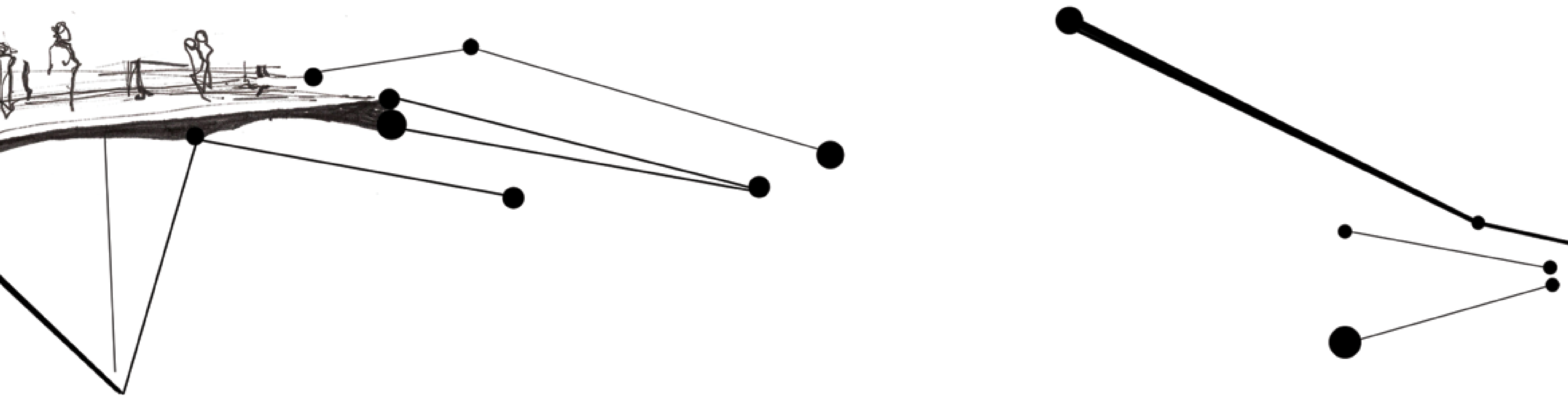
4
FRAMING THE PROJECT



4.1 THE 'LINK' FRAMEWORK

Climate change mitigation needs to be employed on many scales, from an urban scale down to the building details. **The LINK framework aims to develop a sustainable community by addressing transport, production, movement patterns and densities in Salvokop and Station precinct.**

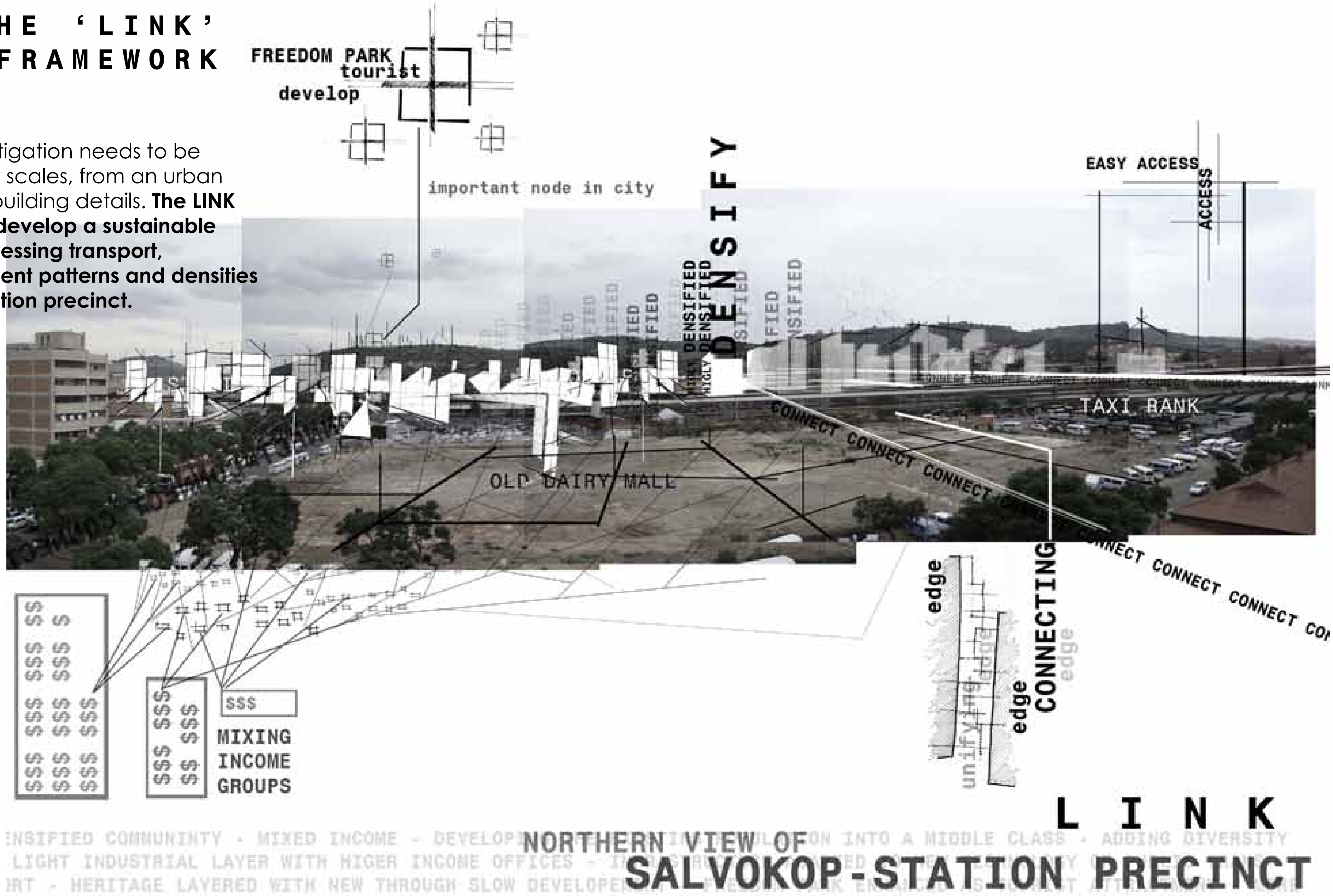


Figure 4-01: The vision for the precinct - developing the barrier [Source: Author]

4.1.1 Analysing the existing frameworks

Figure 4-02: The three frameworks impacting on the study area [Source: Author].

Three existing frameworks have been analysed and taken as starting points for the development of the LINK framework. These frameworks are

- **a) The Tshwane Open Space Framework**
- **b) The Rekgabisa Tshwane Framework**
- **c) The GAPP Culmatrix Framework for Salvokop [GCFS].**

Each of these frameworks has a certain vision for Salvokop. The Rekgabisa Tswhane framework is currently being implemented, whereas the GCFS framework has never been implemented. The Tshwane Open Space Framework is very vague regarding Salvokop but has significant implications for the development of the area.

Tshwane Open Space Framework
This framework was developed in 2005, as an **holistic [city wide] approach to densification which conserves the existing public open spaces and green networks within the city**. It promotes a healthy pedestrian friendly city with open spaces that convey a sense of place [TOSF vol 2 2005:4-6].

The framework divides open spaces within the city into 10 typologically classified areas. Each area is discussed on a macro scale, giving guidelines for development within these areas.

Within Salvokop and the station precinct the following areas have been identified as important public open spaces or networks:

Railroad - [grey way]

Pretoria City Hall - [Red node]
Pretoria Station/
Salvokop/
Freedom Park - [Red node]

Paul Kruger Street - [Red way]
[TOSF VOL 3 2005:59-63]

In essence the framework proposes that the design must enhance the process of place making, while preserving the historical character of these places.

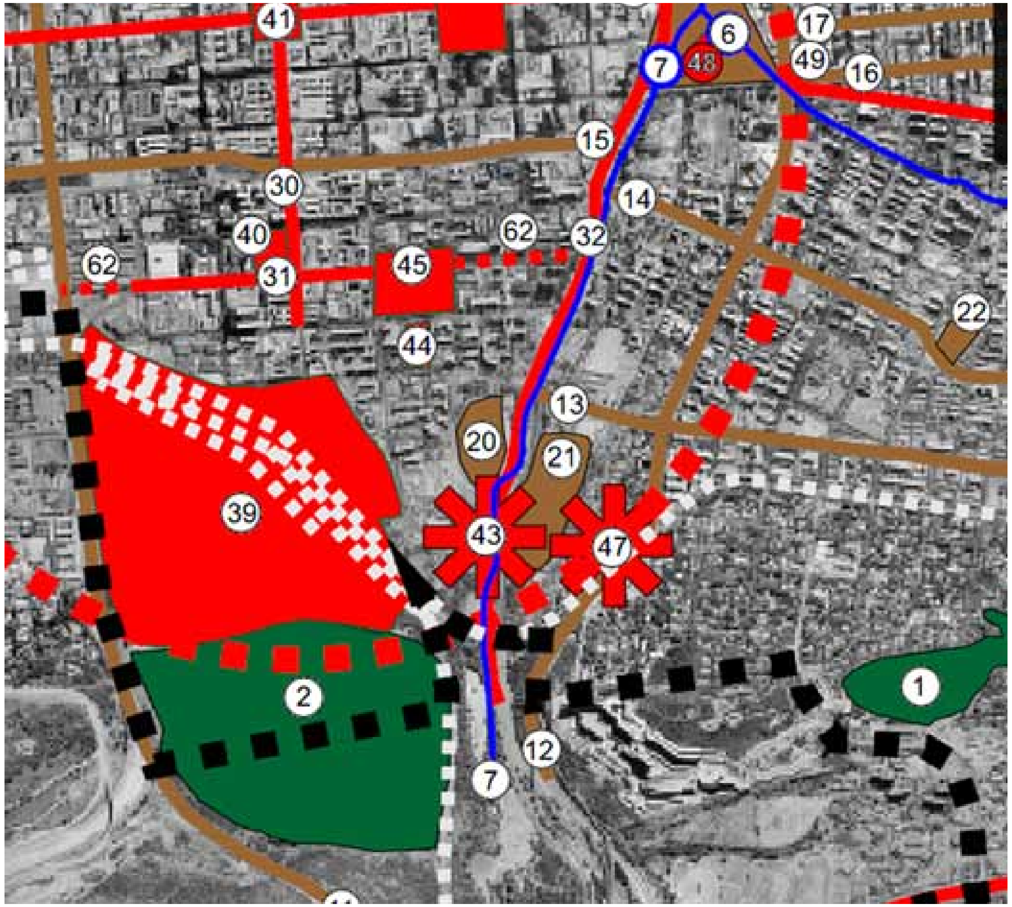


Figure 4-03: Detail of TOSF's vision for Salvokop
[Source: TOSF, p 107]

Large commercial enterprises and light industrial facilities are prohibited within these identified areas. The railroad has to be treated as a grey way where the infrastructure must be maintained with no development allowed over or under it [TOSF VOL 3 2005:59-63].

This framework is very vague on what must be done in Salvokop. Preserving the whole of Salvokop and Paul Kruger street as red ways and nodes will be impede development of the area. A compromise must be researched between the conservation of heritage areas/ buildings and development these precincts.

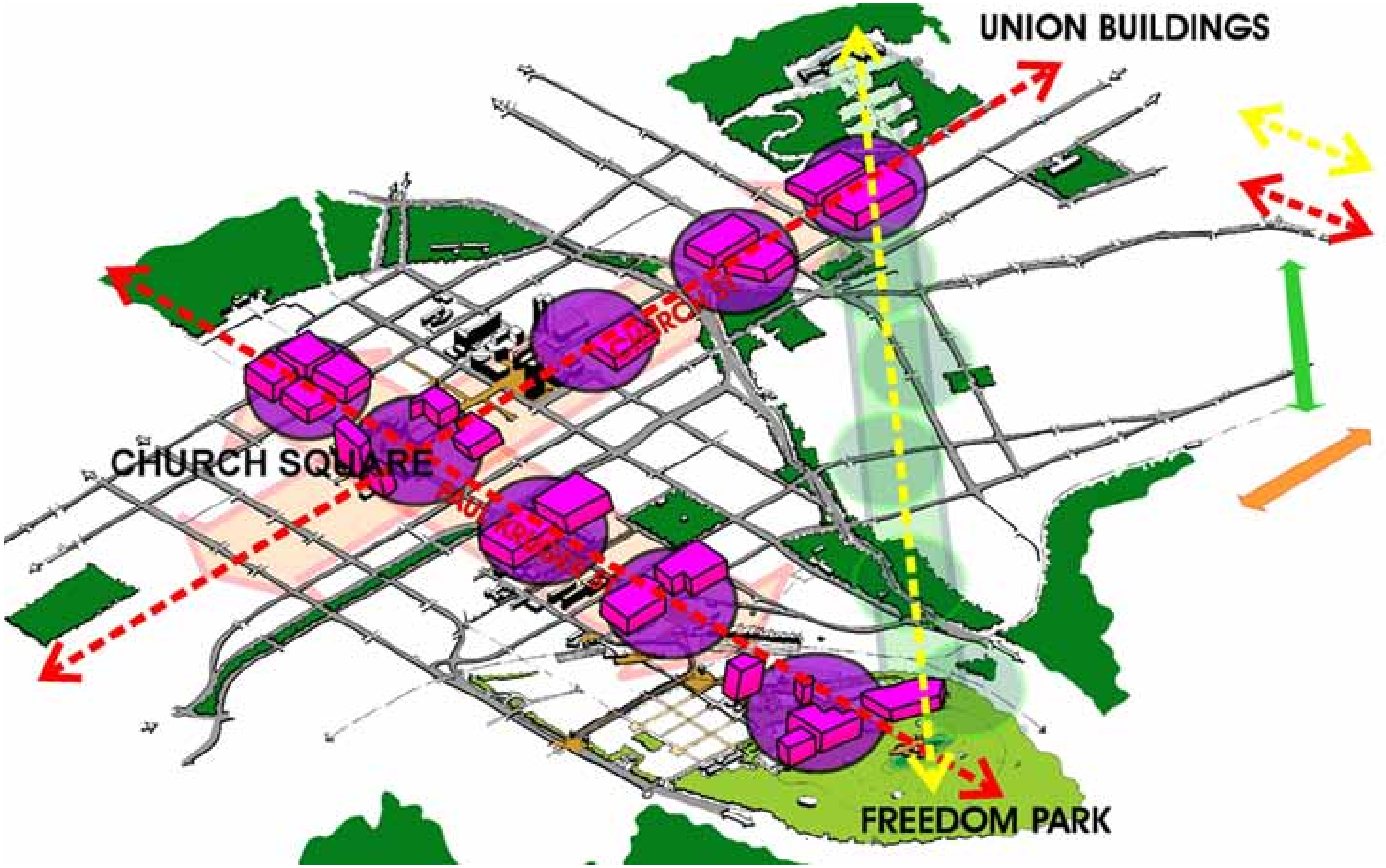


Figure 4-04: The vision of the Rekgabisa Tshwane framework [Source: Rekgabisa Tswane, p. 6]

Rekgabisa Tshwane

The Rekgabisa Tshwane Framework was developed in 2006. **It aims to reinstate the presence of National Government within the city centre, becoming a catalyst for private investment as well as preventing further decay within the city centre.**

This process will assist broader social and economic development. The framework focuses on the two physical axes [Cardo and Decomanus maximus], as well as the visual axis between the Union Buildings and Freedom Park.

Development along these axes is aimed at improving the physical environment and urban security. Developments must promote safe and healthy public spaces while increasing accessibility to government departments.

The framework proposes a public square and marshalling ground within Salvokop as well as the improvement of the Station Square. Salvokop is identified as part of the Southern Gateway into the city centre. the link between Salvokop and the city is not adressed.

Culmatrix Salvokop Framework

The Culmatrix Salvokop Framework was drawn up in 2003 to **assist the sustainable and sensitive development of Salvokop.**

The framework was developed in detail for the whole area. The northern edge was earmarked as a light industrial area, with dense housing added on the western edge. The existing NZASM houses were proposed to be redeveloped as a town centre, while the south eastern edge was proposed as a mixed use development area as shown in Figure 4-05.

A new vehicular bridge is also proposed to reconnect Salvokop with the city [Figure 4-05], Unfortunately it is proposed within a historically sensitive area. The proposal extends the Cardus Maximus into Salvokop forming a high street on the axis [Figure 4-05].

The framework prescribes the preservation of existing building stock as well as retaining existing or historical functions. Thus all new interventions must be in accordance with the Burra Charter, where the new functions must be sensitive and compatible with the historical functions of the site [Burra Charter Article 7; Bakker 2003:01]

The Culmatrix Salvokop Framework does not particularly deal with the issue of dislocation. The linking of Salvokop to the city will be vital for the sustainable development of the precinct.

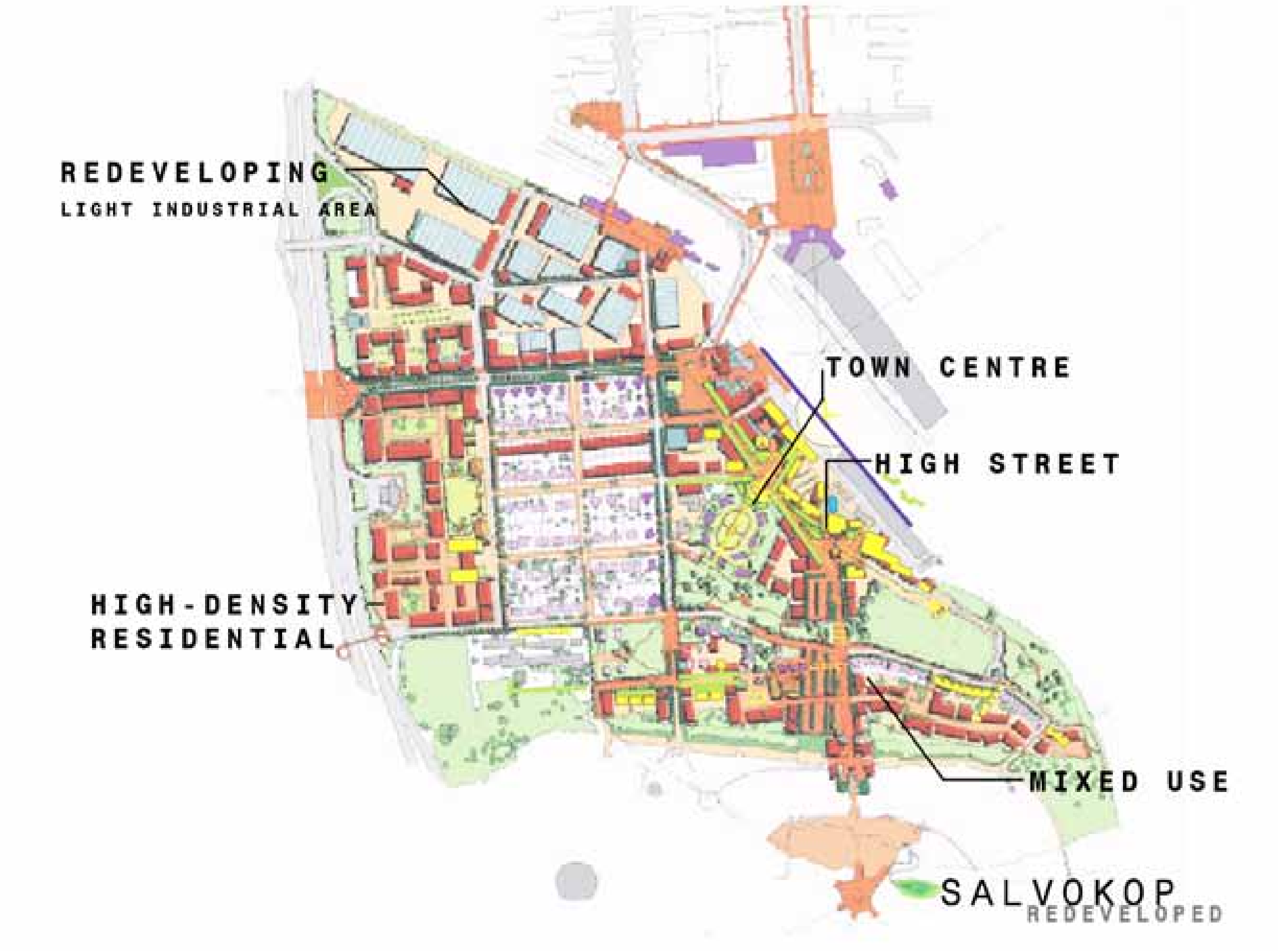


Figure 4-05: The proposed framework for Salvokop, by GAPP [Source: Culmatrix]

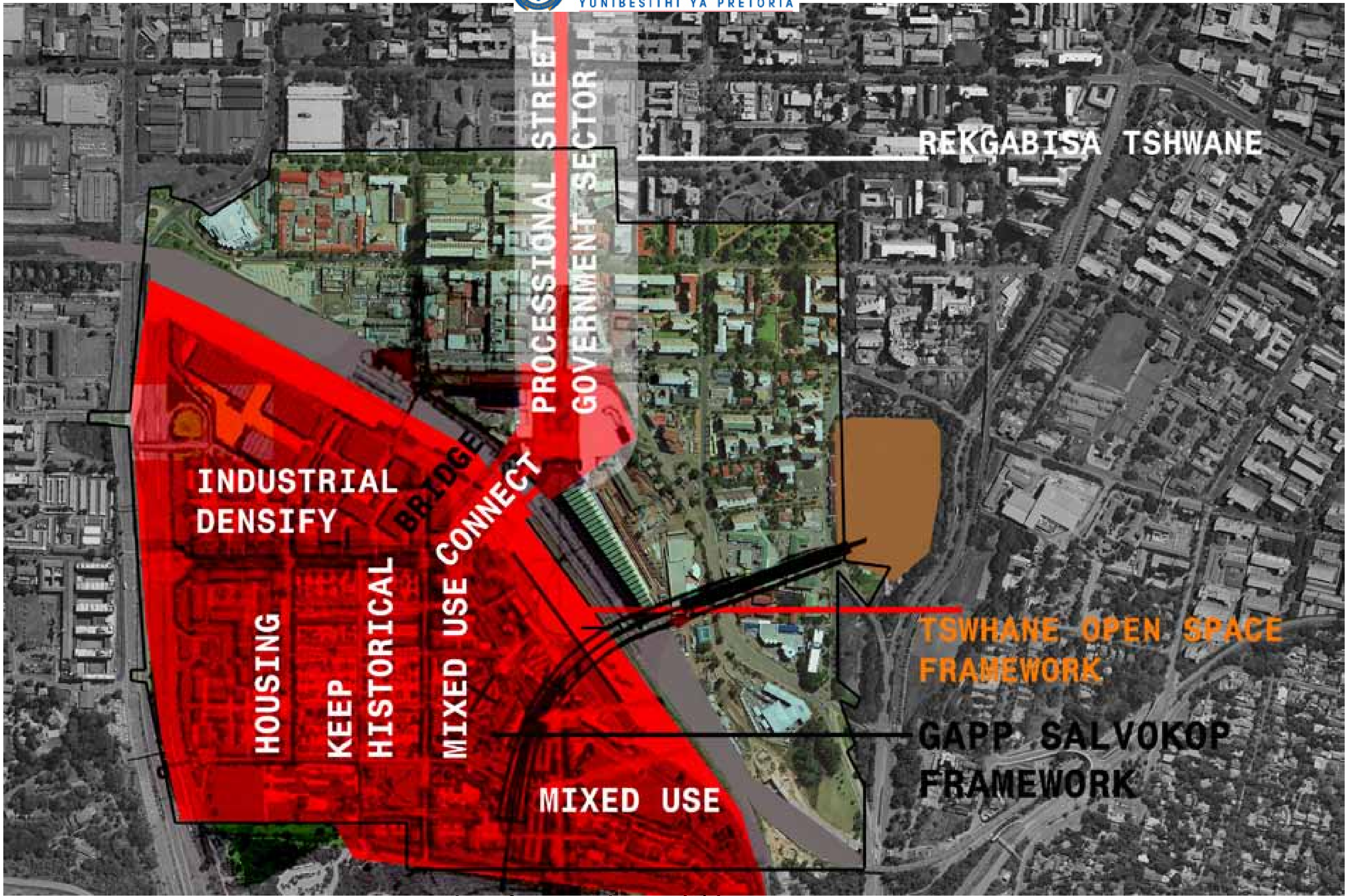


Figure 4-06: A synergy of the three frameworks in the study area
[Source: Author]

Three frameworks overlaid

These three frameworks were integrated into a more cohesive framework that focuses on the area linking Salvokop and the city.

4.1.2 “LINK” - framework

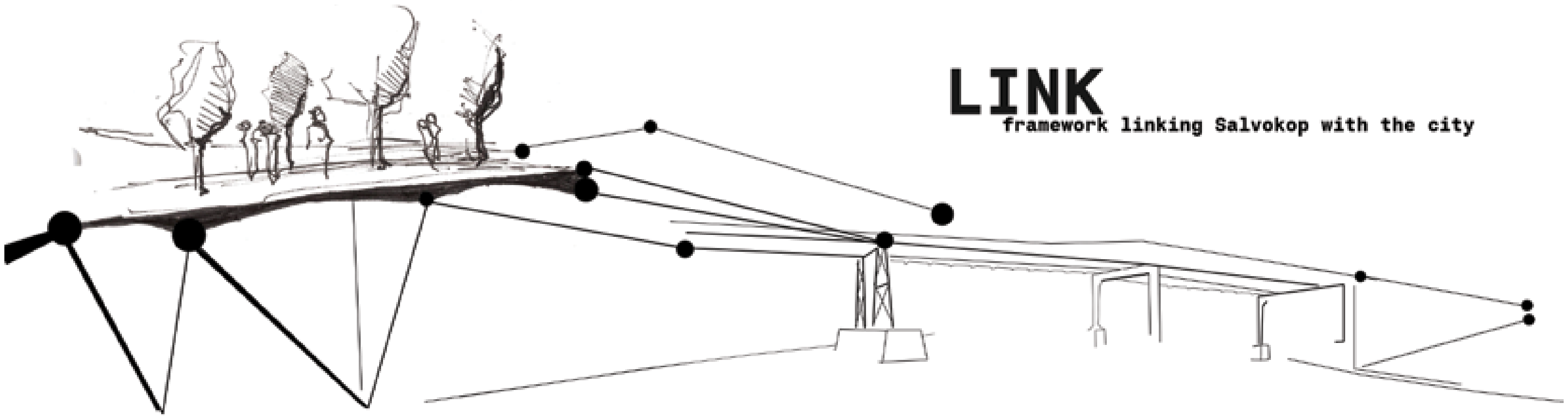


Figure 4-07: The vision for the precinct- linking Salvokop [Source: Author]

The framework proposes to use the existing barriers as opportunities for linkage. By changing the barriers into a seam of movement and energy, a safe and healthy environment for the inhabitants and users of Salvokop and the station precinct can be developed.

Figure 4-08: Zoning and layout of Salvokop and the Station precinct [Source: Author]

Precinct development

The framework proposes that the Salvokop precinct be developed slowly over time, while the Station precinct will be densified and develop at a much faster rate.

When a layered approach is used to develop an underdeveloped area over a long period the existing inhabitants who have taken ownership of the precinct can be retained [Jacobs 1977:285]. This means working with existing positive forces within the precinct and developing a middle class out of the existing slum dwellers [Jacobs 1961:290]. This form of grassroot development also contributes to the education of a part of society that generally does not understand sustainability [Newman& Jennings 2008:87].

The station precinct is proposed to be densified by predominantly offices and retail development, thus renewing the area west of the Station.

Within Salvokop dense residential and mixed use development zones are proposed. The existing brownfield sites will be developed with layered production and mixed use developments.

Phasing

The four stage phasing of the framework is planned over a 20 year period.

Start

First establish government functions in Salvokop.
Establish pedestrian and vehicular links.
Develop the high street and town centre.
Develop area west of station and densify
– rebuilding existing derelict structures

3+

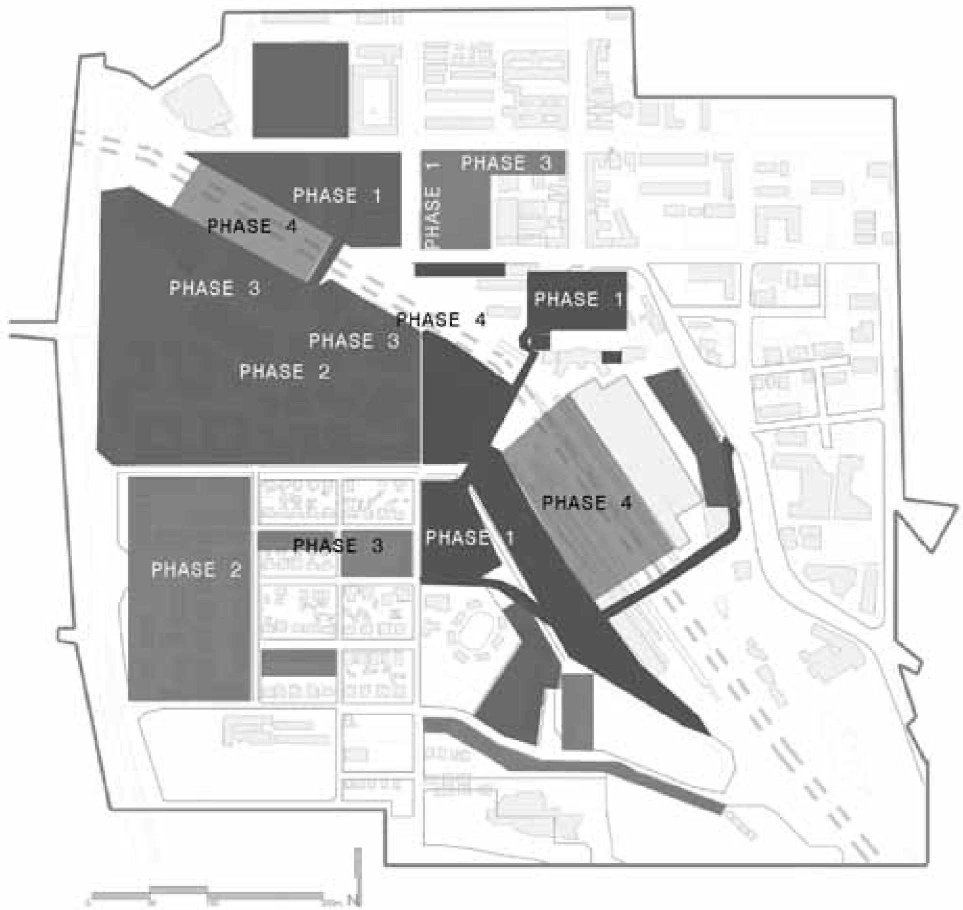
Develop the new Smart industries, production and commercial zones.
Densify western edge with housing.
Develops station to bridge the gap between Salvokop and city.
Develop area west of station and densify
– up to 6 -10 storeys

10+

Layer development of existing houses.
Develop northern edge of Salvokop with office, retail and entertainment areas on top of the smart industries.
Add more pedestrian bridges added and last direct vehicle tunnel.

20+

Densify the whole area with offices and commercial uses.
Develop building rights on top of the railway with mix use functions. Emphasis on developing entertainment functions within bridge buildings.



DEVELOPMENT PHASING

Figure 4-09: Phasing of the LINK framework [Source: Author]

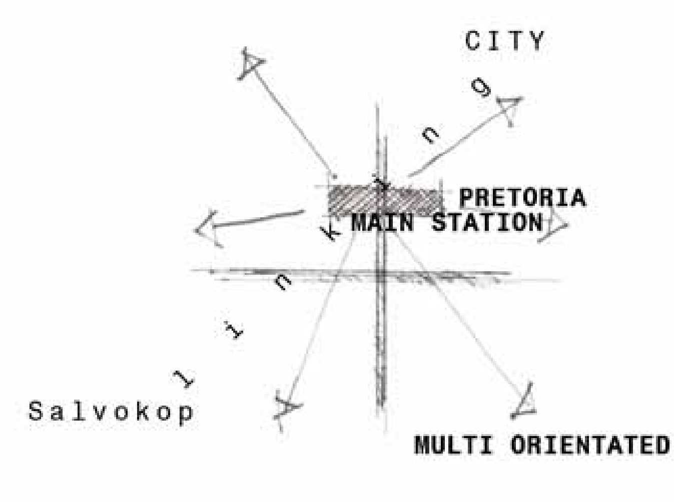


Figure 4-10: Station orientation
[Source: Author]

Proposed interventions

Transport Nodes

The current station platforms are proposed to be developed as a linking structure between the city and Salvokop. A second entrance and parking are proposed for the southern edge of the station, while taxi and future BRT stations are proposed to be housed within Salvokop.

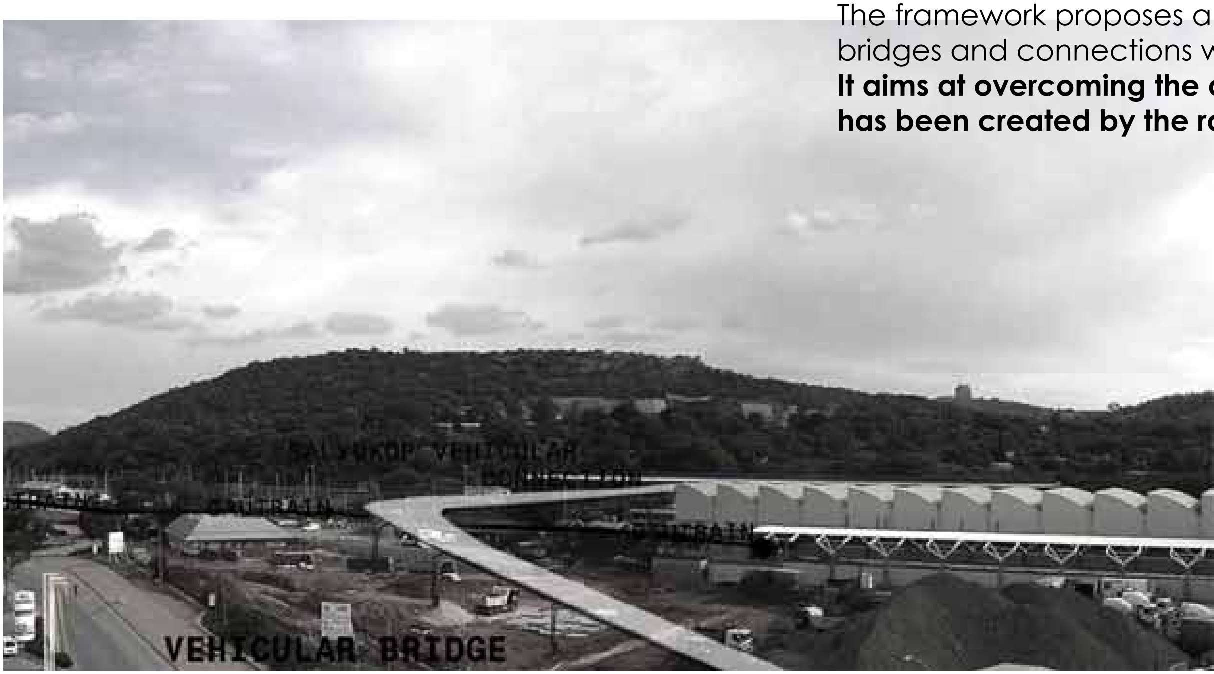
In the process the station will become a multi orientated structure that links the immediate and distant areas within the city, ensuring that the transport node is well connected to all sectors of the city [Alexander 1977:92].

Bridge connections

The framework proposes a series of bridges and connections with the city centre. **It aims at overcoming the dislocation that has been created by the railway line.**

Three new vehicular entrances into Salvokop are proposed, ensuring easy access into the production area. An eastern bridge will provide more energy on the newly planned high street of Salvokop. A third tunnel will be built within 10-20 years with new bridge building typologies developing in response.

To combat slum development on the border between the two precincts [Jacobs 1961:271], **two skypark/pedestrian bridges are proposed in the initial phases, while over time the building bulk themselves will bridge the railway line, leading to the restitching of the barriers.** This will ensure the border area between Salvokop and the Station Precinct develops as a vibrant busy area.



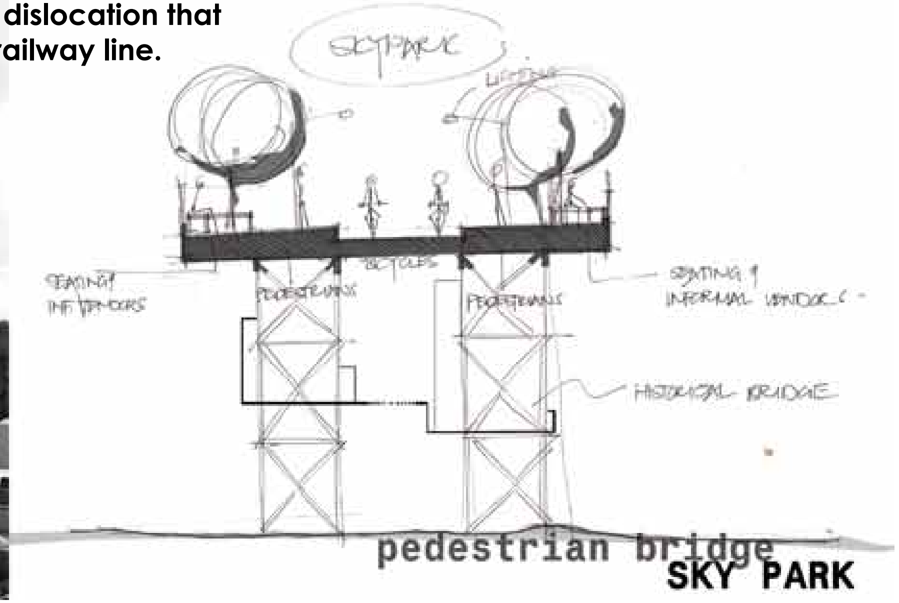


Figure 4-11: Connecting Salvokop [Source: Author]

By adding distinct functions energy can be harnessed and directed to the isolated areas in Salvokop [Jacobs 1961:280-283]. At the end of all the pedestrian bridges retail or civic functions are proposed, ensuring that the bridges will be safe and used regularly. This will lead to passive surveillance and busy, vibrant borders. These border conditions then become "seams" that will have a positive influence on the neighbouring areas.

Historical and slower layered development

To ensure diversity in the precinct the framework proposes retaining the historical structures within the precinct. The mixed ages of building stock[Jacobs 1961:162] ensures the inhabitants can redevelop the area themselves [Jacobs 1961:207]. This will also lead to diversity and a mixture of users of varies tastes and income levels [Jacobs 1961:207].

The layering of development on the historical will ensure a slow enough development, yet a highly dense and diverse precinct will be developed in 10-20 years.

Mixing functions and increased densities

The framework proposes the mixing of functions within the precinct. By establishing a government sector in the precinct the initial investment and development will be ensured. The introduction of commercial sectors, transport interchanges, and a smart industry / production sector is aimed at providing work and income to the existing inhabitants. The added functions will attract developers and new affluent groups to the area.

Housing will then be added to ensure that sustainable densities are achieved. It has been found that denser cities consume fewer resources per capita, leading to more efficient systems and retaining the existing bioregion of the city [Newman & Jennings 2008:87].

The framework proposes a smaller scale of a diverse selection of functions within the precinct [Jacobs1961:266]. **Diversity and vibrancy close to the historical centre will be achieved by smaller mixed-use areas and by layering new development over the existing historic fabric. Only the northern edge will be developed with large plot sizes and building bulk.** Large over-scaled players such as big banks, insurance companies and franchises will be accommodated on the northern edge, or rather kept within the city centre and Station precinct.

The framework aims at retaining the inhabitants of the area and growing the middle class, enriching the precinct and ensuring that a sense of ownership is retained within the area [Jacobs 1961:299].

Figure 4-12: Existing houses in Salvokop [Source: Author]

Pedestrian/ bicycle routes and block size
The framework proposes the accommodation of **cycling and pedestrian routes along the existing streets. This in conjunction with the placing of transport interchanges will discourage the use of private transport** [Brain 2005:227].

By retaining the existing smaller block sizes in Salvokop the movement of pedestrians will be accommodated and encouraged, ensuring that areas within the precinct are not isolated by allowing more movement through the streets. This will increase the passive surveillance within the area, making it a much safer place to stay [Jacobs 1961:195].

Green structure
A green structure is proposed throughout the precinct. The southern edge of the precinct as bordered by a conservation site, within which Freedom Park is situated. The green structure throughout the precinct will form part of the proposed cycling and pedestrian routes.

The framework proposes keeping the existing trees in Salvokop while adding as much as possible green spaces and vegetation within the city and on the pedestrian bridges. This will contribute to climate change mitigation through cooling and carbon sequestration [Newman & Jennings 2008:86].

Smart Industries and production
The heterotrophic[1] nature of urban economies has led to cities changing from local to global economies. In the process all production and consumption has become unsustainable [Newmann & Jennings 2008:38]. **The framework aims to bring the production of user goods back into the city, through clean/smart industries and production.** This refers to smaller scale producers of goods such as clothing, furniture and electronic assembly.

This endeavour will respect the original functions of the site as a starting point from which the area can develop [Burra Charter article 7; Bakker 2003:01] as proposed in the GCSF-framework.

The book *Cradle to Cradle* [Mcdonough & Braungart 2002:114] suggests a paradigm shift were products are more easily recycled and reused. In essence “products of service” should be created. Yet at the moment most of the products used in cities are produced in countries like China. By bringing small scale production back into the city a more sustainable form of consumerism can be practised [Newman & Jennings 2008:41].

The smart industry zone will densify in time with office developments and mixed use functions added to the existing. **This process can create a diverse precinct within the city, providing much needed work for the inhabitants as well as utilising and developing diverse forms of skills.**

Note 1: **Heterotrophic** - refers to an ecosystem that does not produce sufficient energy to meet its own needs but is dependant on sources outside the system [Newmann & Jenning 2008:38]

Conclusion

By linking the precinct to the greater urban whole and allowing the energies from the city to develop and regenerate the area. Salvokop will in turn serve the city in the future.

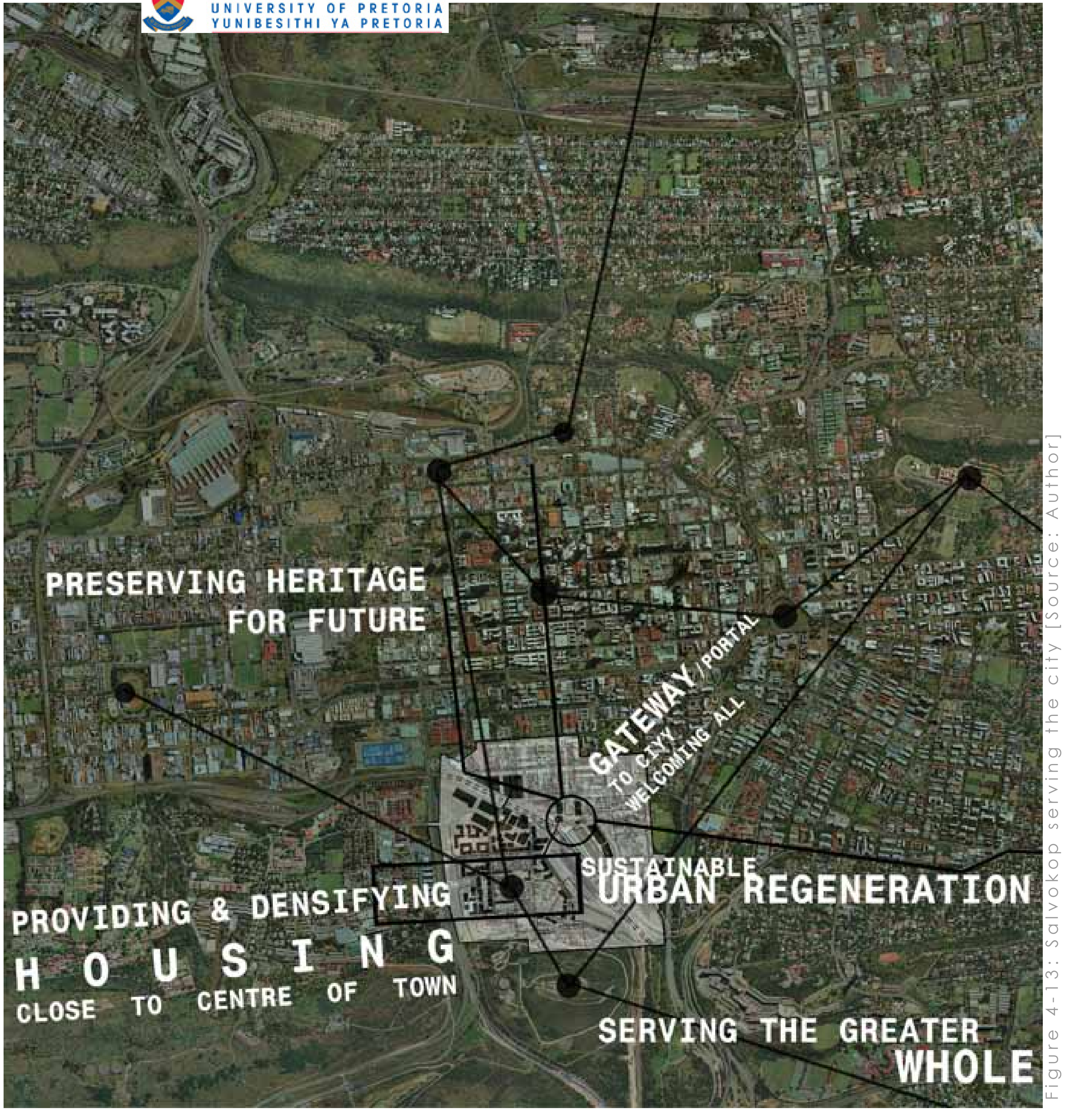


Figure 4-13: Salvokop serving the city [Source: Author]

4.2. HISTORICAL SITE FRAMEWORK

4.2.1. Statement of Significance

Place
The intervention is situated on a very important point within the City of Tshwane. **It acts as a termination point for the cardus maximus [Holm 1998:61] which links up with the heart of the city.**

The precinct forms part of the living heritage of the city: it has been used as a transport interchange since 1894 [Bakker 2004:04]. Even though it has undergone many changes over the years, the precinct played a significant role in the industrial and economic development of both the city and the country [Bakker 2004:2;6].

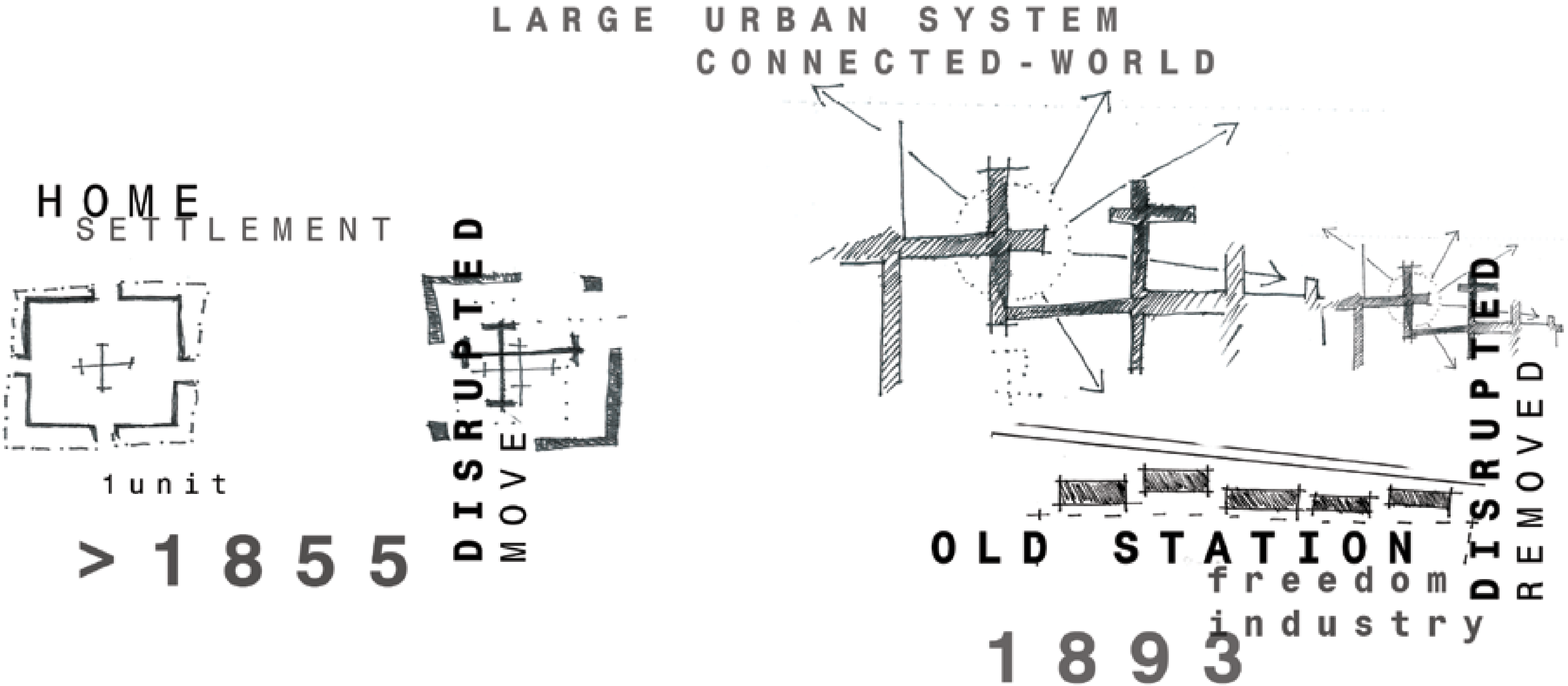
As a symbol of freedom, this interchange played a vital role in ensuring the sovereignty of the Transvaal Republic [ibid]. While currently it acts as a gateway to the sprawling metropolis of Tshwane.

The Station Square
This monofunctional neo-classical forecourt, has undergone significant changes over the years and has shown a robust character with the potential to enhance the gateway into the city. **The square acts as an approach to the neo-classical station building and still displays the WWI & WW II memorial.** The square used to carry important symbols of the city.

The square needs to be readdressed as it is currently a dislocated, isolated open space which only serves a visual function and acts as thoroughfare for commuters.

Pretoria Main Station
It is a building of historical architectural value, **with the main facade lining up symmetrically with the cardus maxmimus, creating an important vista within the city.** The façade, especially the porte cochere and station tower act, as symbols of importance and vision.

The station building will need to be readdressed to ensure the sustainability and success as a transport interchange accommodating different transport systems.


LARGE URBAN SYSTEM
CONNECTED-WORLD
HOME
SETTLEMENT
1unit
>1855
DISRUPTED
MOVE
OLD STATION
freedom
industry
1893
DISRUPTED
REMOVED

4.2.2 SITE: DEVELOPING FROM HOME TO STATION

Figure 4-14: Depiction of the development and key moments of the site [Source: Author]

According to oral history the first people to settle in Salvokop were members of a Setswana tribe. They lived to west of Salvokop where the jail is currently situated. The tribe was called the Bakgatla (Tswana family group) of kgoši 'Andries' Moepi, and was moved to Makua [close to Garankuwa] by President Paul Kruger. The reason for their removal was never stated, but it could have been to make space for the development of the station precinct.

The completion of the railway line to Lourenzo Marques in 1894 ensured the sustainability of the gold mines in Johannesburg, as now the Transvaal Republic had access to the international market [Bakker 2004:2+6]. It provided job opportunities and was at that time the biggest industrial intervention in the Transvaal Republic.

After the Anglo Boer War the NZASM rail system and company was taken over by the Central South African Railway [CSAR/SAR&H].

As envisioned by Cecil John Rhodes the railway system of South Africa was developed at a marked pace. **The station and railway system started to have a significant effect on Salvokop and the rest of Pretoria – leading to the development of hotels, offices, goods yards etc [Bakker 2004:3].**

As Pretoria developed the railway line started servicing industries in the west and east of the city. In 1948 the industrial and freight facilities at Pretoria Main Station were moved to the Koedoeskop and Capital Park stations [Bakker 2004:5]. **Currently the Pretoria Main Station only accommodates commuters.**

During the Apartheid era Bosman street station was constructed [1955-1959] as an act of racial separation. Pretoria Main Station was declared a whites only area, while the black African population was forced to use Bosman Street Station [Astrup 2004:29].

Currently Bosman Street Station is still being used as a commuter stop, though it does not have safe pedestrian access.

With the addition of the Gautrain and BRT system the number of passengers moving through this station will increase significantly.

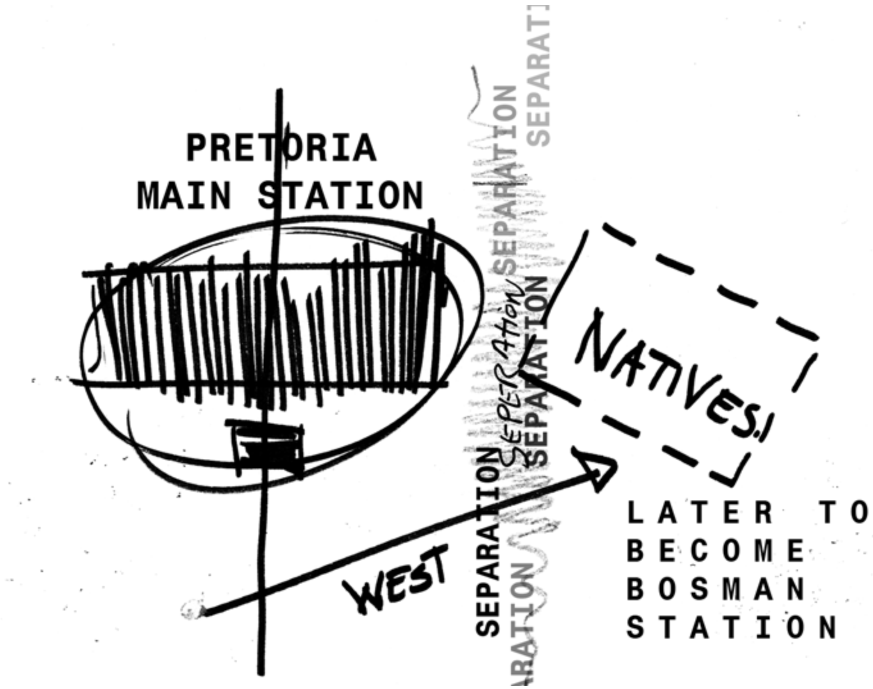


Figure 4-15: The station for the "natives" to the west [Source: Author]

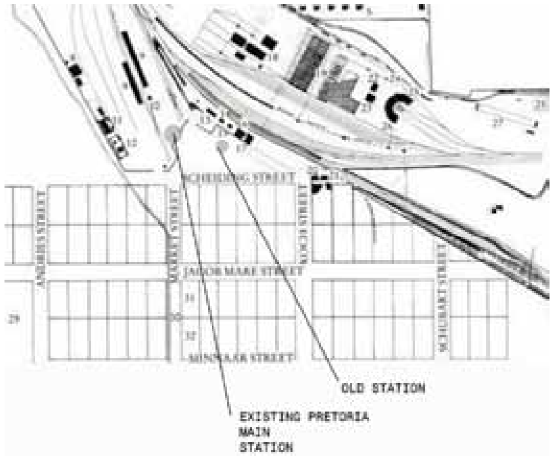


Figure 4-16: Plan of the urban layout 1894 [Source: UP archives; De Waal collection]

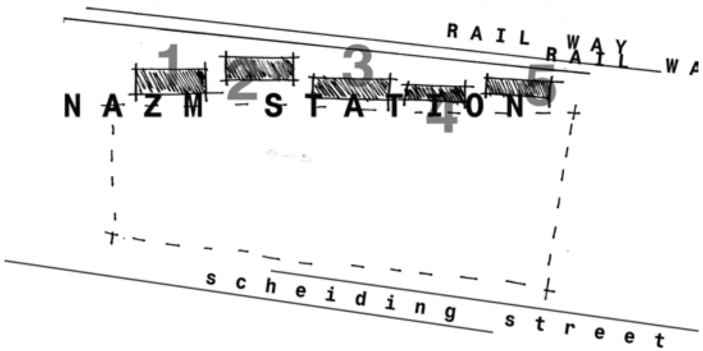


Figure 4-17: Schematic layout of the old station [Source: Author]

The Old Station

The first NAZM station buildings were constructed in 1881and consisted of f**ive buildings: one corrugated parcel office and four red brick structures [Bakker 2004:12].** These structures housed the service buildings, ladies' & general waiting rooms and refreshment rooms. The layout of the station was done in such a manner as to create a square to the south of Scheiding Street [Bakker 2004:13]. **These were only single storey structures and were very pragmatic in their design and layout.**

As indicated in Figure 4-16 the station buildings themselves were not place on the axis of Market Street. They were located to the west of the existing station building.

Figure 4-18: The first station buildings constructed in 1894 [Source: UP archives; De Waal collection]

Pretoria Main Station

The construction of the Pretoria Main Station started in 1909 and was completed by 1912. The station structure was designed by Sir Herbert Baker, as a termination point on the central axis of Market street [Paul Kruger street] [Baker 1912:xviii]. **It is an eclectic Renaissance structure strongly influenced by the availability of local materials [Le Roux & Botes 1992:26].**

The three-principled facade was designed with a central arched porte cochere and deeply arched logias on either side [Baker 1912:xviii]. **The entrance is not overscaled and imposing but kept to human scale [Keith 1998:91].**

The hall has high clerestory windows, which allow for natural lighting and ventilation, the mass of the structure contributes to a very cool and thermally sound building [Baker 1912:xvv]. All floors and ceilings were constructed from wire-woven reinforced concrete. The base of the columns and walls are clad with granite [Baker 1912:xvv].

The central hallway, acts as a movement corridor with a very open hollow design typical of Herbert Baker buildings [Keith 1998:91]. The dining hall and server were placed in the eastern wing and the baggage and parcels in the western wing [Baker 1912:xvv].

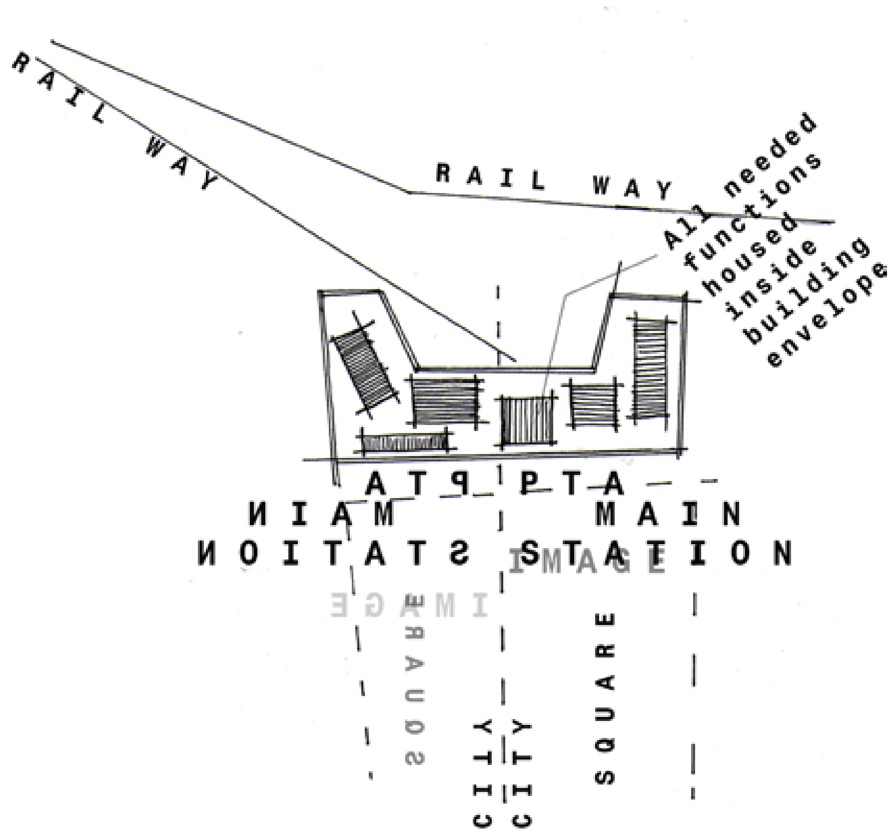


Figure 4-19: Schematic layout of Pretoria Main Station [Source: Author]

West of the main building a separate building was erected for the "natives" thus racial separation was a design consideration from the start [Baker 1912:xvv]. Baker also intended for a government department to be housed in the station building on the second and third floors [Baker 1912:xvv].

The three-storeys-high building was constructed from flatpan sandstone, quarried in the Free State, while the original Italian type tiles were manufactured in Vereeniging [Baker 1912:xviii]. The stone walls are currently to be painted. On investigation it was found that the paint could not be removed.

A sealant was originally added before the stone walls were painted. It has degraded the stone to such an extent that water penetration will be a major problem in future [Lindeque 2002:3].

The timber roof structure was originally constructed from Scandinavian pine and consisted of exposed dual pressed rafters seated on a concrete encased roof beam [Lindeque 2002:8]. The roof had to be reconstructed after it was destroyed in a fire in 2001.

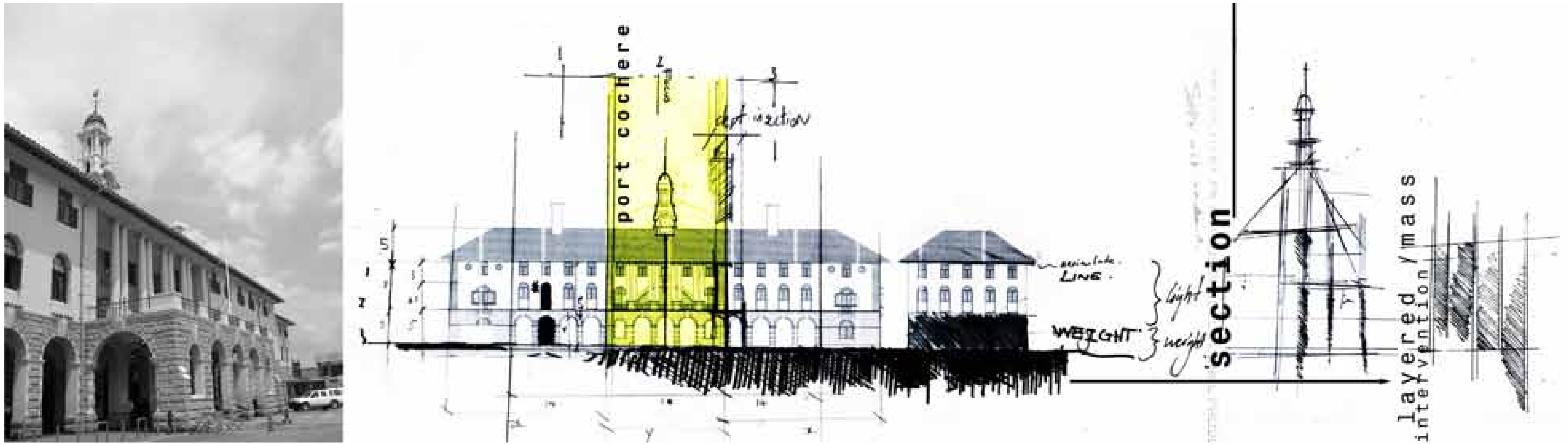


Figure 4-20: Facade of the station [Source: Author]

Development of the Station and Station Square.

The Station Square as undergone many changes over the years. The Station building itself was completed in 1912, while the Station Square was added between 1912- 1925.

In October 1925 the Paul Kruger statue was re-erected on the square. The statue was moved from Princess Park to the Station Square [Bakker 2003:4+17]. In 1954 it was moved to Church Square where it is still located [Astrup 2004:28].

The sunken gardens were constructed in 1946 in preparation for the visit of the Royal family of King George IV and Queen Elizabeth [Bakker 2004:4]. **In front of the Station building the World War I and II memorial was erected, where it still remians.** It is not clear when it was built.

In 1947 the bridge connecting Salvokop with the station was constructed and only white people were allowed to use it [Bakker 2004:19].

On 19 February 2001, angry train commuters set fire to the station buildings. The reason behind the protests being train delays and the lack of service delivery [Lindeque 2001:1]. The whole of the roof structure and the clock tower was destroyed while the ground floor suffered extensive smoke damage [Astrup 2004:32].

Figure 4-21: The Station Square before 1954. [Source: Unknown]

Figure 4-22: [Next page]Changes and adaptations in history [Source: Author]

The first and second floors of the office section survived intact [Lindeque 2001:3]. The restoration of the station buildings started on 25 June 2001 and was completed in June 2002 [Astrup 2004:32].

Currently the Gautrain station is being constructed, though it doesn't appear to be integrated with the station building.


REMOVE
ADD
CIRCA
1911
1932
1880
1880
1932
1946
CIRCA
>2002
1925
CIRCA
2005
1890
2005
1946
1912
1932-2002
CIRCA
1920
>2002
1890
1912
CIRCA
>2002
1923
CIRCA
>1912
1912
2001
1947
2010
1910
CIRCA
>1937
TIME
change

4.2.3 Conclusion _ Manner of intervention

The approach to re-developing the station precinct and the new BRT terminal building will follow general principles of sustainable design and general conservation principles :

- **Existing historically valuable building stock will be retained**
- **The public space will be reinterpreted with a new layer of meaning that is compatible with historic function**. It will be developed to combat the heat island effect and function as an air conditioning zone for the BRT terminal building.
- **The station precinct is proposed to be changed as a whole to an integrated transport node**.

In accordance with the Burra Charter:

1. The Pretoria Main Station Building will be reintegrated with the new station site layout, while ensuring that the new functions are be compatible with the existing function [Article 7].
2. All historical material will be retained and reused on site [Article 9].
3. New work will look distinctly different [Article 19].
4. Station Square and connection into the Main Station Building will be reinterpreted and adapted through layered approach that is reversible[Article 1] .
5. The whole urban setting and related culturally significant material will be retained [Article 8].

Place

In order to develop the new movement layer on the existing, **important points on the site [referring to historical, removed and future points] will be linked**. This aims to integrate and include all aspects of users and systems on the site.

The cardus maximus will be enforced by clearing the vista up Paul Kruger street.

Station Square

The Station Square will be reinterpreted – by linking it with the existing and new interventions. **The new movement layer will be superimposed on the existing. Historical components will be reinterpreted to be more accessible to the public.**

The intervention aims to develop a “background” structure that will define the edge of the Station Square. The background layer will consist of a series of skins that will change and adapt to season and time.

Pretoria Main Station Building

As the façade of the Station building is an important historical symbol/component both on an urban scale and to the immediate context, it will be retained by the intervention.

This solid façade will be reinterpreted within the new structure as two new entrance points – responding the stereotomical nature of the façade.

The hollow open layout of the building will be retained and reinterpreted within the new structure. This new structure will be open in a similar way, becoming more a movement space than a building.

The articulation of the entrance with its arched logia and porte cochere will be interpreted at the new entrances as a manner of developing a structural system and facade.

The intervention will follow a layered ecosystemic approach
_adding layers to ensure diversity of old and new,
leading to a flexible and adaptable site.
[components only to be removed to accommodate
new movement layer or clear axis of cardus maximus].
_these layers will be linked to generate a new intervention.

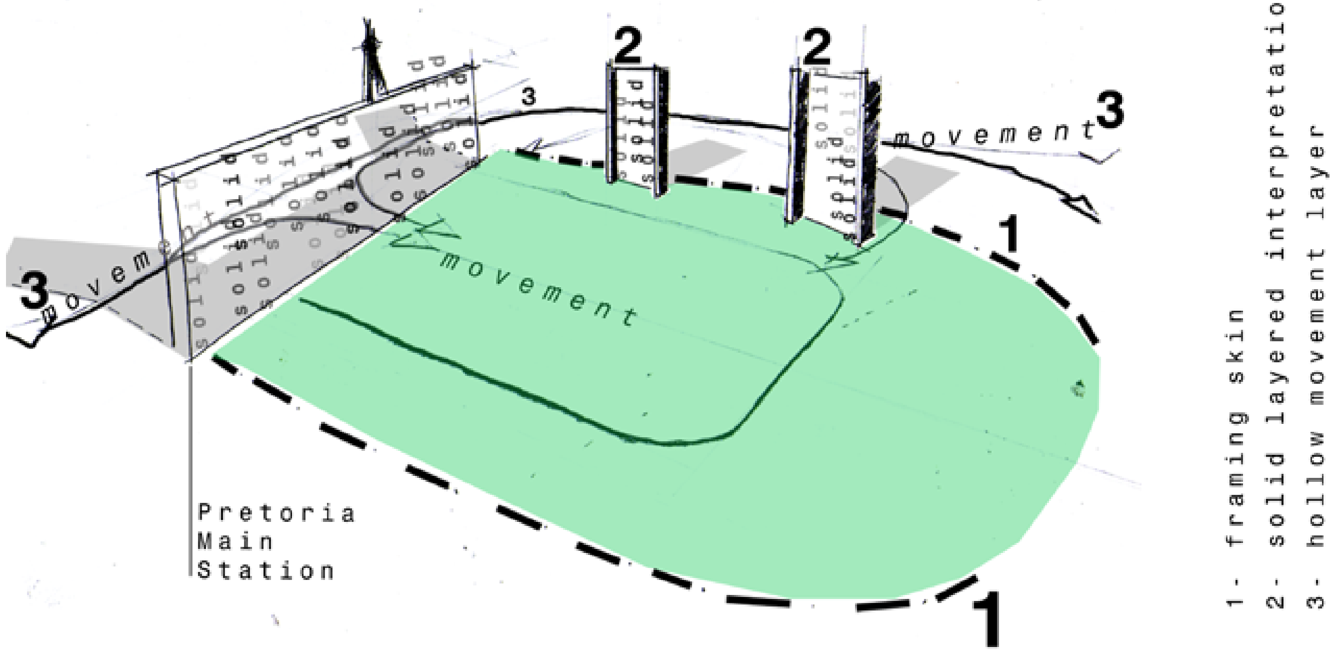


Figure 4-23: Three layers of intervention - responding to the existing station and its context [Source: Author]

4.3 FRAMEWORK – LOW CARBON STRATEGIES/ TECHNOLOGIES AND APPROACHES

In order to achieve a low-carbon building, design strategies, systems and technologies must be identified to guide the design process. These will be classified as passive and active strategies, and have been adapted and identified to specifically suit the site and nature of the project.

4.3.1 Passive design approaches.

Solar orientation
The architect must always **aim to ensure that the building is orientated north [15° E and 10° W of North]** [SANS 204-2:33]. As the building must frame the Station Square, link to Salvokop Bridge and fit the BRT stations into the site – most of the structure will not achieve that aim. Office functions that require little movement of the user need to be orientated correctly as the indoor environment is critical in these zones. The indoor thermal comfort as prescribed by the Green Building Council ranges from 22-29 °C for summer, while 19-26 °C in winter [taking an average increase of 3 ° C cause by climate change into consideration][GBCSA 2008:87].

As the building is situated in the "highveld" – thermal heat gain will still be important in winter while the shading of windows and large sections of high mass walls are essential in summer [Holm 1998:69]

Landscaping and the heat island effect
The designer must make use of as much planted landscaping close to the building as possible. **The Station Square, east of the intervention, should be utilised to cool the immediate environment and air-condition the summer winds that are harnessed for ventilation** [Haselbach 2008:69+73; Dimoudi & Nikopoulou 2003:75].

Light coloured roof materials must be used and western walls must be shaded to minimise thermal heat gain in heavy materials [Haselbach 2008:69+73; Roaf et al 2009:55].

Natural Ventilation.
Rooms must be as narrow as possible to ensure good cross ventilation, preferable keeping the eastern ventilation openings lower for cool air to filter into spaces [Van Lengen 2008:49]. **A room should not to be deeper than 5 times its height [Halliday 2008:258].** Higher floor to ceiling heights will contribute to a better indoor environment and allow hot air to rise above the user [Van Lengen 2008:273].

A central walkway should be used to promote a stack effect [refer to CH2 precedent]. This will ensure that spaces adjacent to the walkway ventilate efficiently by using the thermal energy generated by commuters during busy periods [this principle was used in the Beddington Zero Energy Developement in Brittian] [Peason 2000:47].

Natural lighting
As much as possible **diffused natural lighting must be allowed into the structure;** to ensure this the central roof structure must be high enough [Holm 1996:7]. **The outer skin of the structure must ensure that all glare is eliminated from the indoor spaces**. Plant screens, natural landscaping, building components and movable screens can be used to ensure good lighting in indoor spaces.

4.3.2 Active systems

Architects are in control of the passive strategies and technologies used in buildings. These can have a significant influence on the efficiency of the building [Holm 2010]. Active systems must only be used passive strategies and technologies are not adequate. For this project active systems will be used for space heating, mechanical ventilation and selective energy generation.

Generating energy
Photovoltaic energy is the only viable renewable energy to use in Pretoria. **The project will aim to generate enough photovoltaic energy for its lighting needs.** This can also be integrated with the national electricity grid, which will lessen the strain on the use of non-renewable resources [Holm 2010].

The solar voltaic panels will be integrated with the roof sheeting as a dematerialisation strategy to achieve material efficiency [GBSCA 2008:261].

Ventilation systems
The building will use a **series diverse systems to ventilate the structure and ensure adaptability and efficiency of the "whole" [refer to CH2 precedent study]**. The different systems will be adapted to the season/ time and outdoor environment.

Water will be used as a phase-changing material for space heating, in solar water heaters, or integrated with a rock store for cooling/heating.

The Station Square will be used to pre-cool and filter the air, the air will be collected at the reflective pools that are proposed for the gardens. The ventilation system will use an earth tube and rock store to condition the air before servicing the different spaces within the building[1].

The rock store will also be cooled during the night to ensure the stored coolth can be used during the day.

4.3.3 Conclusion

By laying down these strategies beforehand the designer can make decisions with more ease during the design process. The strategies will guide the process and ensure that an energy efficient and sustainable building is achieved.

1. Note: The use of an earth tube and rock store for ventilation was discarded during the process as it will not be efficient for cooling purposes

4.4 FRAMEWORK – LIFE CYCLE ASSESSMENT: MATERIAL CHOICE

Bennett et al [2003:126] propose the use of life cycle assessments as a means of addressing the green house gas emissions and embodied energy of architecture. This would mean the full understanding and quantifying of the resources used and emission that are produced by the structure.

In essence, life cycle assessment can be defined as follows:

> **...[It is] formulated to assess the non-site-specific potential environmental impacts of a product regardless of where, when or who uses it.**
>
> [Bennett et al 2003:98]

Life cycle assessment analyses the whole construction and building management process. It focuses on the extraction of material as well as the manufacture, construction, maintenance through to the recycling and dismantling of these materials [Milne & Reardon s.a.:1].

It takes all the material inputs and outputs generated throughout the whole life cycle of the structure into consideration [Graedel 1998:3].

It is important to note that if a structure is used for an extended period its embodied energy becomes less important [Holm 1996:84]. In such a case the energy used during the operational stage of the structure needs to be addressed.

To ensure that a structure has a low embodied energy content, the designer should focus on locally sourced and recycled material, while always designing for the eventual dismantling of the structure [Milne & Reardon s.a:4].

4.4.1 Material choice

LIFE CYCLE ASSESSMENT

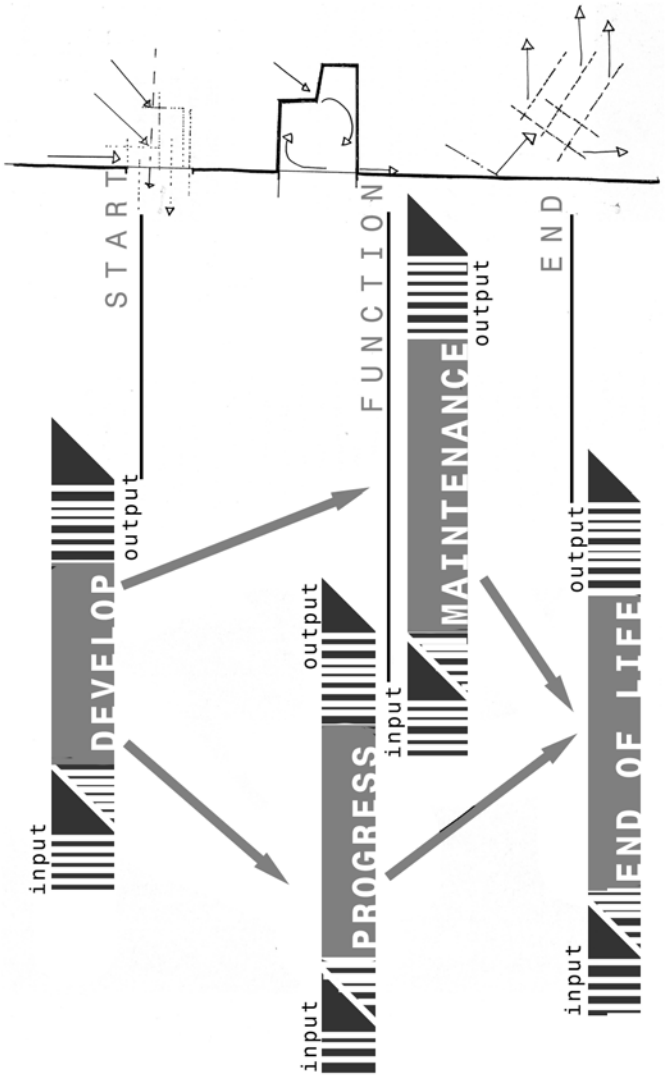


Figure 4-24: The different processes to take in account when doing a life cycle assessment [Source: Author].

Life Cycle Performance
The life cycle assessment of a specific material assesses the following

A) Where the materials is extracted from
B) What manufacturing processes it has undergone
C) What transport methods were used
D) The construction processes used
E) The maintenance of the material
F) The recycling or disposal of the material

[Halliday 2008:118-131]

In order to assess the life cycle performance of a specific material
the following steps are to be taken:

A_1. Be clear beforehand of what processes or materials are analysed
A_2. Decided what aspects of these materials or processes are going to be analysed and quantified

B_1. Do an inventory analysis beforehand to assess all inputs and outputs

C_1. Assessment must be done over whole life cycle

D_ 1. Interpret the results.
[Greadel 1998:21-23]

The interpretation phase is of vital importance to ensure that conclusions and adaptations can be made in future. The data used for the assessment must be new and updated and it is always good to go to suppliers for information regarding specific materials [Milne & Reardon s.a.:4].

Cradle to ... Cradle?
In assessing the whole lifecycle of materials the concept of "cradle to grave" was developed. This refers to:

- **the extraction of the raw material**
- **the transportation of the raw material**
- **the manufacturing process and all energy used in the factories**
- **the transport to site**
- **the construction process and the energy consumed by it**
- **the maintenance of the material [during its operational stage]**
- **the disposal of the material**

[Jones & Hammond 2008:1]

Definitions of other timescales:
1) Cradle to Gate _ from extraction of material to the finished product [excluding site and construction]
2) Cradle to Site _ from extraction of the material to its transportation to site

Embodied energy

The embodied energy of a material can be defined as the total amount of energy that has been used over a specific timescale [Jones & Hammond 2008:1].
Many studies have been done regarding the embodied energy of materials, but most focus on the cradle to gate period [Jones & Hammond 2008:4].

In conventional buildings the embodied energy of materials usually make up 10-25% of the total embodied energy over its whole life cycle. Lately the development of energy efficient buildings has led to the embodied energy of materials reaching up to 50% of the total embodied energy over the whole lifetime [Berge 2006:19].

Carbon footprint - carbon released

The carbon footprint of a material refers to **the total amount of carbon released into the atmosphere during the life cycle of the material**. It is closely linked to the embodied energy of the material, yet these quantities can differ [Jones & Hammond 2008:1].

The carbon footprint depends on the primary energy source used during production as well as the transport method used to transport materials. 95% of South Africa's total energy supply is generated by coal fired power plant [IEC 2009:21], thus the relation between the embodied energy and carbon foot print is closer.

Methodology

The life cycle performance of selected materials are analysed. **The materials are chosen specifically to be used in the design of the prototypical BRT station. The carbon footprint, embodied energy, maintenance and transport are analysed.**

At the time of the study the embodied energy of specific materials in a South African context has not been made publically available. The study uses figures that have been developed in the UK, and reported in the *Inventory of Carbon & Energy* [2008], by Geoff Hammond and Craig Jones.

Cradle to gate figures were used, as specific information on the manufacture, transport and construction methods is not available for this study. The possible energy saved through recycling and reusing was not calculated as the energy and carbon footprint of these processes will differ vastly in the future from what is currently available.

The transport figure was derived from Bjorn Berge, and taken as 2.2 MJ/ton km [Berge 2006:20], thus 0.0022 MJ/kg km.

The material distance travelled was only worked out fot the manufacturers closets to the Pretoria Main Station site.

The figure for pre-cast concrete has been calculated and adapted by using the difference from the energy calcular [Austrup 2009;104].

4.4.2 Material assessment

The choice of materials researched was done according to what is foreseen to be used in the prototypical BRT station. The cradle to gate cycles of steel, aluminium, concrete, masonry, glass and insulation materials were researched.

Timber is excluded from the material selection due to the fact that it requires a high amount of maintenance. It will not be a suitable material for an environment that needs to accommodate up to 6000 people per hour [Advanced Logistics Group 2008:09]. The harsh climate in Pretoria also causes a lot of damage and exposure to the timber, unless it is sealed and detailed correctly [Wegelen 2006:4.3].

Structural material- High Mass
As indicated in Table 4-01 it is clear that **concrete blocks have the lowest embodied energy and carbon footprint per square meter of all the materials researched.** Concrete blocks have a compressive strength of 7 or 14 Mpa respectively [Wegelen 2006:7.9]. The walls will have to be plastered and painted and will require maintenance through the years. The blocks can be manufactured close to the site, ensuring a low embodied energy over the cradle to grave life cycle.

The second option is to use normal clay brick masonry. The transport energy for clay brick masonry is also low as there are many manufacturers close by.

The first two options will have to be maintained regularly, yet adding 50.4 MJ/m2 after 50 years to the total embodied energy, plastered and painted masonry walls still perform a lot better than off-shutter concrete or face brick walls.

Reinforced off-shutter concrete performs better than face brick, but a face brick wall will be easily recycled or reused at the end of its life cycle. Unfortunately recycling masonry still requires a lot of time and labour [Berge 2006:207].

All these materials are manufactured at sites close to Pretoria.

Structural material – Lightweight
The use of recycled Steel and aluminium will ensure low embodied energies for the structures. The recycle rate of steel and especially of aluminium is very high. The recycling process also requires much less energy, aluminium requires as little as 7% of the initial energy [Berge 2006:79].

Recyclability and use of recycled materials also depends on the expected life cycle of the structure. If the structure will last 100 years one should rather opt for recycled materials. The recyclability of materials becomes important if the structure will change frequently [Jones & Hammond 2008:07]. **For the BRT stations the designer must ensure that the steel and aluminium sections are demountable.**

As analysed in Table 4-01 stainless steel sections require high amounts of energy to manufacture. Even though it requires little maintenance the saving is still minimal. One should opt to use as little stainless steel as possible. It is still a good material for handrails and areas that come in close contact with users as it is easy to maintain and clean [Wegelen 2006:8.9]

It is clear that **lightweight structures will be more energy intensive, as the per meter quantities of steel structural sections are very much the same to that of per square meter concrete walls/floors**. Yet these lightwieght materials are much easier to recycle. Parts of the station that will change frequently will have to be designed using lightweight demountable materials

The steel manufacturer closest to Tshwane is in Van der Bijlpark, at a distance less than 400 km as indicated by the GBCSA as the maximum distance materials travel to be classified as locally sourced [GBCSA 2008:267].

Aluminium smelters are situated further away from the site. Virgin aluminium will have a very high embodied energy and carbon footprint as the smelters are in Coega, Port Elizabeth and Richard's Bay [AFSA 2010]. One can opt for recycled aluminium products from a producer situated in Benoni, which is within 400km from the site.

On the whole these are the most energy intensive and carbon producing materials.

Roof Sheeting
In terms of roof sheeting polycarbonate sheeting initially outperforms corrugated steel sheeting as well as galvanised sheeting. Polycarbonate is the strongest and most durable of all translucent plastics [Weeglen 2006:9.8]. Yet the durability of polycarbonate as roof sheeting is a problem as in many instances plastics suffer from degradation very quickly. This can be caused by many factors of which ultraviolet rays are a major contributor [Berge 2006:153-154]. Polycarbonate roof sheeting is normally guaranteed for only 10 years [www.safintra.co.za].

After 50 years polycarbonate roof sheeting has double the embodied energy content than galvanised roof sheeting.

It is clear in Table 4-01 that galvanised corrugated metal sheeting saves enough carbon and energy over the long run to justify its use instead of normal sheeting.

Corrugated steel sheeting recycles much easier than polycarbonate sheeting. Polycarbonate can only be downcycled to a lower type material and is not biodegradable [Berge 2006:155].

Choosing galvanized roof sheeting proves the most efficient over a longer time period.

Translucent sheeting
Glass sheeting does the best in terms of embodied energy and carbon footprints of translucent materials . Yet oil based products such as poly methyl methacrylate [perspex, PMMA], polypropylene and polycarbonate sheeting will be more durable in heavily used environments.

Polycarbonate is the toughest of all these products and up to 200 times stronger than glass [Weglin 2006:9.7 & Polyglass product info]. PMMA has a maximum lifespan of only 40 years [Berge 2006:155]. The supplier of polycarbonate sheeting does not state how durable their product is yet a lifespan of 40 years can be expected [roof sheeting is only guaranteed for 10 years].

Glass can be made of 50% recycled glass, but laminated glass cannot be recycled to be used as window glass [Berge 2006:103]. Thus the recycling possibilities of glass is limited, as laminated toughened glass will have to be used to ensure its robustness. Plastics generally lose their quality once they are recycled and current technologies only allow them to be downgraded [Berge 2006:155].

PPMA will be the best choice, as the product is ultraviolet resistant and very robust [Wegelen 2006:6.15]. This will be vital in a high traffic environment, and under changing climatic conditions where high levels of insolation will occur.

Thermal insulation
As analysed in Table 4-01 the **best choice for insulation will be mineral wool or fibreglass insulation panels,** even though expanded polystyrene is manufactured closer to the site. The lightweight quality of the materials makes transportation energies much less.

Mineral wool is biodegradable while fibreglass insulation can be recycled [www.valmic.co.za]. All the products require no maintenance if detailed and constructed correctly.

Aluminium foil [sisalation] can also be used, yet the embodied energy of this materials is not available for assessment.

	Material	Composition		Energy /Carbon Cradle to gate MJ/kg	kgCO2/kg	Typical quantity per square meter	MJ/m2	kgCO2/m2	Transport Origin	Energy MJ/kg	Total CO2 per trip CO2 kg	Maintenance Finish PER SQUARE METER	5 years MJ/m2	kgCO2/m2	10 years MJ/m2	kgCO2/m2	50 years MJ/m2	kgCO2/m2	End of life
STRUCTURE HIGH MASS	PRECAST CONCRETE	Cement		3.7	0.39	300mm depth	2.68	283.5	Hercules	0.0152		Off shutter							Downcycle
		Aggregate							VanderBijl park[5%]	0.0152									
		Steel							Total	0.0304									
		Fly ash																	
	REINFORCED CONCRETE	Cement		2.42	0.256	300mm depth	1742.2	184.32	Hercules	0.0152		Off shutter							Downcycle
		Aggregate							Van der Bijl park[5%]	0.0152									
		Steel							Total	0.0304									
		Fly ash																	
	CONCRETE	Cement		1.39	0.209	200mm depth	667.2	100.32	Herculus	0.0152	225	Off shutter							Downcycle
		Aggregate																	
		Fly ash																	
	CLAY MASONRY	Clay		3	0.22	220 mm wall	1254	91.96	Kameel drif	0.0484	34.32	Plaster&Paint	5.04	0.27	10.08	0.54	25.2	1.35	Downcycle & Reuse
						15mm plaster	28.2	3.9					10.08	0.54	20.16	1.08	50.4	2.7	
							1282.2	95.86											
	CLAY MASONRY	Clay		8.2	0.52	220 mm wall	3 427.60	217.36		0.0484		Facebrick							Downcycle & Reuse
	CONCRETE BLOCKS	Cement		0.81	0.098	200mm wall	307.8	37.24	On site	8%??0.464		Plaster&Paint	5.04	0.27	10.08	0.54	25.2	1.35	Downcycle
		Soil				15mm plaster	28.2	3.9					10.08	0.54	20.16	1.08	50.4	2.7	
		Aggregate					336	41.14											
STRUCTURE LIGHT	STRUCTURAL STEEL	Iron		36.8	2.78	178x102x19	883.2	66.72	VanderBijl park	0.304		Handpainted	4.7	0.24	9.4	0.48	23.5	1.2	Recycle&Reuse
													9.4	0.48	18.8	0.96	47	2.4	
	STRUCTURAL STEEL	Iron	Recycled	29.44	2.22	178x102x19	706.56	53.28	VanderBijl park	0.304		Handpainted	4.7	0.24	9.4	0.48	23.5	1.2	Recycle&Reuse
													9.4	0.48	18.8	0.96	47	2.4	
	ALUMINIUM	Bauxite	Extruded	214	11.2	178x102x19	5 136	268.8				Handpainted	4.7	0.24	9.4	0.48	23.5	1.2	Recycle&Reuse
													9.4	0.48	18.8	0.96	47	2.4	
	ALUMINIUM	Bauxite	Extruded Recycled	34.1	1.98	178x102x19	818.4	47.52				Handpainted	4.7	0.24	9.4	0.48	23.5	1.2	Recycle&Reuse
													9.4	0.48	18.8	0.96	47	2.4	
	STAINLESS STEEL	Steel		56.41	6.15	178x102x19	1 353.84	147.6	Vande Bijl park	0.304		Polished finish							Recycle&Reuse
		Chromium																	
Roof							MJ/m2	kgCO2/m2											
	METAL SHEETING	Iron		31.5	2.51	IBR	212.7	16.95	VanderBilj park	0.304		Painted	7.32	0.382	14.65	0.764	36.6	1.91	Recycle&Reuse
													14.64	0.764	29.3	1.528	73.2	3.82	
	GALVANISED METAL SHEETING	Iron		39	2.82	IBR	263.3	19.04	VanderBilj park	0.304		Painted							Recycle&Reuse
	POLYCARBONATE SHEETING	Bisphenol		112	6	IBR	97.4	4.8	Johannesburg										Downcycle
SHEETING							MJ/m2	kgCO2/m2											
	GLASS	Sand		23.5	1.27	10mm sheet	56.4	3.04	Springs	0.2		Wash and clean							Recycle
		Silica																	
	POLY METHYL METHACRYLATE		[general plastics]	80.5	2.53	6mm sheet	454.02	14.27				Wash and clean					Lifespan < 40 years		Downcycle
	POLYPROPYLENE		Injected moulding [opaque]	115	3.9	6mm sheet	648.6	22				Wash and clean					Lifespan < 10 years		Downcycle
	POLYCARBONATE SHEETING	Bisphenol	Injected moulding [opaque]	112	6	6mm sheet	631.7	33.84	Johannesburg			Wash and clean					Lifespan < 40 years		Downcycle
	Wire mesh		Rolled	36	2.83	weight per meter													
INSULATION							MJ/m2	kgCO2/m2											
	MINERAL WOOL	Quarts		16.6	1.2	25mm thickness	24.9	1.8	Springs	0.2		No Maintenance							Biodegradable
		Soda																	
		Dolomite																	
		Lime																	
		Sand																	
	EXPANDED POLYSTYRENE	Oil based		88.6	2.5	40mm thickness	70.88	2	Silverton			No Maintenance							Downcycle
		styrene																	[non biodegradable]
	FIBREGLASS	Glass wool		28	1.35	50mm thickness	15.4	0.74	Springs	0.2									50% recyclable
		Resin										No Maintenance							
	ALUMINIUM SHEETING	Aluminium		217	11.5														
	ALUMINIUM SHEETING	Aluminium	Recycled	27.8	1.67							No Maintenance							Recyclable

Note: Embodied energy quantities were aquired from Jones & Hammond - Inventory of Carbon & Energy - 2008
These figures are applicable for the UK
The densities were aquired from B Berge - The Ecology of Building Materials - 2006 and Product Manufactures
The paint figures were adapted from Plascon paint products

Table 4-01: The embodied energy of construction materials, and their transportation and maintenance [Source: Author]

4.4.3 Embodied energy of a typical prototype

Building ID: **Rea Vaya BRT Prototypical Station**
Location: **Johannesburg, South Africa**
Architects: **Ikemeleng Architects, Osmond Lange Architects & Planners**
Client: **City Council of Johannesburg**
Date: **2009**
Area: **158 m^2**

Figure 4-25: Embodied energy and carbon footprint of Rea Vaya Station [Source: Author]

The carbon footprint and embodied energy of the structure has been analysed .

The materials were analysed for a cradle to gate period. Only basic core materials were analysed:

- Concrete
- Glass
- Steel
- Stainless steel
- Masonry
- Insulation – basic – fibreglass

The following have not been included:

- Urban Infrastructure
- Electrical equipment
- Sanitary fittings
- Signage and fittings
- Foundations and substructure
- Doors and doorframes

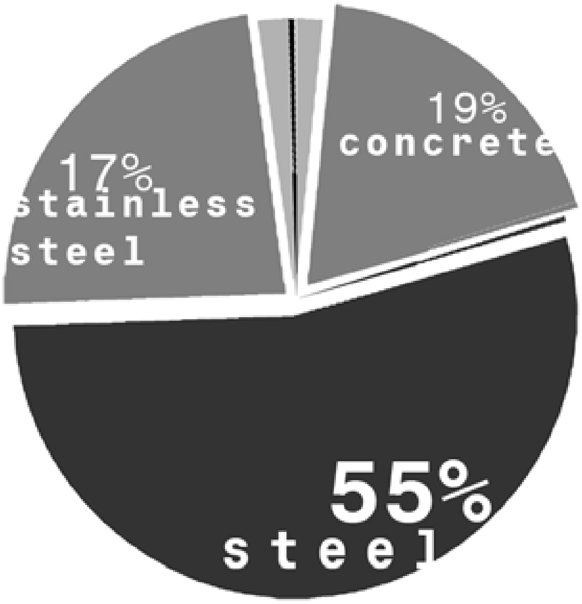
Embodied energy _Case study REA VAYA

NOTE: This is only an interim calculation and will be checked .

Material	Component	Size	Density	Weight	Embodied Energy	Carbon footprint	Embodied energy	Carbon Footprint	COMPONENT TOTAL EE	COMPONENT TOTAL CF
		m3	kg/m3	kg	MJ/kg	kg CO_2/kg	MJ	kg CO_2	MJ	kg CO_2
Infill aggregate	Infill base 800 deep	87.95	2000	175 900	0.1	0.005	**17590**	**879.5**	**17590**	**879.5**
Concrete	Ramp	3.38	1900	6 422	1.39	0.209	**8926.58**	**1342.198**	**204722.4**	**23192.97**
	Plinth/Base	28.9	2400	69 360	2.42	0.256	**167851.2**	**17756.16**		
	Floor 100mm	9.2	1900	17 480	1.39	0.209	**24297.2**	**3653.32**		
Masonry	Ramp Paving	2.37	1900	4 503	0.81	0.098	**3647.43**	**441.294**	**3647.43**	**441.294**
Alumium	Doorframe [not calculated]								**0**	**0**
Steel	Steel "vastrap"@ bus entrance	0.036	8000	288	29.44	2.22	**8478.72**	**639.36**	**612027.5**	**41491.84**
	I-beam Colums	0.3	8000	2 400	29.44	2.22	**70656**	**5328**		
	Roof beam	0.23	8000	1 840	29.44	2.22	**54169.6**	**4084.8**		
	Purlins @ 700 centres	0.12	8000	960	29.44	2.22	**28262.4**	**2131.2**		
	Bracing member	0.19	8000	1 520	29.44	2.22	**44748.8**	**3374.4**		
	Corrugated roof [1.6mm thick]	0.26	8000	2 080	39	2.82	**81120**	**5865.6**		
	Corrugated Ceiling [1.6mm thick]	0.26	8000	2 080	31.5	0.256	**65520**	**532.48**		
	Steel fascia	0.08	8000	640	29.44	2.22	**18841.6**	**1420.8**		
	Steel door frame	0.03	8000	240	29.44	2.22	**7065.6**	**532.8**		
	Steel gate [not calculated]	0	8000	0	29.44	2.22	**0**	**0**		
	Structural window frame	0.8	8000	6 400	29.44	2.22	**188416**	**14208**		
	Window bead	0.19	8000	1 520	29.44	2.22	**44748.8**	**3374.4**		
Stainless Steel	Handrail	0.12	7500	900	56.41	6.15	**50769**	**5535**	**192922.2**	**21033**
	Seat-rest	0.262	7500	1 965	56.41	6.15	**110845.65**	**12084.75**		
	Stainless steel office	0.05	7500	375	56.41	6.15	**21153.75**	**2306.25**		
	Boarding balustrade	0.024	7500	180	56.41	6.15	**10153.8**	**1107**		
Glass	Glass elevation	0.78	2400	1 872	35	2	**65520**	**3744**	**77868**	**4449.6**
	Glass door@ BRT boarding door	0.1	2400	240	35	2	**8400**	**480**		
	Glass panel @ kiosk office	0.01	2400	24	35	2	**840**	**48**		
	Emergency exit	0.037	2400	89	35	2	**3108**	**177.6**		
Insulation	Ceiling	11.07	11	122	28	1.35	**3409.56**	**164.3895**	**3409.56**	**164.3895**
						TOTAL	**1108539.69**	**91211.3015**		
						Area	158	158		
						per meter	7 016.07	577.29		

Abreviations: Embodied energy [EE], Carbon Footprint [CF]

Table 4-02: Embodied energy and carbon footprint of prototype station [Source: Author]



Embodied Energy

Energy consumption per materials

1.8%	1- Infill
19%	2- Concrete
0.2%	3- Masonry
55%	4- Steel
17%	5- Stainless steel
7%	6- Glazing [Glass]
0.1%	7- Insulation

Graph 4-01: Embodied energy per material as contained proportionately in the station [Sourrce: Author]

Conclusion - interpreting the analysis

It is clear from the lifecycle analysis that all buildings have a high embodied energy and carbon footprint – even if it is a small structure.

The steel structure represents the highest portion [54 %] of the total embodied energy of the prototypical station, thus steel should be used sparingly.

Concrete takes up 19% of the total embodied energy, yet it takes up 24 % of the total carbon footprint. Even though it has a low embodied energy per kilogram ratio, the large volumes that are used in the structure amount to a high total.

Stainless steel still has a high embodied energy. Even though very little is used in the station, it makes up 24% of the total embodied energy. The use of stainless steel should be avoided.

Insulation has a relatively low embodied energy in relation to the impact that it has on the indoor environment.

This prototype will be used as benchmark for the development and design of a low carbon BRT station. Out of this life cycle assessment an eco-effective solution can be developed. a design that maximises the positive qualities, while minimising the harmful or wasteful factors [Mcdonough & Braungard 2002:77]. Reducing the embodied energy content and carbon footprint of the prototypical station.

4.5 CONCLUSION

From these frameworks a design can be generated that responds to the urban context, ensures a structures that contributes to the urban and social sustainability and creates a safe and healthy environment as proposed by the LINK-framework.

The historical framework will be used to guide the manner of intervention to ensure that the new development and intervention respects the existing while adding a new layer of function and architecture that promotes development and much needed change.

Low-carbon technologies and strategies will be used to inform the design from the early stages of the design process

Using the analysed BRT station as a benchmark the prototypical BRT station will be assessed and checked to ensure its sustainability. The material analysis will guide material choice for the project.