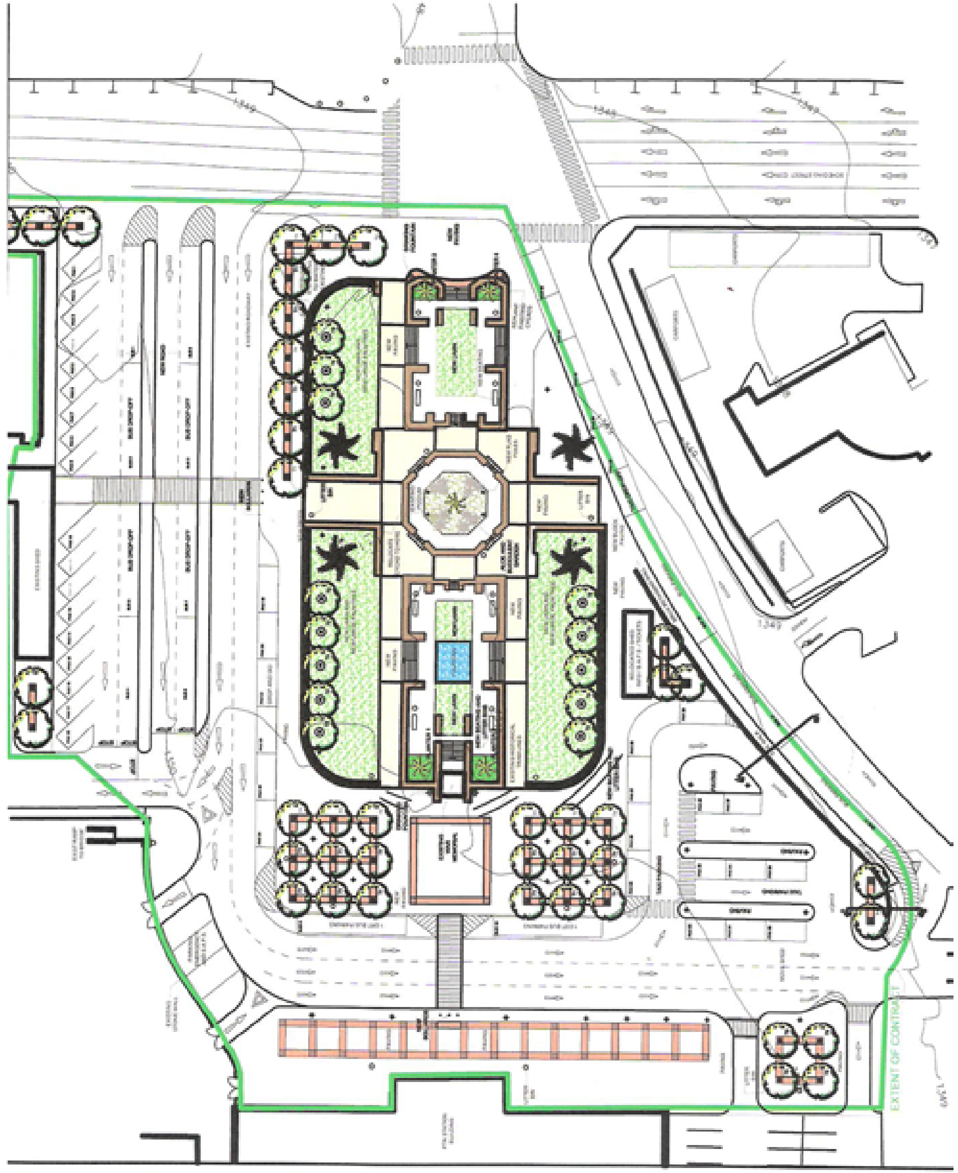
Figure 2-16: Proposal for station by KM architects [SOURCE: Anon]



PRETORIA MAIN STATION
MOVEMENT - FORECOURT

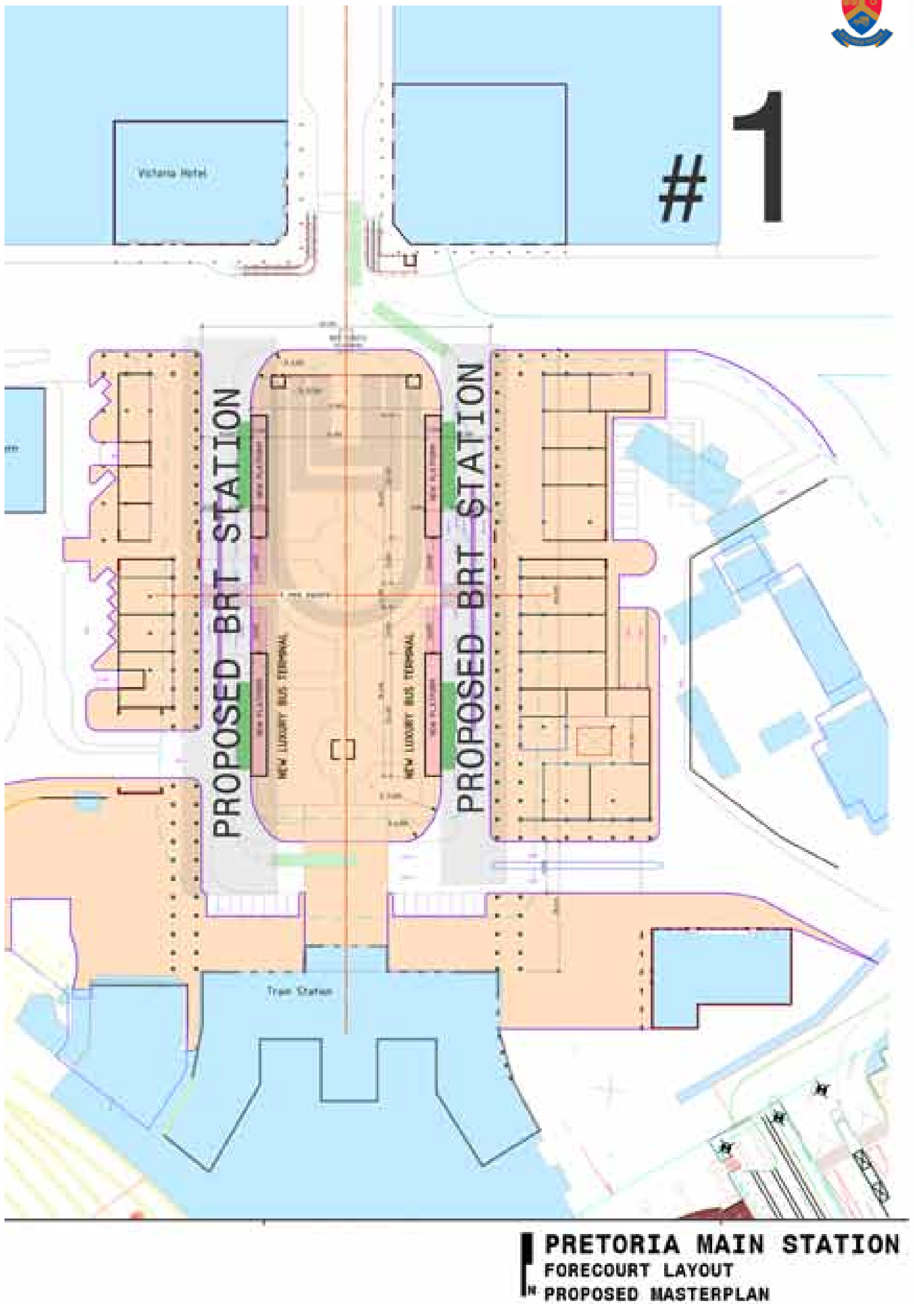
Figure 2-17: Movement in the forecourt [Source: Author]

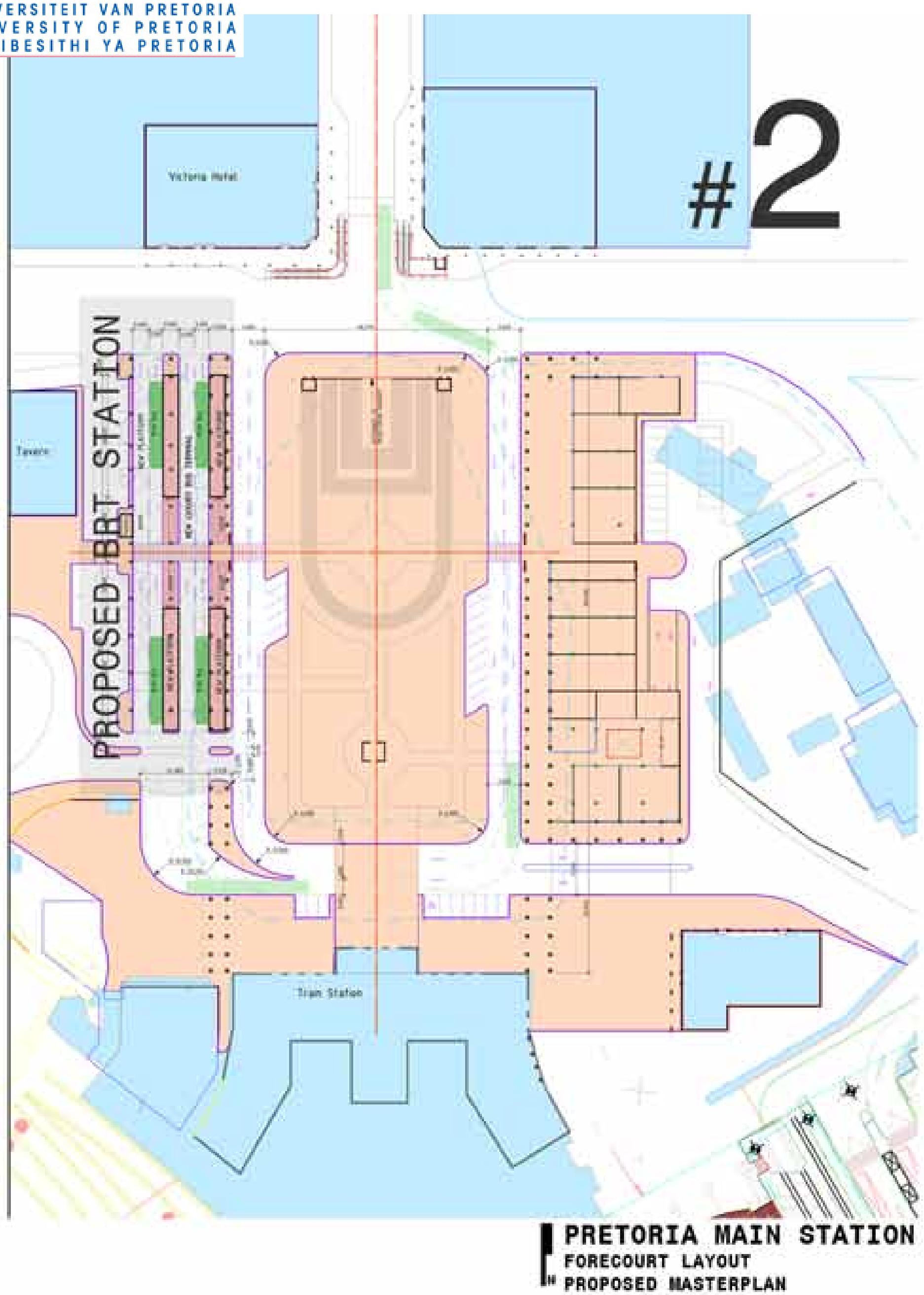
PROPOSAL BY KWP LANDSCAPE ARCHITECTS



PRETORIA MAIN STATION
FORECOURT LAYOUT
INTERIM RECONSTRUCTION

Figure 2-18: Interim proposals for Pretoria Main Station [Source: KWP Landscape Architects]





PROPOSALS BY KM ARCHITECTS AND SSI

Figure 2-19: Proposals for Pretoria Main Station [Source: SSI and KM Architects]

2.3.6 Terminal buildings

Terminals are ideally located at the end of lines [Advanced Logistics Group 2008:58]. Bus depots should also be located close to the terminals to ensure efficiency. The bus depots are proposed to be located in Mabopane and Mamelodi [Advanced Logistics Group 2008:59].
In the Tshwane Bus Rapid Transit Operational Plan the following facilities are proposed to be incorporated at the bus terminals:

1. Information kiosks
2. Lost and Found Offices
3. Restrooms
4. Commercial facilities

[Advanced Logistics Group 2008:58]

These terminals must be treated as public service nodes that also provide a wide range of services such as health care and educational facilities.

Additional functions are best situated at terminal stations, these being more convenient for commuters ensuring that less travel is needed. Usually there is also more space at terminal buildings to accommodate more users and functions [Wright & Hook 2007:374].

Accommodating informal vendors along with formalised retail functions in terminal buildings has many advantages. It provides passive surveillance and integrates different income groups [Wright & Hook 2007:372]. Yet informal vendors must be controlled to ensure ease of movement and safety by keeping the bus runways clear.

Enough seating and resting places for commuters should be provided at stations and terminal buildings.

The intermediate staging area is proposed to be at Belle Ombre station. This will serve as rest room for drivers and will ensure that the BRT buses are always on time[Laubser 2010] . This can be used as an intermediate parking area within the city to service the transport system during peak times
[Wright & Hook 2007:393].

BRT systems use control centres, that monitor the whole system with a GPS tracking system. This ensures that the system works efficiently while being able to respond to sudden changes in movement and passenger needs [Wright & Hook 2007:393].

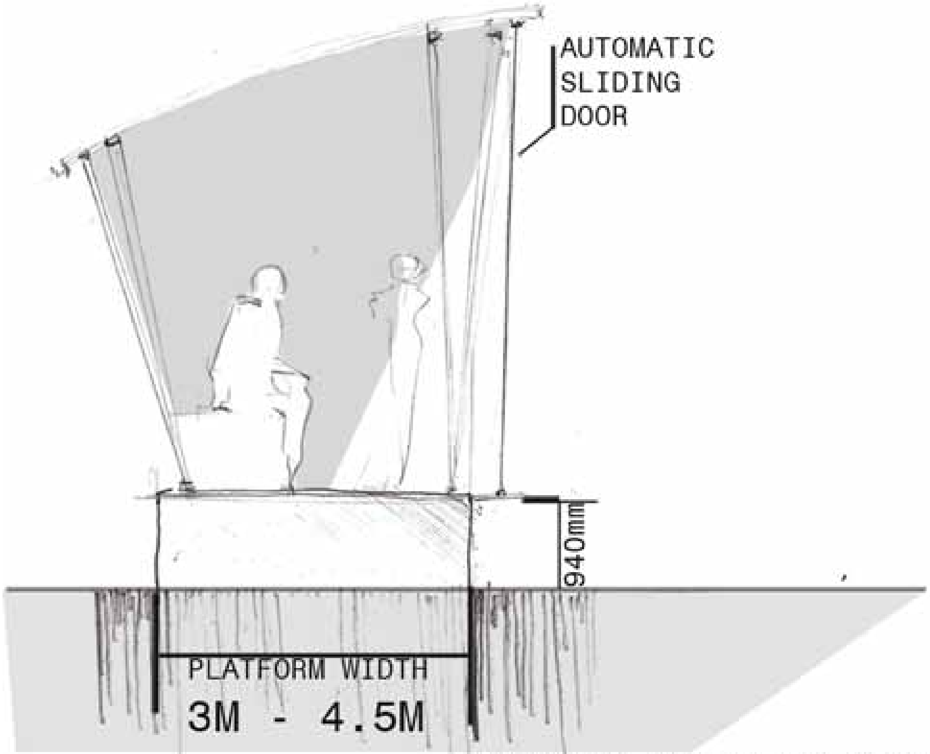
2.3.7 Station/platform parameters

BRT stations are usually placed on the median. Placing them on the curb side usually leads to the BRT system conflicting with the turning traffic, leading to congestion [Wright & Hooker 2007:185].

The designer should ensure that the transfer between station and modes is as easy as possible for the user. The user must be protected from the weather and should not have to walk too far. There must preferably not be any barriers between the different stations [Wright & Hooker 2007:230].

The platform parameters as articulated by the Tshwane Bus Rapid Transit Operational Plan [Advanced Logistics Group 2008:78] suggests the following:

1. **Station will be located on the median**
2. **The platform height should be 940mm above finished ground level.**
3. **The waiting area on the platform should be 1.7 times the length of the bus – 31, 45 meters at multi bay stations.**
4. **The platform should be 3 – 4.5 m wide, with entrances on both sides.**
5. **Doors should be 1100m wide.**
6. **Allowance must be made for seating even though the waiting period is short.**



GENERIC PLATFORM DESIGN EXAMPLES OF STATIONS

Figure 2-21: Generic Platform design and exemplary stations [Source: Rapid Bus Transit Planning Guide p 365, 366,369]

On line 1 [from Mabopane] the stations will require 3 bays to accommodate users while line 2 [Mamelodi line] only requires a single bay per station.

Platform size is dependent on the amount of passenger boarding during peak hours. A 1 m corridor can accommodate the movement of 2000 passengers per hour [pph] and the area needed for waiting passengers is 1 m2 per 3 passengers [Advanced Logistics Group 2008:78]. The platform length must be the 1.7 times full length of a bus between two continuous platforms. The BRT line 1 requires 3 bays per station thus the length of each station should be

Calculations for platform width [LINE 1]

The platform width:

WIDTH

WU [waiting passengers] = QP/total length of station / 3 ppm
=160/81.5 m/ 3
=0.65m

WC [circulating passengers] = 6400pph / 2000 pph
= 3.2m

WP [platform width] = 1 meter + WU [waiting passengers] + WC [circulating passengers]
= 1m + 0.65 + 3.2
= 4.85m

Calculation as per BRT planning guide [Wright & Hook 2007:362]

Thus platform size at the station should be 81.4m x 4.85m [for 3 bays].

QP - Maximum passenger queue [maximum commuters per hour / frequency of vehicles per hour]
PPH - Passengers per hour
PPM - Passengers per meter

In areas where the climate permits the use of naturally ventilated stations is an easy options to achieve comfortable indoor environments, yet in some climates air conditioning must be used [Wright & Hook 2007:368].

The stations must also have on site security and must be "closed stations". This ensures that off board payment can be done and that integrated fare systems can be adopted where the user only pays for the distance travelled or the zones travelled from [Advance Logistics Group 2008:88].

The station must have multiple doors, 3 doors per bus, to ensure that the transfer of passengers can happen as quickly as possible. These doors must be a minimum of 1100mm wide [Wright & Hooker 2007:263]. The use of mechanical doors ensures user safety and stops fare evasion [Wright & Hooker 2007:370]. The BRT system in Johannesburg only allows for the doors of the station to be opened by the Bus drivers.

Bicycles and pedestrians must also be incorporated within the design of these stations as to ensure the transfer between travel modes happens smoothly and easily [Advanced Logistics Group 2008:88].
These platform parameters are proposed to ensure user safety, comfort, on site security and ticket control [Advanced Logistics Group 2008:78+88].
The stations also require electrical energy to

support infrastructure such as lighting, fare collection and verification systems, as well as automatic doors and possible climate control [Wright & Hook 2007:372].

As projected by Pienaar et al [2007:427], during the 3 hour peak period in the morning a total number of 11 354 users [BRT only] will be coming on the northern line from Mabopani through Rosslyn to the Pretoria Main Station. Yet the system can only accommodate 6400 pph [Advanced Logistics Group 2008:9].

Provision will have to be made for a high number of users, moving quickly through the station. It is also clear that the amount of users would increase significantly in future. The most efficient stations have off-board payment points and platforms level with the height of the busses. This increases the efficiency of these stations from 3 777 pphpd [people per hour per direction] to 9 779 pphpd [Wright&Hook 2007:268].

Passing lanes at stations ensure that express lines are efficient [Wright & Hook 2007:263]. Mechanical systems can be used to guide busses at each station to ensure that the boarding of passengers is safe and secure. This is expensive but ensures that the system is efficient and fast [Wright & Hook 2007:258]. Pretoria stations will not make use of any guiding systems [Labuschagne 2010].

2.3.8 Vehicle size and type

The proposed bus type is the same as being used in Johannesburg BRT system. It is an articulated vehicle that has a central axle. **These vehicles are 18.5 meters long and have a floor height of 930 mm above ground level** [Advanced Logistics Group 2008:99]. The busses will contain Euro III engines that uses clean diesel for fuel [Advanced Logistics Group 2008:99].

As South Africa generates 95% of its electricity with coal power plants [IEA 2009:21], using cleaner low sulphur diesel as fuel is the lowest greenhouse gas emitting method available in South Africa at the moment [Wright & Hook 2007:85].

Figure 2-22: Articulated busses used on Johannesburg [Source: Author]

These busses can carry up to 130 passengers and have 3 right sided doors that are 1100 mm wide [Advance Logistics Group 2008:99]. Having 3 doors per bus is the most efficient ratio. The system can be designed to have entrance and exit doors, yet many BRT systems do not make use of such a system [Wright & Hook 2007:264].

Articulated busses have a turning radius of 11.57m and are heavier than normal busses. The surface material at stations must preferably be concrete to accommodate the extra weight [Wright & Hook 2007:346].

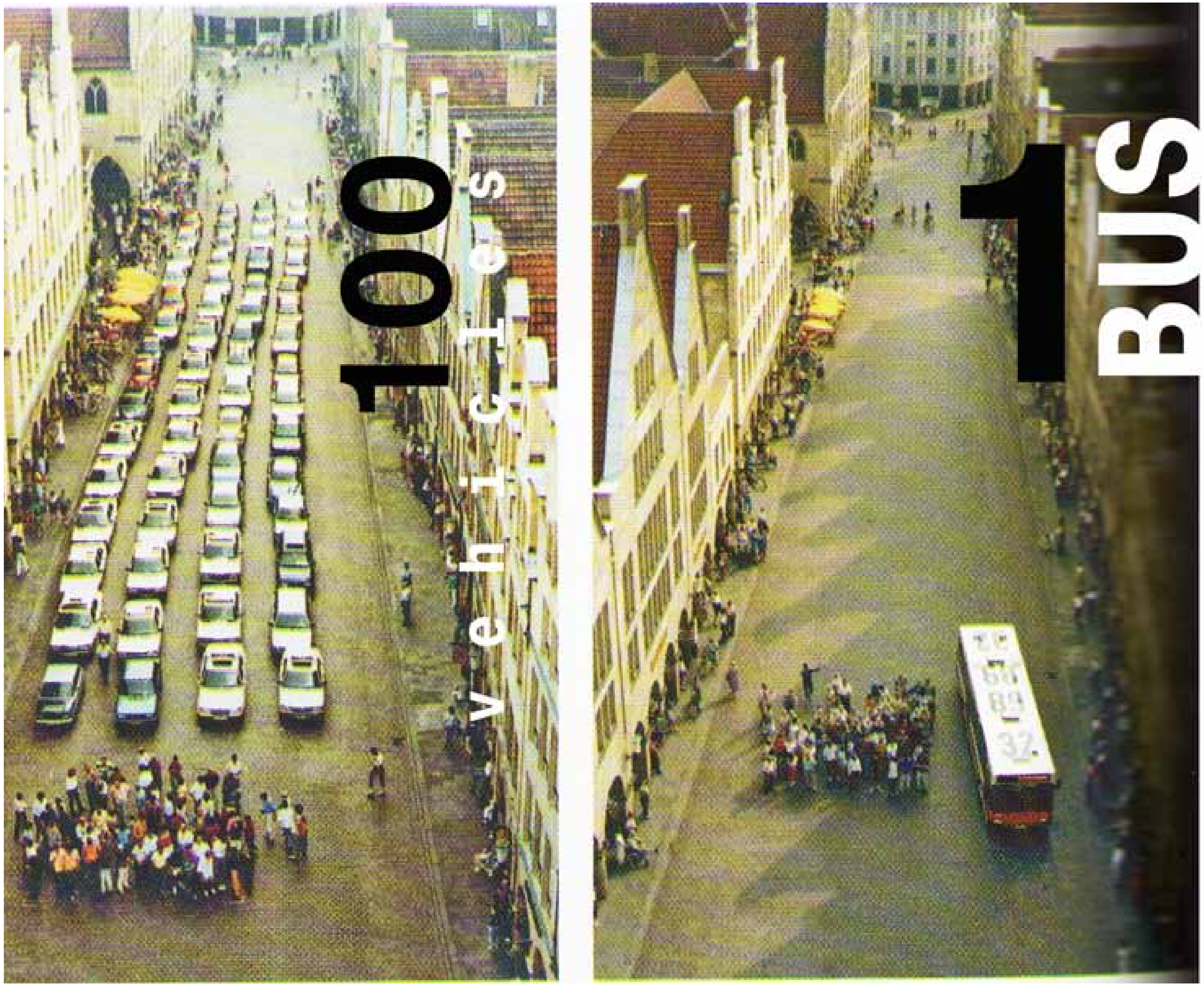


Figure 2-23: Busses displacing single occupant vehicles [Source: Wright& Hook2007 p 86]

2.4 CARBON CONTENT AND THE BUILT ENVIRONMENT

Architects have a specific role to play in the mitigation of climate change, as buildings are directly responsible for the depletion of natural non-renewable resources and the production of greenhouse gas emissions [Bennett et al 2003:03].

Globally buildings are responsible for emitting 9 billion tons of CO_2 eq per year, that amounts to 18% of global greenhouse gasses [Walker & King 2008:107]. Greenhouse gasses were expected in 2003 to rise globally with 15% for residential architecture, with a full 50% increase for commercial architecture for the period 1990 – 2010 [Bennett et al 2003:120].

South Africa emitted 345.8 million tons CO_2 in 2007 and this figure rose with 35.8% from 1990 – 2007 [IEC 2009:45]. This makes South Africa the largest producer of greenhouse gasses on the continent. The carbon footprint per capita for South Africa has only increased with 0.4% [between 1990-2007], to 7.27 tonnes CO_2 per capita [IEC 2009:92]. Compare to the average of 0.92 for Africa it is still very high, yet it is very average in comparison with developed countries [IEC 2009:90].

The total volume of greenhouse gas emissions can be divided into different sectors. The energy sector contributes 80%, while 20% is produced by agriculture and the urban environment [Du Plessis et al 2003:245].

In a report assessing the contribution of the energy sector the IEC [2009:49] stated that buildings produce 10% of the CO_2 in many developing countries, which amounts to 34,6 million tons of CO_2. The heating and cooling of the buildings and the use of mechanical equipment, for example lifts, contributes the biggest portion of this number [Du Plessis et al 2003:245].

At the time of the study specific carbon figures have not been available for Tshwane.

Even though the energy sector is one of the chief CO_2 producers, saving energy at a micro level will make a difference on energy consumption at a macro level [Bennett et al 2003:119].

Du Plessis [2003:245] gives the following reasons why commercial buildings are so inefficient:

a) The heating and cooling of the indoor environments.
b) No solar panels or innovative technology.
c) Little use of passive solar heating methods.
d) Bad lighting design leading to the use of artificial lighting throughout the day, adding to the energy use of the building.

Issues a, b and d can be addressed by designing more energy efficient buildings, which will not necessarily increase the building costs significantly. It is clear that the built environment has two components that produce CO_2 emissions. The first component is the construction phase and related embodied energy requirements. The second is the management of services and the energy consumption of the structures.

2.4.1 Achieving a low carbon building

In the article *A Low Carbon Built Environment* Jones [2009:381] targets three key areas of development: newly constructed buildings, existing building stock and infrastructure in the urban context specifically transportation, waste and services.

An holistic view is needed to achieve a low-carbon building, city or society, as greenhouse gas emitting energy consumption is closely intertwined with all aspects of mobility, housing and production. Societies will have to be restructured to wean themselves from a dependency on fossil fuels [Roaf et al 2009:256].

The following design guidelines are suggested to achieve a low carbon structure:

a) Respond to predicted effects of climate change on architecture

b) Reduce greenhouse gasses during the construction phase:

- **Focus on the material used for the construction?**
- **How is it extracted and manufactured?**
- **What transportation methods are involved and what distances are travelled?**
- **Focus on construction techniques and energy use.**

c) Reduce greenhouse gasses during the operational and maintenance stage of the building:

- **What systems are used to achieve a healthy indoor environment?**
- **What maintenance costs and needs would be required?**
- **How much CO_2 is developed during operational phase**

[Bennett et al 2003:121]

2.5 METHODS AND TECHNOLOGIES FOR LOW-CARBON INTERVENTIONS

2.5.1 Urban environment

A current international strategy for designing **more sustainable and energy efficient cities is to develop smaller, walkable medium to high density urban environments** [Du Plessis et al 2003:252]. **The integration of functions and facilities leads to easier access for city dwellers and a reduction in carbon emissions as less transport is needed** [Jones 2009:381; Alexander et al 1977:56].

The single zoning of areas discourages walking. The development of isolated areas is dismissed as irresponsible and unsustainable [GBCSA 2008:189 & Brain 2005:227].

GBCSA [2008:179+187] suggests that interventions must be within 400m from facilities such as greengrocers, ATM's, gyms, etc. and 1 km from public transport nodes.

The design of car orientated roads has led to the alienation of the pedestrian within cities and is counterproductive to the use of public transport [Brain 2005:227]. City block sizes and road widths play an important role in creating the perception that a city is walkable.

By making sure that city blocks are not oversized and establishing shorter distances around or through them will ensure that the pedestrian moves around easily within the city [Gehl 2006:111]. In Pretoria the use of arcades ensures the total distance for pedestrians is shortened significantly by allowing shortcuts through city blocks.

The use of open space is very important. Brain [2005:229] states that in many modern cities open space has always been regarded as left over space. The value of open space has been neglected and should be integrated with the development of green/ open spaces within the city.

These parks or **green open spaces have a cooling effect on the ambient temperature in areas greater than themselves**, and influence the greater urban context in a positive way [Dimoudi & Nikopoulou 2003:75].

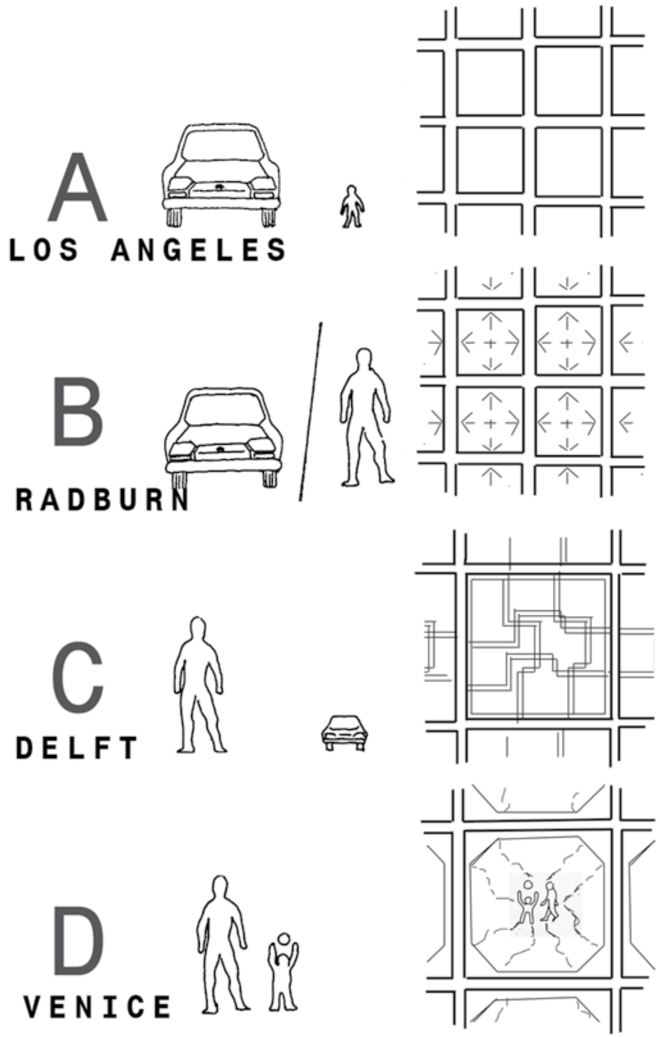


Figure 2-24: Size of block and street. [Source: Jan Gehl, p.110]

2.5.2 Adapting the site

The use of brownfield sites is a very important aspects addressed by the GBCSA. **By rehabilitating brownfield sites, greenfield sites and prime agricultural land, which act as carbon sequestration sinks, are protected.** The Green Star SA manual promotes the enhancement of the existing ecological character of a site to ensure that all manners of carbon sequestration are protected and encouraged [GBCSA 2008:273+289+298].

The adaptive reuse of existing buildings or facades, leads to the preservation of existing finite resources and reduces the greenhouse gasses emitted during the construction and transportation of goods [GBCSA 2008:223].

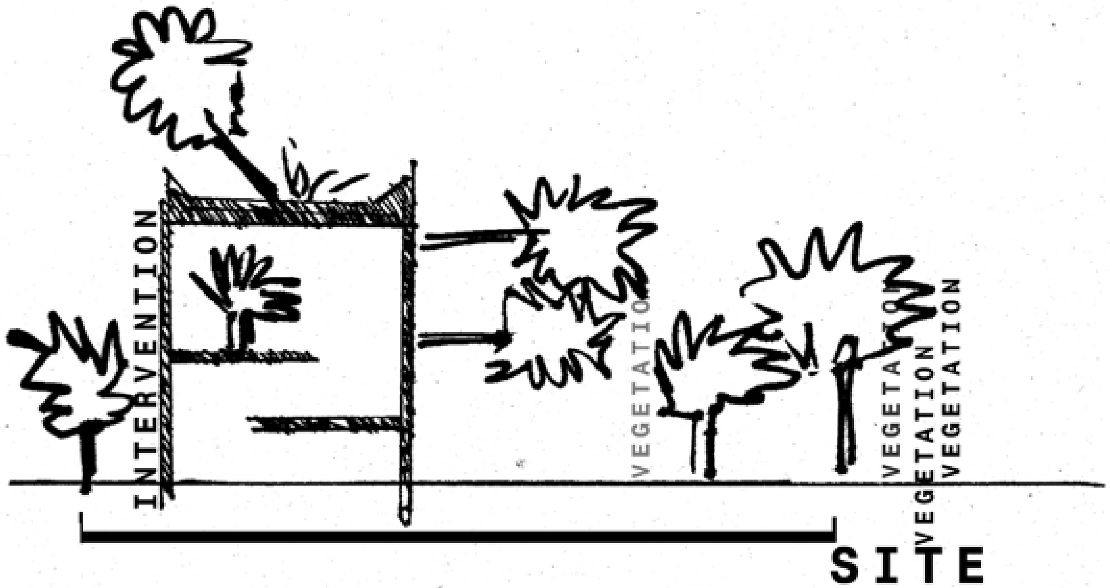


Figure 2-25: Integrating planting and the building [Source: author]

The embodied energy of reused material is much lower than that of recycled material. By salvaging materials more than half of the original investment is saved [Goldbeck & Goldbeck 1999:270].

Integrating planting within the site layout of the design will lead to significant energy savings. Trees cool the micro-environment by reducing the radiant load on the user of the environment. Through evotranspiration trees add moisture to the immediate atmosphere that cools the immediate environment [Dimoudi & Nikopoulou 2006:70]. Trees also shade buildings and windows, reducing the long wave transmission and heat exchange of buildings. In hot climates one could save up to 30% of heat load by painting the roof colour white and adding planting close to the building [Barnett & Brown 1999:12].

Within the site layout allowance should be made for cyclists to have easy access to the buildings. Safe storage for the bicycles must be provided. This will **encourage the use of more sustainable carbon free transport methods** [GBCSA 2008:173].

2.5.3 Working within the Building

One of the prerequisites of the Green Star SA Office Rating tool is to lower the energy use of buildings. "The design must demonstrate that its energy use is equal to or less than the national SANS 204:2008 'Energy efficiency in Buildings' prescribed levels..." [GBCSA 2008:133].

There are a few methods of addressing energy use within buildings, the first being passive design principles and the second being the use active technological methods. The third consideration is the building material itself and the embodied energy it contains and energy required for its maintenance.

Using passive design principles can lower the energy consumption, carbon footprint and greenhouse gas emissions of buildings [Omer 2007:2334].

By looking at local and vernacular architecture one can learn a lot about sustainable passive technologies. These tried and tested methods has been developed and perfected over time [Barnett & Brown 1999:11]. Passive design principles are essentially grounded in the existing context and available materials, yet with the expected climatic changes these vernacular technologies will need to be adapted.

2.5.4 Building-Passive design principles

Plan and position
The plan form and position of the building must be considered when designing a structure in Pretoria. During the winter period heat gain is essential, while during the summer period the structure needs to be shaded to ensure a cool internal temperature [Holm 1996:69]. **The optimum position for the structure would be to orientate it directly north [15° NE to 10° NW]** in order to ensure maximum solar control [SANS 204-2:33].

Landscaping and hardscaping
Heat island effects are generally found within urban areas. These are generated by large paved/hard surface areas or the roofs of structures [Haselbach 2008:68]. This can be mitigated by shading car parks and using open grid paving with planting. **The use of vegetated roofs or lighter coloured roofs** with high solar reflective index values ensures that he micro climate is cooled considerably [Haselbach 2008:69+73].

Ventilation
Natural ventilation and evaporative cooling are both ways of dealing with the indoor temperature and air quality within structures to ensure thermal comfort [Holm 1996:71-72; GBCSA 2008:41] One must keep in mind that natural ventilation influences the thermal comfort of the structure [GBCSA 2008:41].

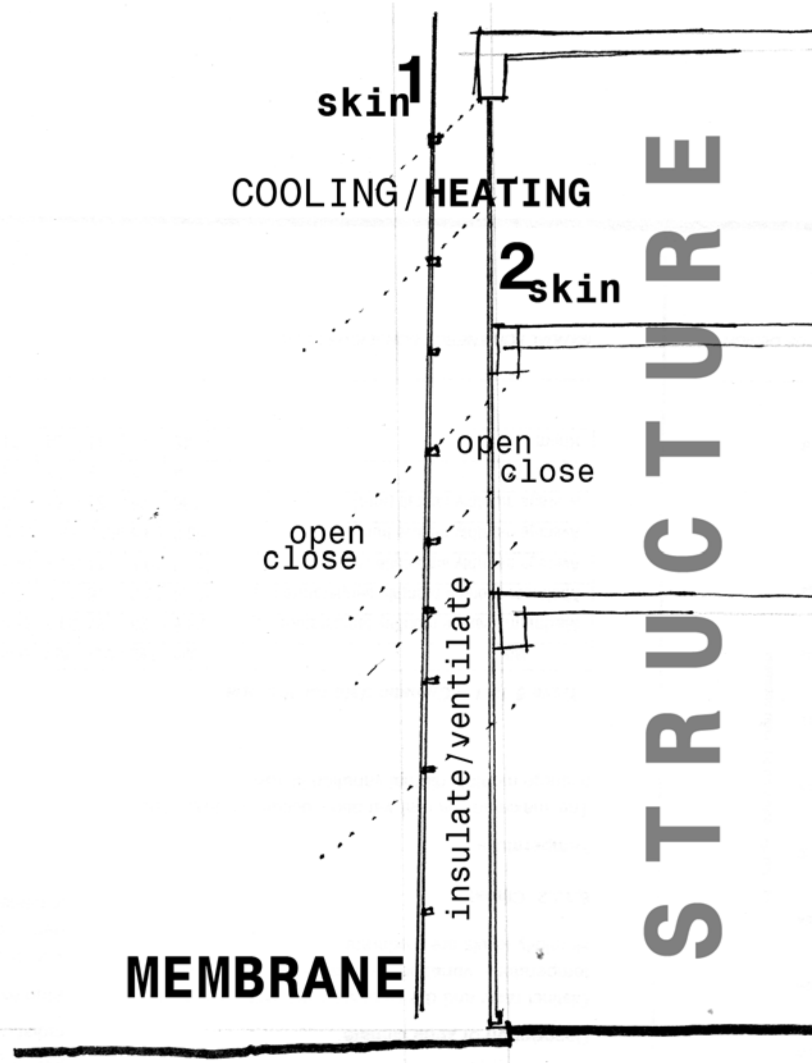


Figure 2-26: Making use of a double skin to accommodate heating or cooling of structure [Source: Author]

It is important though to design for the user to have control over the ventilation as over-cooling or heating can easily become a problem.

Artificial cooling and air handling consumes 50% of the total operational energy use of a building [GBCSA 135]. By making use of natural ventilation substantial CO_2 savings can be achieved.

One method of dealing with the ventilation, heating and cooling of structures is making use of double skins, where the membrane of the building becomes intelligent and responsive to the climatic conditions [Bisch 2002:259].

This method though will increase the embodied energy of the structure, while ensuring that the energy use throughout the building's life cycle is minimised. A double skin membrane can be used for daylighting control as well, controlling glare and lux levels.

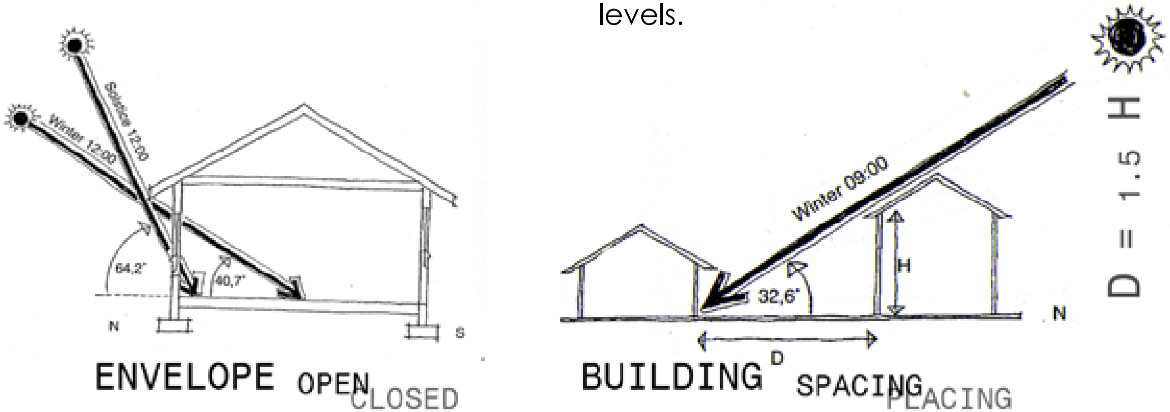


Figure 2-27: Allowing passive solar energy into the building structure [Source: Holm 1996, p71+72]

Lighting

Using natural daylight to achieve acceptable lighting levels within the structure is a strategy that can achieve a lower carbon footprint for the structure. While it lowers the building's energy consumption, a healthier and more productive indoor environment is created at the same time [GBCSA 2008: 63-64&135].

When natural lighting is utilised the designer must take care to eliminate glare within the building. Making use of southern diffused light an effective strategy without increasing glare. Ensuring that eastern and western light are adequately screened will eliminate overheating and glare [Holm 1996:7].

Thermal mass

Thermal mass is a very effective method of dealing with outdoor temperature changes. The flywheel action contributes to maintaining a comfortable average indoor temperature.

In Pretoria the thermal mass of a 220mm masonry wall will be sufficient to keep the indoor environment cool during the summer period. **Night cooling can be used, in summer, to ensure a cool structure during the day [Refer to Section 5 - Precedent 4].** With a temperature increase of 4-6 ° C, caused by global warming, cooling will be needed during extremely hot periods.

During the coldest period in winter heating will have to be used in most structures [Holm 1996:71]. Fortunately climate change will lead to warmer winters, minimising the use of space heating .

2.5.5 Buildings -active systems

Renewable energy sources
One must have a more ecosystemic understanding of energy on site when addressing renewable energy sources, Jones [2009:381] advocates the use of hybrid systems to achieve an energy independent system: using solar, geo-thermal, photovoltaic, wind and biomass systems. **Diversity in nature achieves sustainability; the same approach can be taken with energy sources or systems within a building to ensure sustainability** [Kilber et al 2002:18].

Solar energy
South Africa has the great advantage of extensive sunlight; **the potential for the use of solar power in this country is enormous** [De Plessis et al 2003:252]. The average sunshine South Africa receives is 235h per month, with two thirds of the country having radiation of 7000MJ/m2 – 9500 MJ/m2 [Du Plessis et al 2003:241]. Solar energy can be utilized by employing three approaches: passive solar methods, active solar methods, and photovoltaic systems [Omer 2007:2342]. Passive solar methods were discussed in the previous section.

The use of thermal solar water heaters is a cheap and effective method of saving energy. Integrating this with photovoltaic systems could make an even bigger impact [Du Plessis et al 2003:252]. Photovoltaic systems are more expensive to install, but have a life cycle of 20-30 years [Omer 2007:2339]. Solar panels can generate up to 100 W/m^2, yet there are only 6,4 effective sunlight hours per day [allowing $0.64kWh/m^2$ per day] [Holm 2001].

To ensure the optimal use of solar energy the building design must have a large roof or envelope sections facing north, fixed at a 30° angle [vertical panels are very inefficient on South Africa's latitudinal position] [Moraal 2010].

Wind energy
The wind energy harvesting potential in Tshwane is very low. The area experiences wind still periods for about 50% of the total time. As indicated in the wind rose wind speeds rarely achieve levels beyond 25km/h [Holm 1996:70].

Lighting
Energy can be saved by making use of CFLs and LED lighting technology [Walker & King 2008:246]. One should take care not to overdesign the lightning levels but rather making use of task orientated lighting. The GBCSA advocates the maintenance of illuminance levels to a maximum of 400 LUX [GBCSA 2008:75].

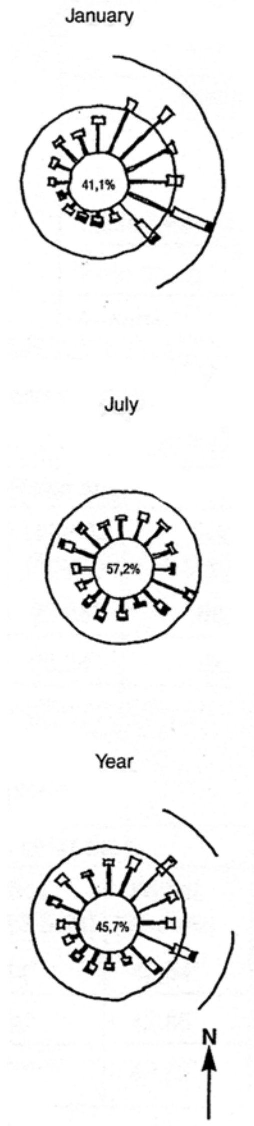


Figure 2-28: Wind rose of prevailing winds in Tshwane [Source: Holm 1996, p70]

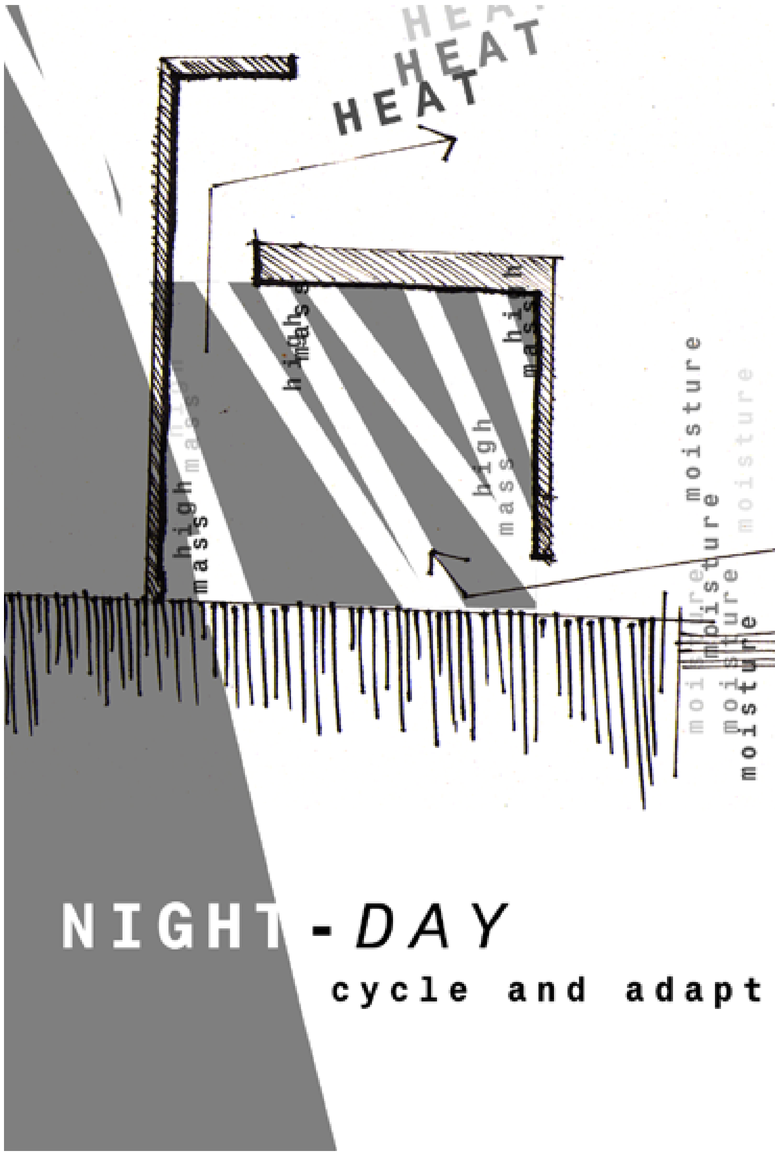


Figure 2-29: Making use of evaporative cooling, high mass and night cooling to ventilate the structure [Source: Author].

By making use of flexible lighting zones and movement sensors, much lower energy consumption levels can be achieved [GBCSA 2008:153].

Ventilation

Pretoria has a very mild and temperate climate, with an average maximum average temperature of 24.81 °C and lowest minimum temperature rarely below 4.8 °C. This means that active air-conditioning is not needed for most building types. **The use of evaporative cooling is very effective during overheated periods while mechanical ventilation might be needed to achieve adequate ventilation rates** [Holm 1996:71+72].

Yet as discussed in section2.2.2, the future increase in air temperature [of up to 6°C] will lead to the need of more efficient ventilation systems and methods.

By making use of a diverse system that incorporates a series of different strategies the adequate temperatures can be achieved [Kilber et al 2002:18]. This method has been used in the CH2 building in Melbourne, as discussed in Chapter 5.

Evaporative cooling

Evaporative cooling is an effective method for lowering the ambient air temperature. **The air quality is improved by adding moisture without adding extra heat. In the process the air temperature drops** [Holm 1996:12].

Geothermal heating or cooling

Air temperature and fresh air quality can be controlled by means of underground ducts that utilise the geothermal qualities of soil. **By pumping fresh air through an underground duct the air temperature can be cooled in summer and heated in the winter** [Bisch 2002:259].

Night cooling

Night cooling ensures that radiant beams are cooled at night through natural or mechanical ventilation. This method is used in the CH2 house in Melbourne [CH2 s.a.:03]. By using heavy structural materials as heat sinks the cooled structure would absorb excess heat that is generated during the day.

Mechanical cooling and heating

When the only option is to use an HVAC system one should not specify ozone depleting refrigerant gasses. As greenhouse gasses HFC's and CFC's have up to 8000 times more heating capacity than CO_2, making the use of these gasses very dangerous [Miller 2004:282]. Rather choose to use hydrocarbons or ammonia based refrigerants [GBCSA 2008:311]. Yet a low carbon structure must preferable not make use of an HVAC system at all.

2.5.5 Material use

Choice of materials
When choosing materials for a project, the life cycle of the building must be understood. Match the choice of material and building structure to the rhythms of nature – using the analogy of a weed like structure and tree structure. **Make use of easily replaceable and simple structures if the building or site is disturbed regularly, and choose a more [tree like] structure if it is permanent** [Kibert 2002:285].

This can be taken one step further, where the structure itself is understood in terms of long life cycle and shorter life cycle components. By choosing and grouping different materials and functions together, certain materials can easily be dismantled and recycled while the more robust sections are kept in place [Odum 2002:52-55]. This entails understanding the different materials and their life cycles [Van der Ryn et al 2002:243]. Use of composite materials makes the dismantling of the structure more energy intensive, in which case one should ensure that dismantling is always possible afterwards [Bisch 2002:262].

With declining global resources, one should consider new and innovative building materials while limiting the amount of materials used. LEED proposes that rapidly renewable materials be used as building materials [Haselbach 2008:196].
These can be animal based products or plant materials.

The advantage of using plant materials lies in the fact that throughout the photosynthesis process carbon sequestration occurs which already contributes to a lower CO_2 content in the atmosphere. When plant material is used as building materials their carbon content is taken out of the carbon cycle
[Berge 2010:34].

Reuse and recycle
The ultimate method of dealing with materials is to reuse and recycle them. Ultimately, if need be, they should be biodegradable [Bennett e al 2003:97]. This ensures that the embodied energy of the material is much lower than that of virgin materials [GBCSA 2009:228+31].

Materials that can be recycled and reused could either be whole building components such as doors and windows etc. or the materials themselves such as

a) bricks reused as building units
b) crushed bricks and mortar for onsite landfill
c) timber, steel and aluminium
d) foam or packaging for insulation

[GBCSA 2008:33; Haselbach 2008:189]

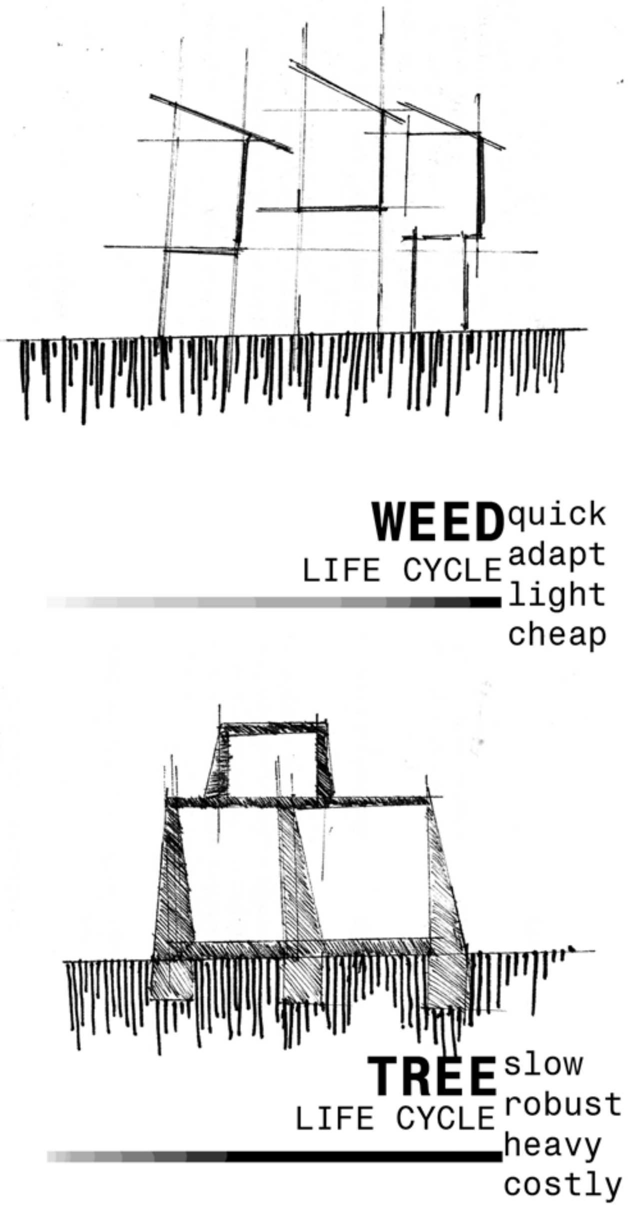


Figure 2-30: The type of material determined by their lifecycles [source: author]

Building waste makes up one third of the world's total waste and its removal uses large amounts of fossil fuels [GBCSA 2009:228+31]. By reusing building materials large amounts of building waste is diverted from landfill sites. This leads to the lowering of transport energy used during construction while methane produced in landfill sites is also lowered.

Embodied energy *

By determining the embodied energy of materials a designer can start choosing a structural system and materials to ensure a design with a low embodied energy. The values also guide the designer to choose which material to recycle and which to keep for the full lifecycle of the building.

Concrete

Concrete is a versatile durable product, yet it requires a lot of cement to ensure its structural strength. The cement is responsible for 90% of greenhouse gasses generated by the production of concrete [GBCSA 2008:238]. Cement has a low embodied energy of 5.85MJ/kg, yet the cement industry is responsible for 5% of global man made greenhouse gasses [Kendall et al 2007:1]. This can be linked to the fact that materials with low embodied energy are usually used in large amounts.

When choosing concrete as a building material, it's optimum use of concrete must be considered. To reduce the quantity of cement used in concrete, oversized and recycled aggregate can be used. Fly ash cement makes use of industrial waste [a by product during the production of steel] as an admixture to reduce cement usage. In this way 30% cement can be saved [GBCSA 2008:235; 238].

When using robust, durable materials such as concrete, the concept of dematerialisation should guide the process – this would mean using structural systems innovatively to ensure that less materials are used [Bisch 2002:252].

The disadvantage of using concrete is the fact the recycling of the structure after its life cycle is an energy intensive and difficult process [Fernandez 2006:208].

Steel

Steel is a strong, ductile, durable and lightweight structural material [Fernandez, 2006:109]. Unfortunately steel has a very high embodied energy. Industries are developing decarbonation strategies leading to a cleaner process and large amounts of steel are being recycled [Fernandez 2006:112]

* NOTE: See appendix for list of embodied energy and life cycle of materials

Steel has a very good post-consumer recycle and recovery rate ensuring that its embodied energy is lower [GBCSA 2008:241 & Fernandez 2006:126]. In South Africa 70% of all steel products are recycled while larger structural steel sections produced by big producers have a recycled content of 20% [GBCSA 2008:244].

Steel components can be constructed off site leading to a fast and accurate construction process, meaning less waste is produced on site. Wastage on site can easily amount to 10% of the total material used [Holm 1996:84]. **Steel can easily be disassembled and reused.**

Timber

Timber is a renewable construction material with a very low embodied energy. Timber can easily be reused and adapted for many uses during its lifetime [GBCSA 2008:251]. It is also a natural material that is used for carbon sequestration processes.

One should keep in mind that the irresponsible exploitation of natural renewable resources is detrimental to development. When opting to use timber ensure that all new timber comes from a FSC [Forest Stewardship Certified] timber producer alternatively use recycled timber [GBCSA 2008:251]. Eighty percent of South Africa's timber is FSC certified, thus sustainable forests are within easy reach of all building projects [GBCSA 2008:253].

Unfortunately timber is not such a robust material and can easily degrade due to high usage and overexposure to a harsh climate. The maintenance of timber is very high to ensure a long life cycle [Wegelen 2006:4.3].

Masonry

Masonry is a widely used material in developing countries that requires very little processing. It has a high thermal mass and is durable. The structural system is also flexible to accommodate small shocks and changes [Fernandez 2006:205].

There are many different types and methods of producing masonry units, ranging from burnt clay bricks to hollow concrete blocks, each having its own embodied energy value. The embodied energy can range from 4.75 MJ per clay brick to 1.32 MJ eq for a hollow concrete block.

Many industries are improving the process of production to ensure that their environmental impact is minimised. The only industry that is not improving is the burnt clay brick industry of which 60% are still using "clamp Kilns" extensively which is a very inefficient method that produces high carbon emissions [Du Plessis et al 2003:252].

Bricks can be recycled into separate units, which in certain situations can contribute to sustainability by providing labour [Berge 2000:207].

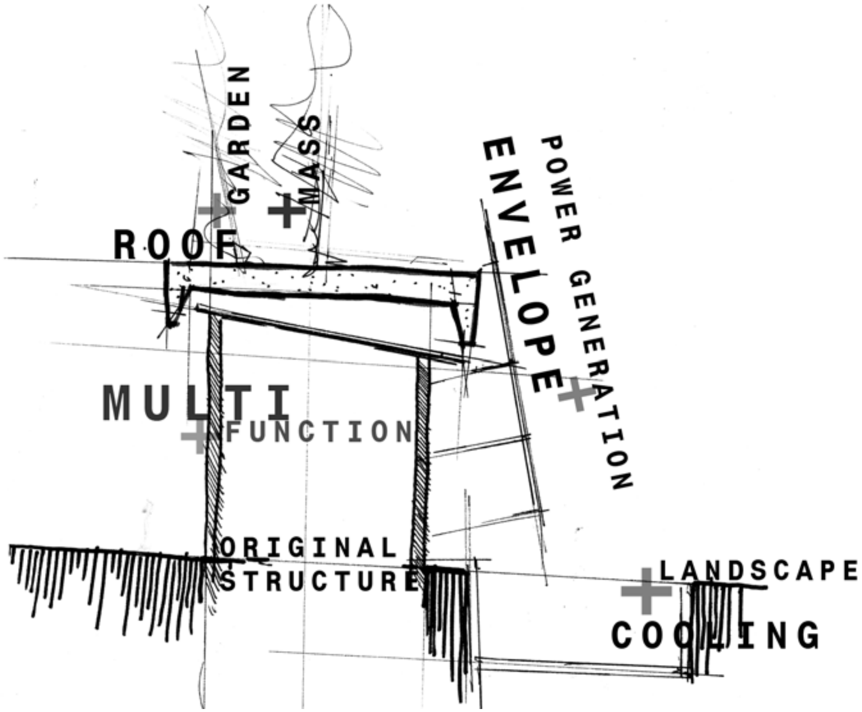


Figure 2-31: Methods of achieving multi functional components [Source: Author]

2.5.6 Innovative materials & techniques

Decarbonisation

The decarbonisations of structures **is a concept whereby carbon absorbing materials or plant materials are integrated with building components. These components subsequently becomes a carbon absorbing structures** [Van der Ryn & Pena 2002:243].

Materials, such as calcium based materials, can also become decarbonising which sequestrate CO_2 during their life cycles.

Decarbonising materials can recapture between 25% to 50% of the carbon released during its extraction and production, lowering the carbon footprint of these materials [Berge 2006:34]. Novacem is a UK based company that has developed a cement product that absorbs 100 kg more CO_2 per ton cement than what is emitted during its production [Novacem homepage 2010]. Unfortunately a similar product is not available in South Africa at present

Dematerialisation

Dematerialisation can be **defined as a method of minimising the use of materials for the construction of structures**. This could either be done by using less material or by optimising building components with multiple functions [GBCSA 2008:261; Van Ryn& Pena 2002:233]

2.5.7 Local sourcing of materials

The local sourcing of materials leads to a lower embodied CO_2 footprint for these materials. The GBCSA [2008:267] proposes that 20% of building materials be sourced within 400km while another 10% be sourced within 50km.

The type of material that is transported is also important to consider, this influence the transportation energy used.

Type of material	Energy [MJ]		
	Production	Transportation	
		50 km	100km
Sand [m^3]	0.0	87.5	175
Crushed aggregate [m^3]	20.5	85.5	175
Burned clay bricks [m^3]	2550	100	200
Portland cement [tonnes]	5850	50	100
Steel [tonnes]	4200	50	100

Table 2-03: Table indicating the different amounts of energy used for transportation of building materials. [Source: Jagadish *et al*, p 5]

It is clear from Table 2-03 that the type of material that is transported makes a big difference to the energy consumption. Transporting low embodied energy materials like sand or aggregate is not a very sustainable practise, as the production thereof is much less than its transportation. The transportation of masonry is the most inefficient, thus sourcing masonry locally is crucial.

The transport type is also of importance. Electrical rail transport uses 0.2 MJ/ton/km while road based diesel transport uses 2.2 MJ/ton/km [Berge 2006:17]. This project will not address the methods by which materials are transported to site.

2.5.8 Conclusion

It is clear from the methods discussed that there are different approaches to ensure a low carbon building, each resulting in specific effects and costs. **It is important to think holistically and systematically about the whole construction process and lifecycle of the structure**. By understanding the full life cycle of the building and its materials the designer can make more informed choice.

NOTE: These figures are only approximate and only applicable for the India

2.6 ENVIRONMENTAL RATING SYSTEMS

The built environment has great potential for delivering long term environmental improvements. Apart from changing the impact of construction and the buildings, architecture can also contribute to the behavioural change of the users and society [GBSCA 2008:ix].

Currently there are a series of barriers that create unsustainable and inefficient structures. One of the issues that has been recognised is the split in incentive between the owner, designer, contractor and developer. The parties involved usually start out with good intensions but these are usually lost through the construction and building management process [GBCSA 2008:ix].

2.6.1 What is a rating system.

An environmental building rating system is a voluntary assessment process [GBCA 2010]. Internationally, certain construction projects are required by legislation to be assessed. In certain states in the USA publicly funded buildings must be assessed, the same applies for housing projects in the UK [Stancich 2009:1].

Rating systems allow for third party assessment of the environmental design and performance of a building [GBCA & USGBC 2010]. The rating systems focus on the design, construction and management of the building and building process [BREEAM 2010].

In the process the different professionals in the building industry are bought together, establishing a common language them. The rating system assigns responsibilities to the various parties involved [GBCSA 2008:xiii]. In the process a complete sustainable building design is developed [GBCA 2010 & GBCSA 2008:9].

A series of lifecycle environmental impacts is identified by these rating systems. The aim is to minimise them through innovative and best environmental practises [BREEAM & GBCA 2010].

The existing rating systems aim to establish a benchmark according to which projects can be judged. The benchmark is usually higher than what regulations require [BREEAM 2010]. Only the leaders in the sustainable building environment are acknowledged; as only 4, 5 and 6 star rated buildings are certified [GBCA 2010 & GBCSA 2010].

This would encourage a constant improvement in standards and will foster innovation in design and construction practises.

2.6.2 Rating systems and climate change

The World Green Building Council [WGBC] has a list of principles to guide the council itself as well as green building councils worldwide. These principles address a wide range of issues: from the triple bottom line of sustainability and establishing transparent leadership to inclusive processes of developing sustainability worldwide.

There are eleven principles, of which two address climate change specifically.

a) The WGBC aims to respond to climate change with all scale, capacity and speed.

b) The effectiveness in creating strategies to reduce greenhouse gas emissions must be improved.

[WGBC 2010]

These have been incorporated into the principles and rating systems of green building societies worldwide.

The Greenstar SA requires as a prerequisite that the energy use for the design is calculated to demonstrate that its energy use is equal to or less than the national SANS 204:2008 "Energy efficiency in Buildings" prescribed levels [GBCSA 2008:133].

The LEED rating system has a carbon commitment, stating that it advises the reduction in use of fossil fuels. It suggests the use of renewable materials and energy sources which do not emit greenhouse gasses [Haselbach 2008:19].

The rating system has the following prerequisites related to climate change:

a) The structure must demonstrate that its energy use complies with the ASHREA standard

b) All CFC refrigerants must be phased out of HVAC systems; these gasses are harmful to the ozone layer in the troposphere.

[LEED rating system version 2.1]

The rating systems addresses various issues that lead to lower carbon buildings if complied with.

2.6.3 World Green Building Council

Most rating tools in the world are affiliated with the World Green Building Council, which means that information and knowledge is shared globally, improving the efficiency of sustainable initiatives.

The World Green Building Council was founded in California in November 1999. The first countries involved were Canada, Russia, the United Arab Emirates, the United Kingdom, Spain, Australia and the United States of America.

The Council was developed to increase collaboration between leaders in the global construction industries which will enable sustainable environments, - economies and - societies can to developed.

The WGBC recognises the following rating systems:

- **Australia** – Green Star Australia
- **Canada** – Canada LEED
- **Germany** – German Sustainable Building Certificate
- **India** – IGBC Rating System & LEED India Green Building Rating Systems
- **Japan** – CASBEE
- **New Zealand** – Green Star NZ
- **South Africa** - Green Star SA
- **United Kingdom** – BREAAM
- **United States** – LEED Green Building Rating System

2.6.4 Choosing a rating system

The Green Building Council of South Africa works closely with the Green Building Councils of Australia, the UK and the USA. This collaboration is speeding up the development of different rating systems for South Africa. The current Green Star SA Office Rating System is based on the Green Star Australia Office Rating System [Buch 2010].

Using foreign rating tools without adapting them is not advisable. Even though sustainability is a global concern, good sustainable practices are not necessarily the same for all areas and societies [Haselbach 2008:1]. The Green Star Office Rating Tools has been developed and adapted for South Africa context. This means that it will be an appropriate guide for this project.

If one needs to use a foreign rating tool, the Green Star Australia is a good choice, as there are numerous similarities between Australia and South Africa. The GBCSA adapted sections of this rating system to the South African context while the rest was directly adopted. When working with buildings that do not have rating systems in South Africa the GBCSA suggests that one uses the Green Star Australia as guide [Buch 2010].

2.6.5 Methodology

The Green Building Council of Australia found that 40% of the total emissions in the built environment are caused by offices and hospitals [s.n. 2008:1]. Therefore the GBCA decided to focus on developing rating systems for these two building types first. Currently the only rating tools that can be used are the Green Star Australia Retail tool and the Mixed Use tool. There is a pilot retail tool available for Green Star SA.

BREEAM, a rating tool from the United Kingdom, allows for international projects to be rated, but will need to be adapted to local regulation and conditions. These changes range from environmental issues & weighting, detail of construction, products and materials to local regulations [BREEAM 2010]. BREEAM has a Retail ating tool and an Other Building rating tool available. According to BREEAM the Other Building rating tool needs to be adapted and changed to accommodate the building type [BREEAM 2010].

There are LEED rating tools available for schools, hospitals, homes, cores and shells, neighbourhoods, commercial [pilot tool] and commercial interiors [pilot tool] [USGBC 2010]. None of these have specific use for the proposed building type and context except for the commercial tools.

For this project the Green Star SA Office Rating Tool will be used and adapted,. As the building type is a BRT station none of the existing rating systems are directly applicable for this project.

GREEN STAR SA – OFFICE
The Green Star SA Office Rating Tool addresses the following categories:

1) Management
2) Indoor Environment
3) Energy
4) Transport
5) Water
6) Materials
7) Land use + Ecology
8) Emissions

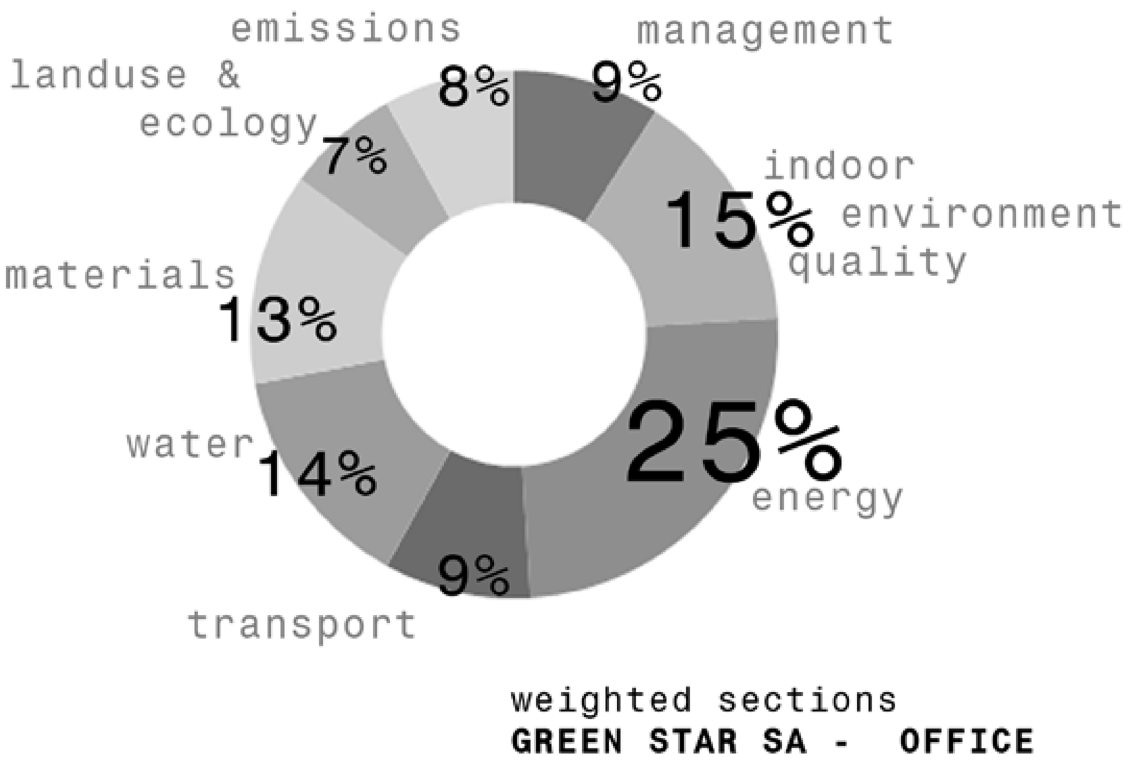
All these sections are weighted to give a single score. From this score the performance of the structure can be developed. In future, as rating tools are developed for different building types, the weightings of the different sections would change for the specific building type [GBCSA 2008:x].

Note that in Graph 2-04 that energy is the most important section of the rating tool, followed by indoor environment and water. This might differ if a different building type is used. Yet for the design of a low carbon BRT station energy is a major concern.

The sections that are most applicable in assessing or achieving a low-carbon building are Energy, Transport, Materials, Emissions, sections of Indoor Environment Quality, the construction waste management section of Management.

For this project, only the prototypical BRT station will be assessed, as it will theoretically be constructed throughout Tshwane.

The station building will not be assessed, but the rating tool will be used as a guide to address the embodied energy and carbon footprint of the structure.



Graph 2-04: Amounts that each section counts to the full score [Source: Author]

2.7 CONCLUSION

A good solution:
...solves more than one problem, while not making new problems...
... is good in all respects...
... accepts its given limits...
...and uses what is at hand...
[Barnett & Brown 1999:13]

Adapting for climate change clearly requires a good solution. This means understanding the problem holistically and adapting our cities, societies and lifestyles.

Achieving this good solution means planning before planning – pre-planning the planning process. From this a sufficient framework and holistic understanding can be developed. An understanding of the present urban context, historical and cultural context will be integrated with the good solutions and ratings to provide a framework within which the design can develop.