Anton de Kom Universiteit van Suriname

Bibliotheek

Universiteitscomplex, Leysweg 86, Paramaribo, Suriname, Postbus 9212
Telefoon (597)464547, Fax (597)434211, E-mail: adekbib@uvs.edu

APPROVAL

NAAM: Sherina Soekhlal

verleent aan de AdeKUS kosteloos de niet-exclusieve toestemming om haar/~~zijn~~ afstudeerscriptie via de catalogus full-text beschikbaar te stellen aan gebruikers binnen en buiten de AdeKUS.

Plaats en datum, Paramaribo, 11 aug 2021

Handtekening ....

ANTON DE KOM UNIVERSITEIT VAN SURINAME
FACULTEIT DER TECHNOLOGISCHE WETENSCHAPPEN
MILIEUWETENSCHAPPEN

DEVELOPMENT OF A SUSTAINABILITY INDEX FOR URBAN LAND USE PRACTICES IN SURINAME

And practical implementation guidelines in GIS

Thesis research thesis in conclusion
to the study Bachelor of Science (BSc.) in
Environmental Science

SHERINA
ANASTASHADEVI
SOEKHLAL

August 16th, 2021
Paramaribo, Suriname

ANTON DE KOM UNIVERSITEIT VAN SURINAME
FACULTEIT DER TECHNOLOGISCHE WETENSCHAPPEN
MILIEUWETENSCHAPPEN

DEVELOPMENT OF A SUSTAINABILITY INDEX FOR URBAN LAND USE PRACTICES IN SURINAME

And practical implementation guidelines in GIS

Sherina A. Soekhlal

STUDENT NUMBER:	20130483
PROGRAM:	Bachelor of Science (BSc.) in Environmental
DEPARTMENT:	Science Faculty of Technology
FACULTY SUPERVISOR:	Mrs. Namdar, Angelika MSc.
FIELD SUPERVISOR:	Mr. Bogor, Donovan MSc.
PUBLICATION TIME & PLACE:	August 16th, 2021 at Paramaribo, Suriname

ANTON DE KOM UNIVERSITEIT VAN SURINAME

Faculteit der Technologische Wetenschappen

Milieuwetenschappen

Goedkeuringsverklaring Eindverslag

De begeleidingscommissie verklaart hiermede, voor wat betreft de stijl en intellectuele inhoud, haar goedkeuring te hebben gegeven aan het afstudeerverslag geschreven door:

Sherina A. Soekhlal

met als titel:

DEVELOPMENT OF A SUSTAINABILITY INDEX FOR URBAN LAND USE PRACTICES IN SURINAME

en ondertitel:

And practical implementation guidelines in GIS

Paramaribo,

Namens de begeleidingscommissie,

X

Angelika Namdar
Faculteitsbegeleider

X

Donovan Bogor
Praktijkbegeleider

Contact Information

Student
Name: Sherina Soekhlal
Student ID: 20130483
Email: sherina.soekhlal@live.com
Telephone: +597 8563214

Education
Name: Bachelor’s in Environmental Science
Orientation: Environmental Technology
Institute: Anton de Kom University of Suriname
Faculty: Faculty of Technological Sciences
Address: Leysweg 86, Paramaribo
Telephone: 465-558

Faculty supervisor
Name: Angelika Namdar
Function: DoSenior Lecturer FTeW/AdeKUS
Telephone: +597 465558 # 2329
Email: angelika.namdar@uvs.edu

Field supervisor
Name: Donovan Bogor MSc.
Function: Office Coordinator EPI, NIMOS
Telephone: +597 532635
Email: dbogor@nimos.org

Preface

This thesis is written as completion to the Environmental Sciences bachelor program at the Anton de Kom University of Suriname. The orientation Environmental Technology focuses mainly on the technical aspect of environmental related issues, including GIS and sustainability. The subject of this thesis is developing a Sustainability index for the expanding urbanization in Suriname. The USI will be analyzed via Geographic Information Systems.

Mr. Donovan Bogor MSc. (Office Coordinator EPI) and Mrs. Angelika Namdar MSc. (Senior Lecturer Faculty of Technological Sciences) will be supervising this research.

Abstract

Proper land use and land management is a major challenge in Suriname. Especially in the coastal zone of Suriname, where almost 90% of the population live. This has a major impact on sustainable use of natural resources including water, soil, nutrients, plants and ecosystems. Land use planning, the process of characterization of the potential of land and based on that the destination of the land can be a good solution for the limitation of the negative impact. Understanding the land use development and the theories helps to understand patterns that are associated with land and urbanization. A sustainability index for urban land use practices is imperative in assessing future sustainable development policies. The aim of this research thesis is to present a GIS framework of inclusive and sustainable urban development factors to be used as a legislative tool for policy developers in Suriname. This Urban Sustainability Index (USI) will be catered to the unique spatial and social indicators of the Surinamese society. This research is focusing on a conceptual USI for urbanization. The scope will be demarcated to urban land use practices in the case study area Paramaribo. Through desk research, it will be examined which indicators are most relevant to the sustainable development of the case study area and those will be categorized on importance and mapped out via GIS. This study will optimize existing and validated data to create a Sustainability Index for Paramaribo. The expected results of this research are: a complete detailed overview of the existing land use in the study area Paramaribo; the identification of sets of indicators important for the analysis of land use and the development of Sustainability Index for Land Use in our environments; a GIS framework of inclusive and sustainable urban development factors to be used as a legislative tool for policymakers in Suriname and similar environments.

Keywords: Urban Sustainability, GIS, Index, Indicators

Contents

Table of Figures

Table of Abbreviations & Symbols

Abbreviation	Definition
AdeKUS	Anton de Kom University of Suriname
AOI	Area Of Interest
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
ArcMap	Aeronautical Reconnaissance Coverage Map
EIA	Environmental Impact Assessment
EPI	Environmental Planning & Information Management
GDP	Gross Domestic Product
GIS	Geographical Information System
IDB	Inter-American Development Bank
NIMOS	National Institute for Environment & Development in Suriname
NMR	National Environmental Council
QGIS	Quantum Geographic Information System
RA	Referential/Reference Area
Rel.USI.Value	The summary of ($RelValue_i$ multiplied by the corresponding weight of each indicator)
$RelValue_i$	Value of each indicator of the Area Of Interest relative to the Reference Data
SD	Sustainable Development
SDG(s)	Sustainable Development Goal(s)
UN	United Nations
USI	Urban Sustainability Index
WHO	World Health Organization
Σ	Sigma (mathematical sum)
△	Delta (variation of a variable or function)

1. Introduction

The Earth inhabits approximately 8 billion people, and this number rises each day. In order to sustain ourselves, it's almost inevitable, that we must occupy more land. There is however a finite number of resources available to accommodate everyone, whilst sustainably preserving forests and other natural assets. Most of the population of Suriname is concentrated in the capital Paramaribo. By 2030 almost 5 billion people are projected to live in cities (Division, 2019). Urban land use poses one of the biggest concerns to the 21st century, threatening both ecosystems and biodiversity.

"Rapid urbanization is resulting in a growing number of slum dwellers, inadequate and overburdened infrastructure and services (such as waste collection and water and sanitation systems, roads and transport), worsening air pollution and unplanned urban sprawl" (United Nations, 2016)

A(n) (urban) sustainability index (USI) is a scientific framework, based on a compilation of specific indicators, to measure the sustainability of the environment. In this research the focus will be the urban context. An USI is used as an instrument to project a potential trend to environmental sustainability. If properly utilized, it can be an asset to i.e., urban policies. This thesis will focus on how to use indicators to monitor sustainable urban development, integrating the information provided by many of them into a complex general sustainability index. Having this general indicator is essential for decision makers as it is very complicated to evaluate sustainability based on multiple indicators.

Land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants, and animals. Land use is the characterization of land, based on what can be built on it and what the land can be used for. Understanding land use helps to understand patterns that are associated with land and urbanization. Understanding how land was used in the past can be a significant indicator of how the property will be used in the future.

1.1 Problem Analysis & Background.

While most studies are focusing on the indicators to determine land use sustainability within the analysis, their interconnection is overseen, especially in Suriname. We live in a society where it is common for families to build their home from the ground up. This strictly contrasts most western cultures where it is customary to rent or buy pre-owned houses or to live in apartment buildings (maximizes land coverage by expanding in altitude).

The UN 2030 Agenda for Sustainable Development is adopted by all United Nation members, including Suriname. At its heart are the 17 Sustainable Development Goals (SDGs). The SDGs were adopted by all Member States of the United Nations (including Suriname) in

September 2015. Its official name came into effect on January 1st, 2016, and is to be achieved by 2030. Suriname has a commitment and responsibility in implementing these SDG's.
This study attempts to create a tool to help realize the following SDG's (United Nations, 2016):

- SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable.
- SDG 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Suriname therefore has a need for optimizing land management to preserve urban and environmental quality, especially in densely populated cities such as Paramaribo.

The case study area will be Paramaribo (showcased in Figure 1 below).

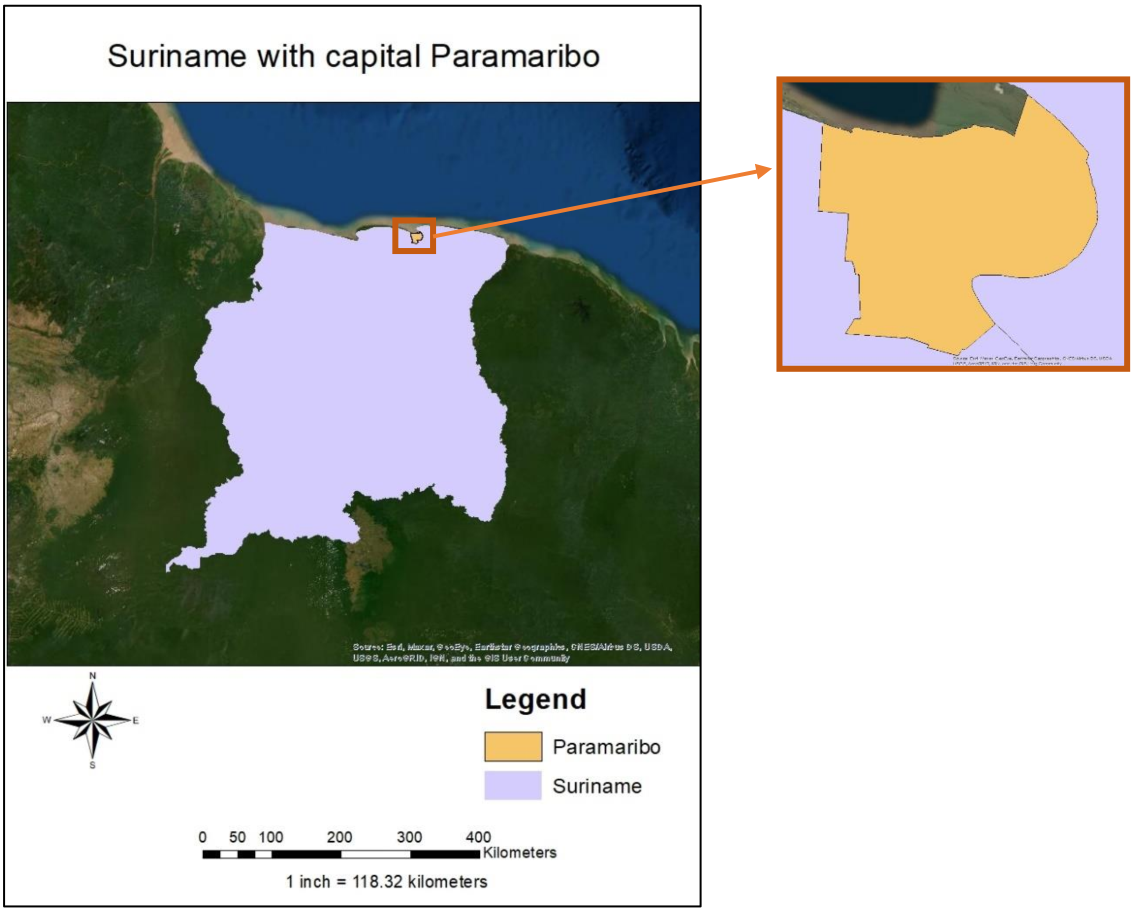


Figure 1 Suriname with Capital Paramaribo (MI-GLISS)

Research Objective

The aim of this research is to develop a GIS framework of inclusive and sustainable urban development factors to be used as a legislative tool for policymakers.

Research Question

What are the building blocks and the thereby corresponding GIS technical applications for a conceptual Urban Sustainability Index for Suriname to transfer the existing urban environment to an inclusive and sustainable urban environment through sustainable spatial planning policy?

Thesis Statement

"Building a conceptual Urban Sustainability Index for Paramaribo and effectuating the corresponding technical implementation guidelines for GIS."

Research Sub Questions

This study will be conducted through the following research sub questions:

- What is sustainability?
- What is the current state of the urban environment in Suriname?
- Which framework indicators are applicable to Suriname?
- What is the added value of sustainability in Urban Development?
- How do the indicators compare between themselves in terms of importance?
- How to integrate these indicators in the conceptual USI?
- How to develop a conceptual GIS matrix based on the USI?
- How can the validity of the USI be tested?

1.2 Research Relevance

A sustainability index for urban land use practices is imperative in assessing future sustainable development policies. A geographic information system (GIS) is a conceptualized framework that provides us with the ability to create a clear and concise analysis.

To enable cities to achieve sustainable development, urban governance must check urban development trends, overcome unsustainable urban development problems, and establish a mechanism to measure the sustainability of urban development (Huang, C.T, & Che, 2005). One such mechanism is an urban sustainability framework.

1.3 Scope & Conditions

This research will focus on a conceptual USI for urbanization. The scope will be demarcated to urban land use practices in the case study area. All data must be integrated in GIS. This study will optimize existing data to create an Urban Sustainability Index.

1.4 Research Methodology

The research method (Figure 2**Error! Reference source not found.**) to achieve the formulated objective is mainly based on desk research. In this theoretical research, an assessment is made based on existing professional literature. The insights obtained from this are processed in a conceptual sustainability index for urban land use.

An in-depth explanation on the theoretical and practical methodology can be found in Chapter 3: Research Method.

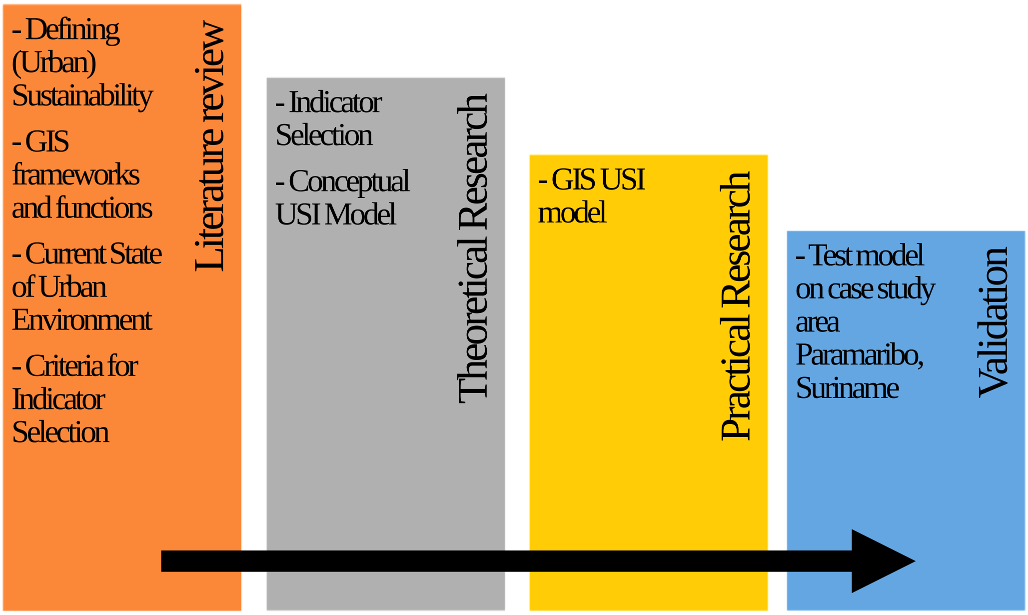


Figure 2 General Methodology Research Thesis (left to right)

Relevant existing literature will be gathered to gain an overview of the current urbanization state of the case study area. Through desk research, it will be examined which indicators are most relevant to the sustainable development of the case study area. The chosen indicators will be categorized on importance and mapped out via GIS.

A conceptual USI Model will be developed based on the insights obtained from the preliminary study. Numerical data of the indicators will also be calculated. This data will serve as a supporting role to the USI. This USI Model will then be tested on the case study area (also called the Area of Interest (AOI)), against the Reference Area (RA)

1.5 Structure of this Research Thesis

Chapter 1: Introduction

The topic of this Research Thesis is discussed, along with a problem analysis. In this chapter, a description is given for the problem statement, research (sub) question (s), objective, relevance, scope and lastly the research methodology.

Chapter 2: Literature Review

The literature review introduces the definition of sustainability and its regard to the urban environment, specifically the case study area Paramaribo. This chapter also discusses the selection of relevant urban sustainability indicators for this study. Lastly, a breakdown is given for the GIS platforms.

Chapter 3: Research Method

This chapter explains the GIS methodology and action plan, along the GIS functions that are used for this study. The indicators are weighted against each other and a conceptual USI is designed.

Chapter 4: Research Findings & Discussion

This chapter focusses on the building blocks of the USI. The indicators are assessed on a deeper level, paving the way to conceptualizing the USI model. The integration of this model in GIS is explained. Data is gathered and then used to validate the conceptual model. The research is critically examined, and the results are interpreted. Lastly, the limitations of this research discussed.

Chapter 6: Conclusion

The conclusion restates the thesis statement, summarizes the thesis and highlight the key points of this thesis. Furthermore, this chapter will discuss the research (sub) questions and their answers and the recommendations.

Timetable

This chapter gives an outline of the study load and the research timetable.

2. Literature Review

2.1 Defining Sustainability and Urban Sustainability

Sustainability can be defined as:

Meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them. And more specifically, as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity. (Morelli, 2011)

The term sustainable development (SD) entails the balancing of meeting humankind's present demands while protecting the environment within multiple approaches to ensure the fulfillment of future generations' rights and needs. The overall goal of SD is to apply a long-term stability policy integrated with economic and environmental protection rules. Such an approach can be obtained through the integration of economic, social, and environmental concerns as a basis for more informed decision-making processes. (Mohamadzadeh, Pourmoradian, Feizizadeh, Sharif, & Vogdrup-Schmidt, 2020)

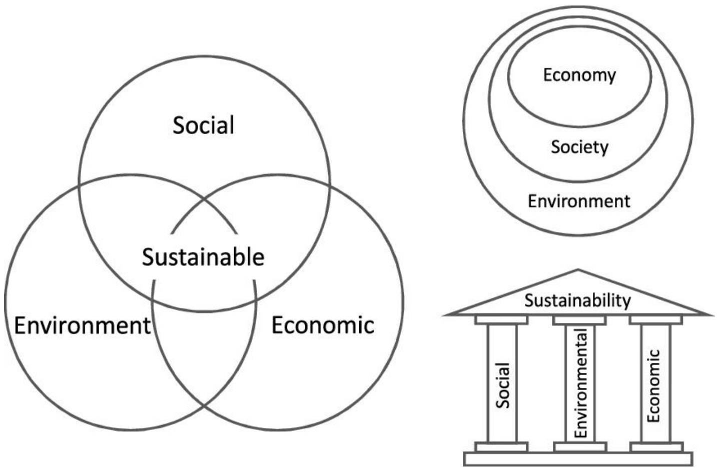


Figure 3 Left, typical representation of sustainability as three intersecting circles. Right, alternative depictions: literal 'pillars' and a concentric circles approach. Source: (Purvis, 2019)

Sustainability has three main areas or pillars: social, environmental, and economic, as portrayed in Figure 3. These three pillars are informally referred to as respectively people, planet, and profits.

A broader perspective on these pillars:

- Social

  This pillar focusses on the idea that the social wellbeing of a country, community, or organization can be maintained in the long term. The purpose of social sustainability is to protect investment and social services through investment that forms the framework of our society. This concept embraces a broader perspective on communities, cultures, and globalization. It means sustaining future generations and acknowledging our environmental impact. Social sustainability involves the idea of sustainable development as defined in the United Nations Sustainable Development Goals. The principle of sustainable development is concerned with social and economic reforms that protect the environment and support equality, so the economy, society and the ecosystem are interconnected.

- Environmental

  The environmental pillar is arguably the most demanding pillar because it centers around preserving the current environment, but also around rehabilitation. Some visualizations of the pillars even portray the environment as the larger whole containing the social and economic subsystems within it (Figure 3 upper right image). It aims to improve human well-being through the protection of the environment and the protection of natural resources. The steps and programs are environmentally defined to ensure that the needs of the new generation are met before the needs of the next generation are identified. Some calculations, derived from the journal "Natural Resources in 2020, 2030, and 2040: Implications for the United States" (Office of the Director of National Intelligence USA, 2013), showcase the effects of the **current** global sustainability trend on natural resources:

By 2030 freshwater availability will be threatened for 50% of the world population.

50 years until oil runs out.

50-100 years until we run out of phosphorus (necessary resource for agriculture)

Zinc, gold, and lead reserves will be depleted by around 2030.

Silver and iridium will last until about 2035.

150 years until coal depletion.

52.6 years of natural gas available for use.

Copper could run out before 2050.

- Economic

  This pillar refers to the capacity of an economy to uphold a certain level of economic output infinitely. Economic sustainability aims to maintain the capital intact and to improve the standard of living. This pillar is not only beneficial to global sustainability but is also imperative to businesses and organizations who rely on natural resources as their main source of income.

  To achieve true sustainable development, we must find ourselves in the overlap of all 3 pillars.
  Accomplishing two out of the three pillars of sustainability (Figure 4), results in:

  Social + Economic Sustainability = Equitable

Social + Environmental Sustainability = Bearable
Economic + Environmental Sustainability = Viable

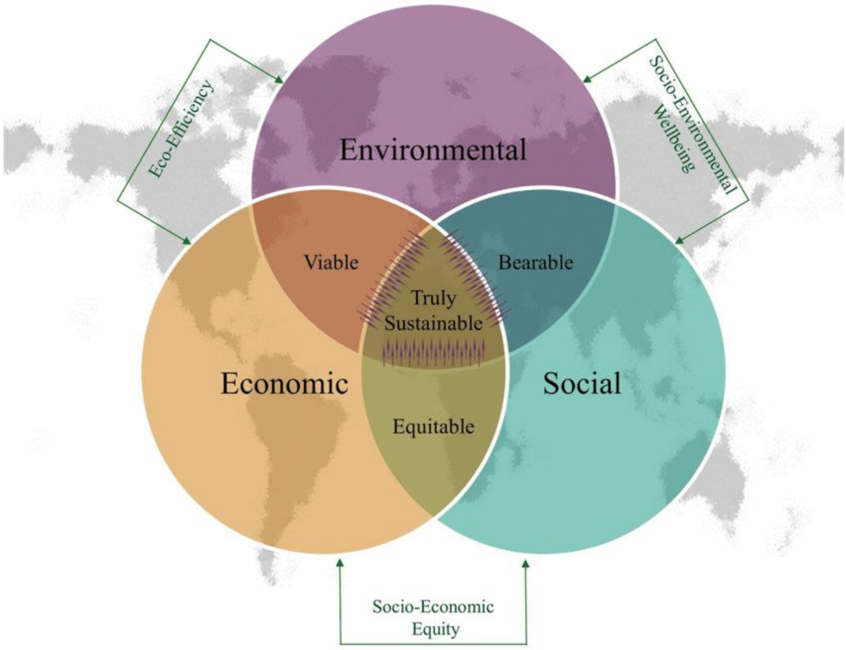


Figure 4 Triple bottom line philosophy and inter-relationship of sustainability pillars (Tasdemir, 2020)

Sustainable development can be assessed by measuring the environmental footprint. Also called the ecological footprint, is a measure of the resources necessary to produce the goods that an individual or population consumes. Simply put, the ecological footprint is a method of calculating the **demand for** and **availability of** natural resources.

The ecological footprint adds up all the productive areas for which a population, an individual, or a product competes on the demand side. It assesses the ecological assets needed by a population or commodity to generate the natural resources it consumes (as illustrated in Figure 5 . It shows how efficient surface areas are used. Cropland, grazing land, fishing grounds, built-up land, forest field, and carbon demand on land are examples of these surface areas (Ecological Footprint, 2016).

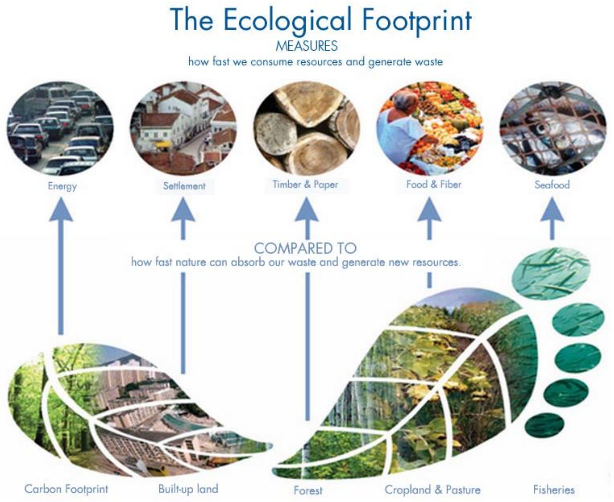


Figure 5 Illustration of the ecological footprint (Ecological Footprint, 2016)

URBAN ENVIRONMENT & URBAN SUSTAINABILITY

The environment surrounding a city is referred to as an urban area or an urban environment. The density of human structures such as homes, commercial buildings, highways, and bridges is very high in urban areas.

The term "urban area" can be used to describe towns, villages, and suburbs. The city itself, as well as the surrounding areas, can be referred to as a metropolitan environment.

A city has a large population of people who mostly live next to one another. These people need a variety of things, including food, clothing, and shelter. They need energy and clean water and means to dispose of their waste. This could have a significant impact on the environment. Large areas of land could be used to grow food for city dwellers. Flooded areas may be used to store and supply water.

It wasn't until the twentieth century that rates of urbanization started to rise significantly. This is particularly evident in the second half of the twentieth century (Ritchie, 2018):

- Globally more people live in urbanized settings than not (disputes in these figures are all above the 50 percent urban mark).
- The broad distribution and density of where people live across the world (sometimes at very high resolution).
- Rates of urbanization have been increasing rapidly across all regions (in 1800, less than 10 percent of people across all regions lived in urban areas

UN Habitat states that human activities account for about 78 percent of carbon emissions in cities and produce more than 60 per cent of greenhouse gas emissions. Yet, they account for less than 2 per cent of the Earth's surface. Cities' ecological footprints extend well beyond their urban borders (through emissions, consumption, and other human activities) to forests, farmland, water, and other surfaces that supply their inhabitants, having a huge effect on the surrounding rural, regional, and global environment.

The most serious environmental issues are anticipated in the immediate vicinity of developing-world cities, where population growth is outpacing the capacity to provide necessary infrastructure and services. This will have serious economic and social consequences for the urban population. Inadequate water supply to homes, waste accumulation, and unsanitary conditions facilitate premature deaths and illnesses among the one billion people who live in slums around the world. As a result of rapid industrialization and increased motorized traffic, cities in developing countries have some of the worst urban air pollution in the world. According to estimates, global urban air pollution causes one million premature deaths per year and costs developed countries 2% of the GDP and developing countries 5% (Galanis, 2017).

The concept of urban sustainability is that a city can be independently organized and can fuel itself using renewable energy sources. The goal is to leave the smallest ecological footprint and generate the least amount of emissions possible, as well as to make productive use of land, compost used products, recycle them, or turn waste to energy.

Some measures to take on the road to urban sustainability are (Radzi, 2018):

- green building design to reduce operational consumption and to optimize building orientation for solar generation.
- compact development to minimize gray energy use.
- medium- to low-rise building construction to conserve materials and energy.
- building renovation and reuse to increase efficiency and material conservation.
- mixed uses to reduce distances to services and conserve fuels.
- urban greening to save energy in the cooling of urban areas.
- networked public transport for increased modalities and lowered dependence on private motor vehicles; and connected public spaces to save energy in the daily movements through the city.

2.2 Geographical Information Systems

A Geographic Information System (GIS) is a data collection, management, and analysis platform. GIS is a technical field that maps, analyzes, and evaluates real-world problems by combining geographical features with tabular data. An important characteristic of GIS is that some aspect of the data must be spatial. A spatial distribution is a graphical representation of a phenomenon's distribution across the Earth's surface, and it's a useful tool in geographical and environmental statistics. It uses maps and 3D scenes to examine spatial information and organize layers of data into visualizations. GIS provides deeper insights into data, such as trends, relationships, and circumstances, allowing users to make more informed decisions.

A GIS looks like a large panel made up of similarly shaped open boxes, each box representing a specific region on the earth's surface. Each piece of information regarding a specific attribute (land use, built area etc.) that pertains to the region can be entered into the appropriate box. Since there is no theoretical limit to the amount of data that can be entered into each package, rather large amounts of data can be compiled in a systematic manner. After assigning a few attributes to the box framework, the maps can be overlaid to reveal spatial relationships between the various attributes, such as hazardous incidents, and natural resources.

There are many types of GIS, several of which are more suited to advanced construction planning and natural disaster control than others. Simple manual overlay methods have proven to be extremely useful tools at the most basic level. In addition to that, technologically advanced computerized tools that can 1) interpret baseline science data such as satellite imagery and 2) generate large-scale maps of excellent cartographic accuracy using plotters can also be used in GIS (Primer on Natural Hazard Management in Integrated Regional Development Planning, 1991).

The uses of GIS vary tremendously. For this research thesis GIS will be used in the context of urban planning and development. Other uses of GIS, but are not limited to, are:

- ❖ As a tool for **mapping**. Mapping can be done offline, with local data, or it can be done online. The benefits of using online data are that it is usually regularly updated, which gives you a more accurate representation. Google Maps, Bing Maps, etc. are web-based GIS mapping platforms with a relatively easy user-interface. They are easily accessible and widely used by the general public, but their functions aren’t as versatile and as broad as ArcGIS and QGIS.
- ❖ As a base for the development of **contingency plans**. GIS can provide an overview of multiple layers of data simultaneously. This feature is especially important for environmental contingency plans and can assist risk and disaster management.
- ❖ As a geographical data input tool for **surveys**. GIS serves as a hub for data and research, vital to surveying, planning, design, and management. As this information is integrated into a GIS scheme, it can be used to approximate areas and create digital maps.
- ❖ As a platform to view **integrated geological data**. GIS data can used to study soil and measure seismic data. Several types of maps (including 3D maps) can be generated through spatial data.
- ❖ As a tool for **crime mapping**. By detecting and tracking crime sequences, GIS can be used for organizational and tactical reasons. It can also serve as a platform for locating police stations and patrols, targeting crime in high-risk neighborhoods (hot spot analysis), and designing policing programs.
- ❖ As a tool to analyze data for **Environmental Impact Assessments** (EIA). GIS can facilitate in visualizing the date in a geographical context. GIS-based data is important for conserving natural resources and protecting the environment. Data collection, spatial simulation, impact estimation, and impact magnitude measurement can all be aided by GIS.

Data added to a computer-based GIS are arranged in one of two ways: by raster or by vector. The main difference between raster and vector data is that the raster data represents data as a cell or a grid matrix while vector data represents data using sequential points or vertices. Raster data is composed of pixels. A value is assigned to each pixel. This information is represented by a grid of cells. It is essentially a matrix of cells divided into rows and columns. A value reflects information in each cell. Vector data, on the other hand, contains an x coordinate and a y coordinate. Linear features, such as roads and rivers are some examples of vector data. Vector data display latitude and longitude using lines, points, polygons, etc. See Figure 6 below for a more detailed comparison between the two data types.

ArcGIS and QGIS are both Geographical Information Systems used for mapping and analyzing spatial data. ArcGIS is a product of Esri, while QGIS is a free, open-source project. All functions are freely available in open-sourced programs. ArcGIS allows us to store our data online, which enables cross-interfacing on multiple devices. In QGIS, on the other hand, all data must be stored on an external platform.
Both these programs enable us to concurrently view multiple aspects of an area through data layers (see Figure 7 below for example).

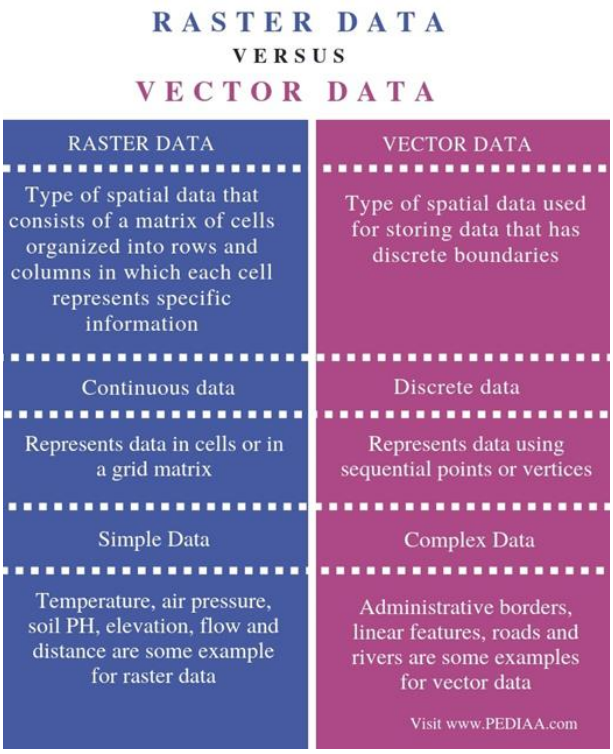


Figure 6 Differences between raster and vector data (Lithmee, 2019)

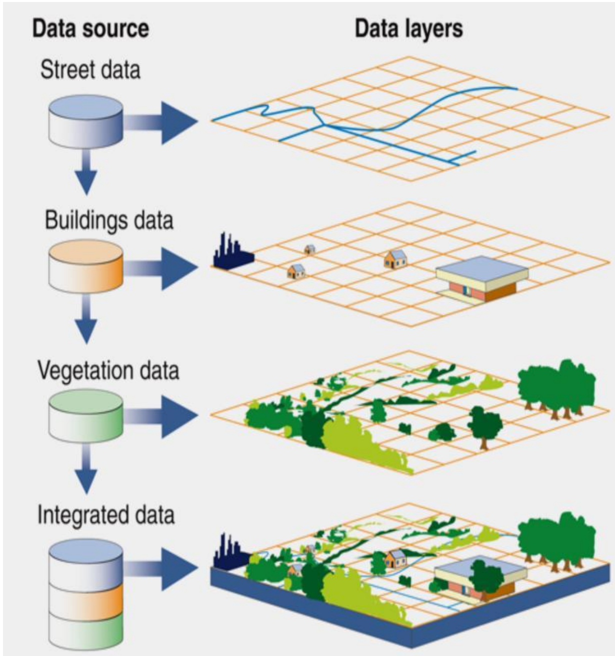


Figure 7 Example of data layers in GIS (Ibraheem & Daham, 2011)

Some important features/tools of GIS for this research include:

- ❖ Satellite image interpretation
  Analyzing aerial or satellite imagery in order to interpret it, determine the characteristics it includes, and estimate their value. E.g., by looking at the size and surroundings of building, it can be speculated which building are of residential character and which are industrial. Other characteristics to look out for are tone shape, etc. (Figure 8).

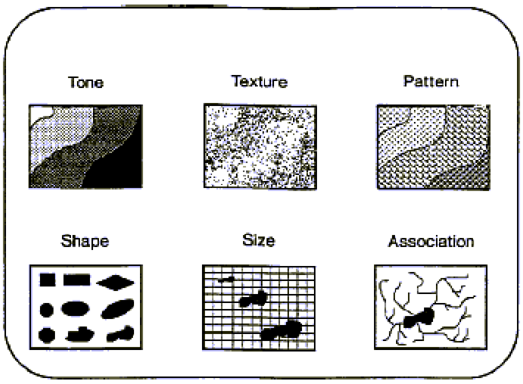


Figure 8 Example of Satellite Image Interpretation (Topic 5: Air Photo Interpretation, n.d.)

- ❖ Reclassification of remote sensing data
  Reclassification is useful when you want to replace the values in the input raster with new values. Spatial data can be categorized in different group though this tool. Figure 9 gives a visual example of reclassification. This tool is used on raster data.

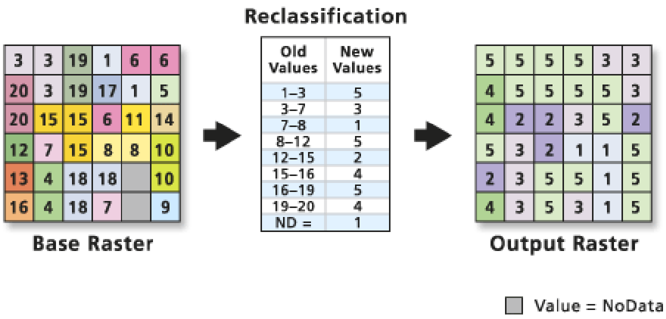


Figure 9 Example of the feature: reclassification (Reclass by ranges of values, 2021)

- ❖ Interactive Supervised Classification
  This tool is one of the methods to reclassify remote sensing data, using training samples (Figure 10)

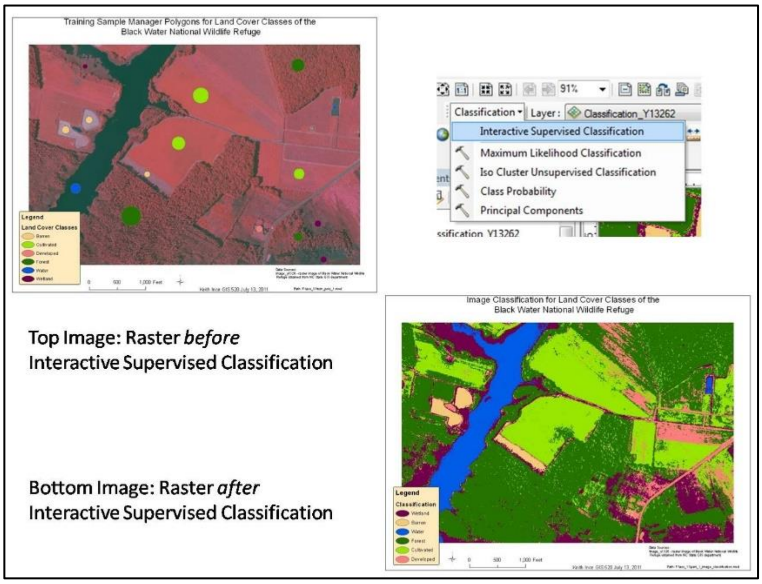


Figure 10 Example of the tool: Interactive Supervised Classification. (Interactive Supervised Classification, n.d.)

- ❖ Training samples
  Training samples are a necessary tool to execute the Interactive Supervised Classification. Training samples can be created interactively using the training sample drawing tools on.
- ❖ Extract by mask
  This spatial analyst tool can select a specific area of a raster using another layer as a base/mask (Figure 11). This tool is handy, especially when demarcating an area is necessary. E.g., have the data be focused on Paramaribo, instead of the whole world.

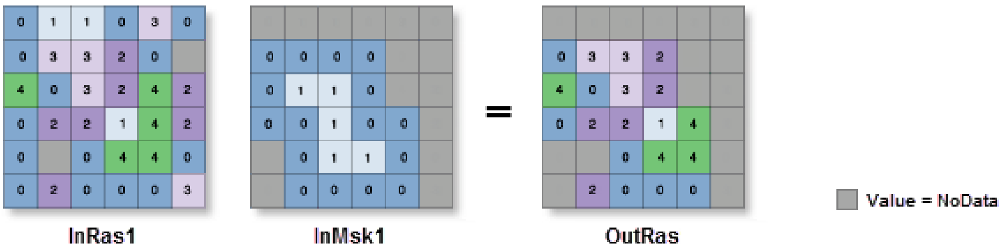


Figure 11 Example of the feature: extract by mask (Extract by Mask (Spatial Analyst), 2021)

- ❖ Erase
  ArcMap's Erase tool allows users to delete sections of a feature/shapefile through the use of an overlapping layer (Figure 12). The overlapping layer can be a point, line, or polygon.

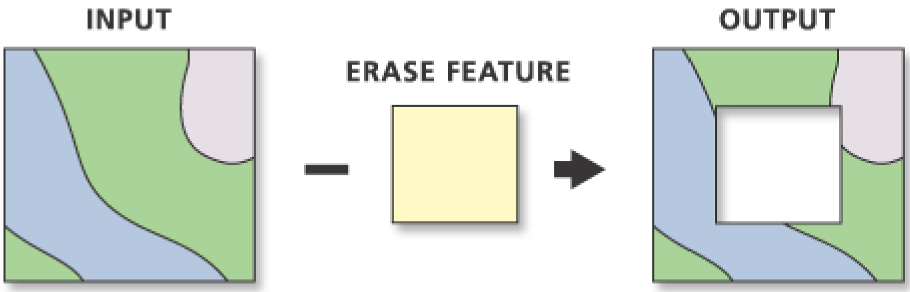


Figure 12 Example of the tool: Erase Analysis (Erase (Analysis), 2021)

- Raster to Polygon
  This tool converts a raster dataset to polygon features. This tool is handy if the surface area needs to be calculated. The calculation has to be preceded by the dissolve tool.
- Dissolve
  Dissolving or eliminating characteristics is another method for obtaining information from more complicated data. The Dissolve tool joins polygons with the same value together to form bigger polygons (Figure 13).

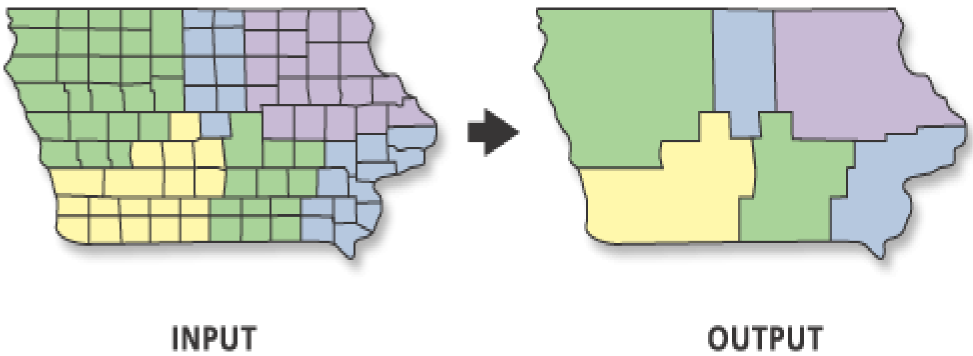


Figure 13 Example of the feature: Dissolve (Dissolve, 2016)

- Geometry Calculator
  This tool can calculate surface area, distances etc.

2.3 Overview of Current Urban Environment: Case Study Area Paramaribo

The capital of Suriname, Paramaribo, is the most densely populated city in Suriname. With a multitude of ethnical races living in this city, it is adorned with a plethora of different types of ethnical and religious urban areas, such as mosques, temples, churches, cultural centers, monuments etc. This city is comprised out of the following resorts (Figure 14 below): Beekhuizen, Blauwgrond, Centrum, Flora, Latour, Livorno, Munder, Pontbuiten, Rainville, Tammenga, Weg naar Zee en Welgelegen.

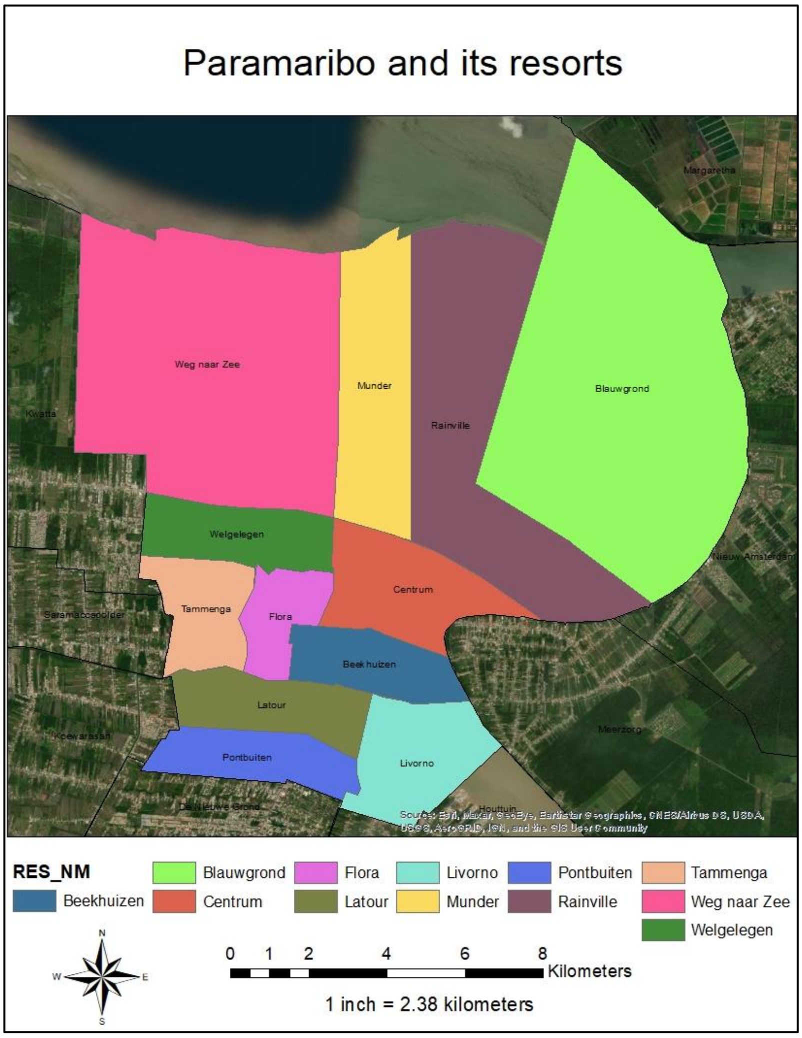


Figure 14 Suriname and its resorts (GISSAT via ESRI ArcGIS)

Centrum is arguably the most commercially active part of Paramaribo. During peak hours, this resort hosts many people who mostly work, shop, or travel there. Peak hours in Paramaribo are also notorious for traffic jams. After regular working hours, the city is relatively uneventful. The residential function in the city center has almost disappeared. And the recreational activities for after-work hours are concentrated in the outskirts of the center. Small initiatives are not successful, because people feel unsafe in the large empty streets.

In addition to traffic congestion, flooding in the rainy seasons is a common phenomenon. Both have a negative impact on the living and working environment and can potentially cause economic damage. Some of the effects are, that properties can get flooded and cars and busses have difficulty navigating through the roads, which are also underwater.

Suriname has a culture of building their homes/ houses from scratch on their own property, which can result in an urban sprawl. Due to the culture of self-building and the constitutional status on land, the concept of urban densification is difficult to apply.

"Urban densification" is a notion that claims that the most socially and environmentally friendly way to build houses today is to make them smaller and closer together, and it can also help to preserve communities and public spaces (CNN, 2008).

Many properties in the city are owned by private individuals or issued to private individuals.

This includes rental houses. Property owners can also choose not to rent their (vacant) buildings.

There are 4 hospitals in Paramaribo, and all of them are easily accessible to the public. Good healthcare is critical for improving and maintaining health, preventing and treating sickness, and preventing unnecessary harm and death.

2.4 Criteria for Indicator Selection

With the increasing world population in metropolitan areas and cities in low- and middle-income countries, the relationship between urbanization and development has become an important policy issue (Ivan Turok, 2013). Measuring progress towards urban sustainability requires an in-depth analysis of relevant sustainability indicators.

Indicator & Index

- Indicators:
  An environmental indicator is a parameter, or a value derived from parameters, that points to, provides information about and/or describes the state of the environment, and has a significance extending beyond that directly associated with any given parametric value (Glossary of Statistical Terms, 2001).
  It is important to clarify the distinction between indicators and data or variables observed. A data or variable observed becomes an indicator only once its role in the evaluation of a phenomenon has been established.
- Indices:
  An index (or composite indicator) is a synthesis of indicators.
  Formalization of an indicator that gathers several data or variables, results in an index. The use of indices in the field of sustainable development facilitates the understanding and interpretation of indicators of a given phenomenon. (Tanguay, Rajaonson, Lefebvre, & Lanoie, 2009)

Choosing indicators

- Model 1

The Urban Sustainability Index (USI) seeks to measure and assess the performance of cities across a range of criteria. This USI is as an equally weighted average of six categories – Air Quality, Built Environment, Sewage & Sanitation, Solid Waste, Roads and Water Quality & Supply, as seen in Figure 15 (CR, Anantram, & Venkataramani, 2012). These 6 categories were selected for a sustainability index in India.

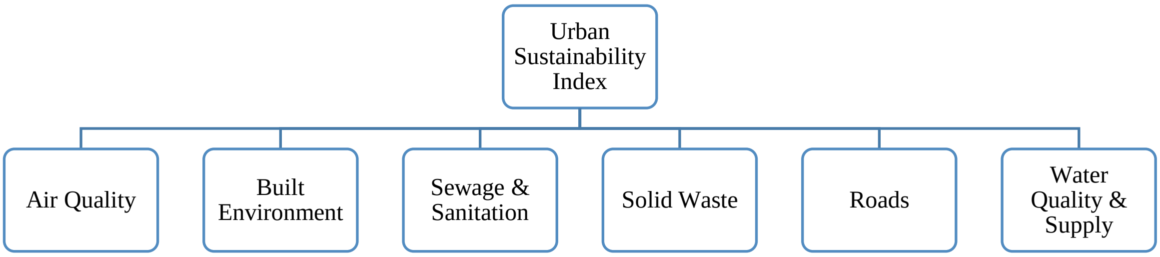


Figure 15 USI with equally weighted categories (CR, Anantram, & Venkataramani, 2012) (Model 1)

- Model 2

Another categorization of the indicators is derived from a numeric research that was concentrated around Germany (Figure 16).

Indicator	Calculation
11.1.1 Residential rental prices	Average basic rent per square meter
11.2.1 Modal split	(Traffic volume of pedestrian, bicycle, and public transport traffic/(Overall traffic volume) * 100
11.2.2. Traffic injuries	(Number of injured and killed persons in traffic accidents)/(Number of inhabitants) * 1000
11.3.1 Land consumption	(Area for settlement and traffic total area * 100)
11.3.1/11.7 Recreation areas	(Amount of recreation areas)/(Number of inhabitants)

Figure 16 Targets and indicators of Sustainable Development Goal (SDG) 11 developed in the project "SDG Indicators for Municipalities". Source: (F & K., 2018) (Model 2) (The Inter-American Development Bank, 2019)

- Model 3

IDB created an Action Plan for case study area Paramaribo in 2019. In this report, a baseline study was conducted to assess the challenges Paramaribo faces in terms of sustainability. The baseline studies first detect, then quantify and ultimately prioritize these challenges, based on a filter system of 1) public opinion, 2) environmental angles, 3) technical angles and 4) economic angels (Figure 17)

Dimension	Topics / % comparative weight	Public Opinion (20%)	Environmental (35%)	Technical (25%)	Economic (20%)	Σ Consolidated (100%)	Σ Scale 1-5 (Scale 1-5)
Environmental Sustainability and Climate Change	Water	2.0	5.0	2.1	1.0	13.1	3
	Sanitation and Drainage	3.0	3.3	2.6		13.9	2
	Solid Waste Management	1.0	4.2	3.4	1.0	14.6	3
	Energy	2.0	5.0	4.1	3.0	19.1	4
	Air Quality	2.0	5.0	1.9		13.9	3
	Climate Change Mitigation	4.0	3.3	4.2		14.5	3
	Noise	3.0	1.0	1.0		10.0	1
	Vulnerability to natural disasters	4.0	4.0	3.2	2.0	18.2	3
Urban Sustainability	Land Use Planning and Zoning	4.0	3.9	5.0	2.0	17.9	4
	Urban Inequality	3.0	2.0	4.3		10.3	2
	Mobility / Transport	3.0	5.0	3.4	5.0	21.4	4
	Competitiveness of the economy		1.0	4.6		8.6	2
	Employment		2.0	3.1		8.1	1
	Connectivity	3.0	1.0	2.4	4.0	11.4	2
	Education	3.0	4.0	4.2	4.0	18.2	4
	Security	5.0	1.0	3.2		14.2	2
	Health	4.0	4.0	4.8		13.8	3
Fiscal Sustainability and Governance	Participative Public Management	5.0	1.0	4.1	5.0	16.1	3
	Modern Public Management	5.0	1.0	4.2	3.0	14.2	3
	Transparency	5.0	1.0	2.8		9.8	2
	Taxes and Financial Autonomy		1.0	2.9		4.9	1
	Expenditure Management		1.0	3.5		5.5	1
	Debt		1.0	2.2		4.2	1

Figure 17 Sustainability indicators and their weight, as classified by IDB (The Inter-American Development Bank, 2019) (Model 3)
See Appendix 1 for a breakdown of the indicators per topic.

Above values in Figure 17 were taken according to the result of the stoplight classification:

- Green = 1 (lowest priority)
- Yellow: 3
- Red: 5 (highest priority)
- Shaded grey = not applicable or not surveyed by IDB

3. Research Method

The GIS Urban Sustainability Index will be created through the steps seen in Figure 18.

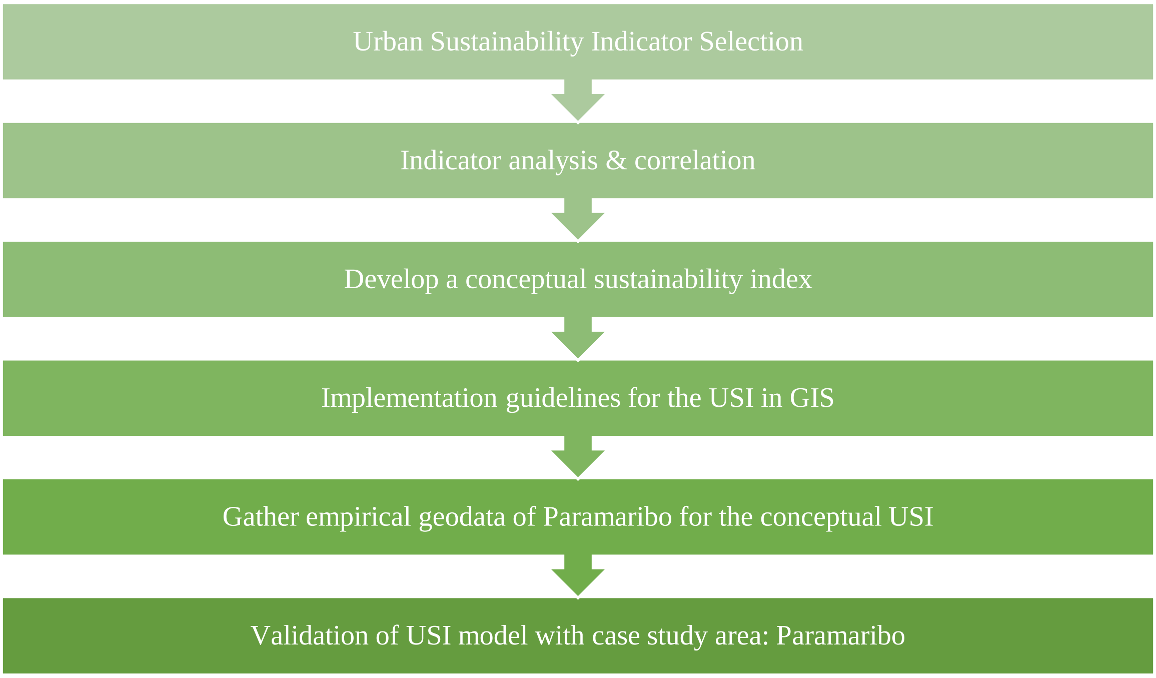


Figure 18 Research Approach

1. Urban Sustainability Indicator Selection
   The USI will be centered around indicators specific to the case study area Paramaribo. The literature review in paragraph 2.4 will serve as a basis. This selection process takes place in paragraph 4.1.
2. Indicator analysis & correlation
   Every indicator influences urban development in a unique way. Therefore, it is important to establish how they compare to one another (paragraph 4.2). The indicator (correlation) analysis is conducted in 2 steps:
   1. Determine indicator category weight and transform data to a comparative uniform value (e.g., 100%)
   2. Create a uniform weight matrix for the indicators in all categories and scale the indicators to this matrix. The weights will be determined on the basis of a survey.

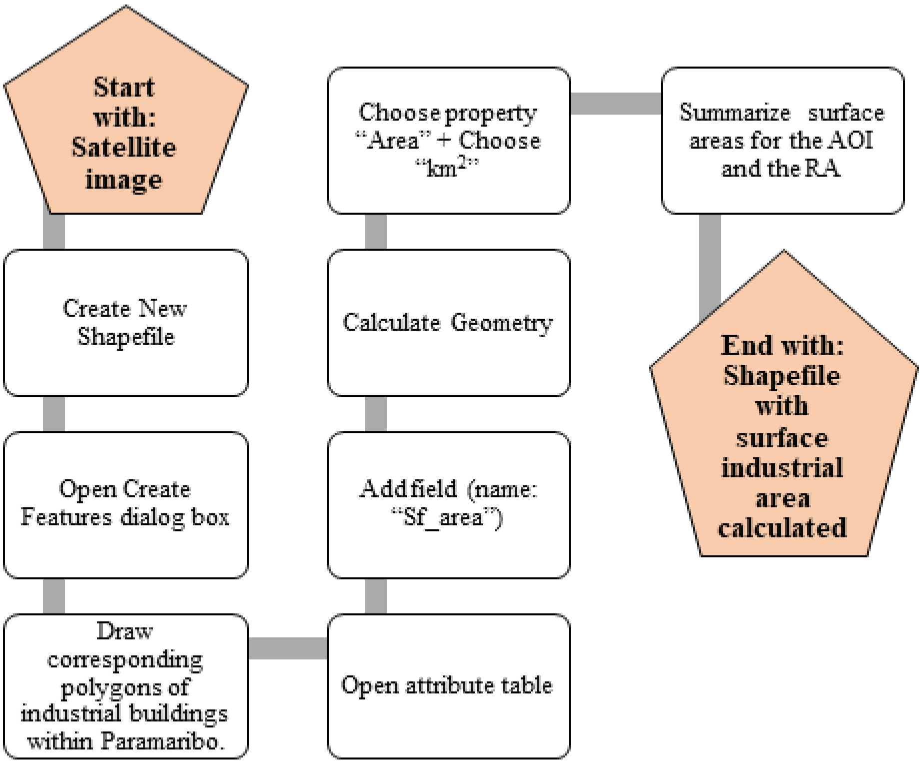
- The USI will be created in paragraph 4.3, based on the weighted indicators.

3. Development of a conceptual sustainability index in GIS
   Finally, a step-by-step instructional (paragraph 4.1) is given to creating a conceptional USI index in ArcMap, based on the weighted indicators and indicator categories.
   There are 2 ways to integrate the USI:
   - ❖ Method A – Integrate the model in its entirety in GIS

This method is effective if working exclusively with spatial data.

- Method B – Integrate the model through a combination of GIS and Excel
  This method is ideal if working with combined data types, such as a combination of spatial and numerical data.

4. Gather empirical geodata of Paramaribo for the conceptual USI.
   In order to test the USI, empirical data must first be collected. This data ideally needs to have a geospatial value as will be described in paragraph 4.1. The empirical data will be collected in paragraph 4.1.
   A brief concise step-by-step method is given below:
   - Spatial indicators:
     - Satellite image interpretation

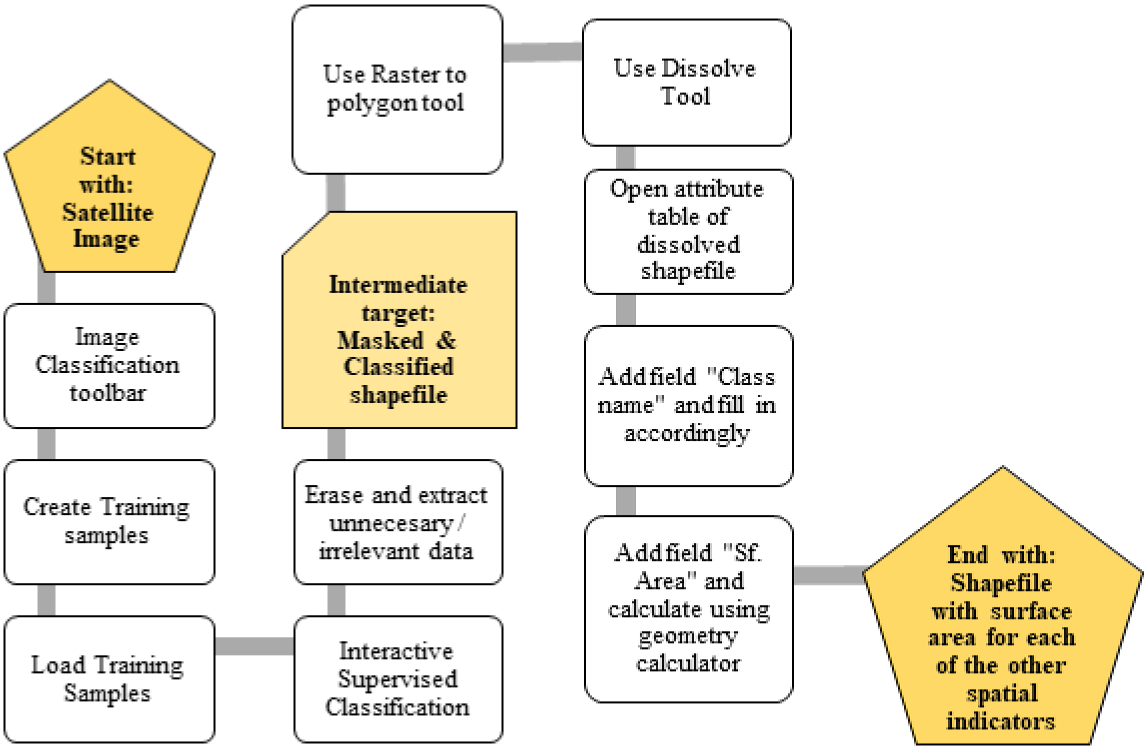


- **Start with satellite image**
  - This image will function as a base layer.
- Create New Shapefile
  - Shapefile allow for drawing and storing of features.
- Open Create Features dialog box
  - Drawing polygons in ArcMap is only possible via the "Create Feature Dialog Box".
- Draw corresponding polygons of industrial buildings/properties within Paramaribo.
  - ArcMap is now ready for drawing polygons in the shapefile. As per a set of predetermined conditions, the relevant polygons can be drawn.

- Open attribute table
  - The next step is to determine the surface area of the collective polygons (the industrial area). This is done via the attribute table.
- Add field (name: “Sf_area”)
  - A special column is created in which the surface area will be determined. The name advised for the column (“Sf_area”) is optional.
- Calculate Geometry
  - Right clicking on the new column gives the option to calculate the geometry, including the surface area of each industrial property.
- Choose property “Area” + Choose “km^2”
  - It is essential that “Area” is chosen in the new dialog box. This research thesis chooses to work with km^2, but this is not mandatory. After clicking OK, the new column will be automatically filled in with the calculated surface area of each polygon.
- Summarize surface areas for the AOI and the RA
  - Each polygon now has a value associated with it, that depicts the surface area in km^2. The lasts step is to calculate the collective surface area of all the drawn polygons through a simple summary. This value is the size of the industrial area.
- **End with: Shapefile with surface industrial area calculated**

- Reclassification of Remote Sensing Data

Through this method a satellite image will be reclassified in different groups/classes relevant to the research thesis.



- **Start with Satellite Image**
  - This image will function as a base layer.
- Image Classification toolbar
  - This remote sensing data can be automatically classified by ArcMap via the image classification toolbar.
- Create Training samples
  - Training samples are miniscule polygons drawn by and then manually categorized the researcher into the desired classification groups. These groups are then used by ArcMap as a guideline to automatically classify the rest of the satellite image.
- Load Training Samples
  - After the training samples are drawn and categorized by the researcher (approximately 10 – 40 miniscule polygons), the file is uploaded in the image classification toolbar. In most cases, the training samples are automatically uploaded as the polygons are drawn.
- Interactive Supervised Classification
  - The satellite image is now ready to be classified. The type of classification used for this thesis is the "interactive supervised classification", due to the use of training samples. The groups are bundled in a new raster shapefile. The classification is done for the whole satellite image, not just the area of interest.
- Erase and extract unnecessary / irrelevant data

- An important step is to demarcate the new shapefile *before* the surface area is calculated. Another important step is to erase the parts of the image that was previously classified as industrial environment. To do this efficiently, a demarcation layer is created by inversing (through ArcMap extract analysis tool) the area of interest with the industrial property polygons. By masking (through ArcMap masking tool) the shapefile of the previous step with this demarcation layer, a new raster shapefile is created: with the geographical values that are relevant to this research and without the industrial area polygons.

➢ **Intermediate target: Masked & Classified shapefile**
  - The classified shapefile is ready to undergo the calculation of the surface areas.

➢ Use Raster to polygon tool
  - The surface area in ArcMap is calculated for polygons. Via the "raster to polygon tool" the raster shapefile can be transformed into a polygon file.

➢ Use Dissolve Tool
  - The "raster to polygon tool" transforms the raster data to polygon features but scatters the data as a result. Through the "dissolve tool" the scattered data can easily be regrouped as per the outcome of the previously done "Interactive Supervised Classification".

➢ Open attribute table of dissolved shapefile
  - The polygons are now grouped together, but the "dissolve tool" does not assign names to the groups. This can be solved manually via the attribute table.

➢ Add field "Class name" and fill in accordingly
  - The respective group names can now be filled in for each class. The original classified shapefile and the satellite image can be used as reference.

➢ Add field "Sf. Area" and calculate using geometry calculator
  - A new column must be added to the attribute table, wherein the surface areas will be calculated. By using the geometry calculator, the surface area can be determined. It is essential that "Area" is chosen in the new dialog box. This research thesis chooses to work with km^2, but this is not mandatory. After clicking OK, the new column will be automatically filled in with the calculated surface area of each polygon.

➢ **End with shapefile with surface areas for each of remaining spatial indicators**

- Non-Spatial indicators
  Gather textual data from reliable sources.

5. Validation of the USI model with case study area: Paramaribo
   The USI is tested in paragraph 4.1
   A selection will be made between method A and B from paragraph 4.4, and is dependent on the type of data gathered:
   ❖ Method A – Test the model in its entirety in GIS

The guidelines in paragraph 4.4 are to be followed in order to validate the model.
This method is effective if working exclusively with spatial data.

- Method B – Test the model through a combination of GIS and Excel
  This method is ideal if working with combined data types, such as a combination of spatial and numerical data.

4. Research Findings & Discussion

4.1 Urban Sustainability Indicator Selection

The indicator selection is preceded by choosing the indicator categories. Through literature review, 3 models were chosen to function as a guideline for the latter selection. The models were chosen based on how they apply to the case study area Paramaribo, Suriname:

- Model 1 showed the urban sustainability indicators for a study done in India[i]
  This model was chosen because India, like Suriname, is a developing country.
- Model 2 showed the urban sustainability indicators for a study done around Germany[ii]
  This model was chosen because of the strong disparity Germany has with Suriname in terms of lifestyle and development.
- Model 3 showed the urban sustainability indicators for a study done in Paramaribo[iii]
  This model was chosen because the focal point of this model is the same as this research's case study area.

4.1.1 Choosing the categories

The case study area of this research thesis is Paramaribo, which is also the focal point of Model 3. For this reason, the preference for indicator categories will be favorable to Model 3.
For model 3, the IDB conducted a survey on the weight prioritization of each indicator category. The research behind Model 3 consisted of a baseline study done in Paramaribo, focusing, amongst other things, on the public opinion the Surinamese society has on different dimensions and their corresponding indicator categories. The most significant dimension of Model 3 to this USI was the Urban Development dimension. For the USI, this research will choose the highest-ranking categories in abovementioned dimension, based on public opinion, due to the high relevance to the Surinamese society. According to model 3, the highest scoring indicator categories, based on public opinion, are **1) Land Use Planning and Zoning, 2) Health, and 3) Security.**

4.1.2 Choosing the indicator(s) per category

For each of these categories, indicators were assigned:

- Inspired by the other 2 models
- Based on the relevance to Suriname
- Based on independent research

The indicators chosen per category are:

- ***Land Use Planning and Zoning:***

---

[i] Figure 15 USI with equally weighted categories (Model 1). - Page 17

[ii] Figure 16 Targets and indicators of Sustainable Development Goal (SDG) 11 developed in the project "SDG Indicators for Municipalities". Source: (Model 2) - Page 17

[iii] Figure 17 Sustainability indicators and their weight, as classified by IDB (Model 3) See Appendix 1 for a breakdown of the indicators per topic. - Page 18

- **Industrial environment**

The concept "built environment" refers to the human-made surroundings that provide the atmosphere for human life, varying in size from houses and parks to suburbs and villages (Gupta, 2016). The built environment has an important role to play in reducing community exposure to environmental health hazards such as air, water, and noise pollution as well as land contamination. The industrial environment is part of the built environment. According to the EPA (Greenhouse Gas Emissions, 2021) the industrial environment accounts for 23% of CO_2 emissions.
A study in 2018 showcased residents living near industrial complexes have a higher risk of acute and chronic illnesses, including respiratory and allergy disorders (Eom, 2018). It stands to reason societal problems will arise with the residents.

- **Green urban spaces**

Green spaces in cities make a significant contribution to reducing urban heat and have plenty of other psychological, physical, and environmental advantages. The inclusion of green spaces can improve the health and welfare of people living and working in cities (Braubach, 2017). Green space includes parks, schoolyard, playgrounds, public seating areas and forestry.

- **Water bodies**

The presence of water bodies in their natural setting plays an important role in enhancing the quality of physical environment and the socio-economic environment (Bindu, 2016).
A study executed in 2015 even argues that water is a key driver of urban development because it drives urban adaptation, which changes the structure, function, and services of urban landscapes, waterways, and civilizations through time (Kaushal, 2015).
Some examples of water bodies in urban areas are ponds, rivers, lakes etc. Water bodies, especially rivers are central in water transportation and fisheries.

- **Residential environment**

In contrast to industrial and mixed-use zones, a residential environment is an area where housing predominates. Residential environments are ordinarily a component of the built environment. Surinamese citizens generally tend to live in independent housing and prefer to establish roots far from industrial zones. Inadequate water and sanitation, a lack of waste disposal, and industrial pollution are all examples of urban environmental issues.
Residents can be subjected the following residential pollutions ((Residential Pollution, n.d.): - Homes within 1 mile from a: Major airport, Refinery, Mining site and Chemical Plants. - Homes located within 1 block from a: Gas station, shopping mall, Auto repair shop and Construction site.

- ***Health:***
  - **Life expectancy**

Many variables influence life expectancy, including unhealthy habits such as smoking, heavy alcohol intake, inadequate diet, lack of exercise etc. Life expectancy is also impacted by housing, wages, schooling, and economic well-being; the nature of the health system and the means to access it. (Tier 1—Life expectancy and wellbeing—1.19 Life expectancy at birth, 2012)

- **Hospital bed density**

Healthcare should ideally be accessible, affordable and of good quality. Good healthcare is essential in improving and maintaining health, avoiding, and treating illness, and reducing needless injury and premature death. Inpatient beds in public, private, general, specialist hospitals and recovery centers are clustered as hospital beds. For this research, both urgent and chronic treatment beds are included.

The presence of hospital beds is used to indicate the availability of inpatient services. (The Global Health Observatory, 2021)

There is no universal goal for the number of hospital beds per country because the number of inpatient services required for particular countries is dependent on many factors, such as disease patterns. (McKee, 2004)
Access to hospitals and other medical institutes is a fundamental human right (Health is a fundamental human right, 2017). Barriers to this right are categorized as follows 1) Transportation difficulties, 2) Limited health care supply, 3) Lack of quality health care, 4) Social isolation and 5) Financial constraints (Healthcare Disparities & Barriers to Healthcare, 2018).

Hospital beds are calculated per 1000 people.

- **Population density**

More than half of the world's population lives in cities, and this number is rising at a 1.5 percent growth rate (Division, 2019). Rapid urbanization, combined with population growth, is altering the human settlement landscape, posing serious threats to housing conditions, the environment, and sustainability. Population growth is based on four fundamental factors: birth rate, death rate, immigration, and emigration and can be heavily influenced by economic development, education, quality of children, welfare payments/state pensions, social and cultural factors, availability of family planning, female labor market participation and the level of medical provision (Pettinger, 2019). Human demands for services such as water, soil, plants, and electricity are increasing as the human population grows. The population influences many environmental challenges, which makes it a necessary component of achieving sustainability.

Population density is calculated by the number of people per sq. km of land.

Equation:

$$population\ density\ (\frac{people}{km2}) = \frac{\text{population Paramaribo}}{Surface\ Area\ Paramaribo}$$

This indicator will determine the population density of Suriname.

- ***Security:***
  - **Homicide**

Crime has always been a part of the socioeconomic structure, and human cultures have experienced it since the beginning of time. It varies from one culture to the next, and even within a single community, it does not appear in the same ways or in the same manner. Previous studies have shown a connection between crime rates and a variety of social variables, including education levels, poverty rates, and a lack of social organization, whilst others have focused on the built environment (Adel, 2016). Poverty, economic inequality, ethnic fractionalization, and the availability of guns and alcohol are risk factors for homicide (World Health Organization, 2015). Homicide involves murder, manslaughter, etc. (bot psychological and physical).

The homicide is calculated per 100.000 people.

- **Robberies**

For a population increase, the disparity of available resources is indicated by a scarcity of land, shelter, food, and basic services, contributing to competitiveness, rivalry, and, as a result, instability The increase in crime in the city is an expression of this vulnerability. (Santana, 2010).

Urban design and environment may contribute to the decision to commit a crime or not. E.g., a small area may easily be transformed into a potential crime hotspot due to a shortcoming of natural restraint, poor lighting etc. (Santana, 2010).

Robberies are calculated per 100.000 people. The focus will be on theft.

- **Fatal Traffic injuries**

Cars and other motorized vehicles have become a vital part in the daily life of the 21^{st} century people. An increase in vehicles go together with expansive infrastructures (part of urban development), which influence many other factors, such as the surrounding commercial urban development, the accessibility to other places etc.

Traffic injuries are a result of combined variables, e.g., traffic participants, vehicles, roads, the spatial, legal and logistic organization of road traffic and medical care (I., 2013) .

Fatal traffic injuries are calculated per 100.000 people

4.2 Indicator Analysis & Correlation

4.2.1 Weight - indicator category

Each of the chosen indicators has a unique impact on the urban development of Suriname. Going back to Model 3, the public opinion of each of these categories was unique as well. On a scale of 1-5, each indicator category, weighs as follows (according to Model 3):

- ❖ Land Use, Planning and Zoning = 4.0
- ❖ Health = 4.0
- ❖ Security = 5.0

This research thesis focuses exclusively on these 3 categories. In other words, the USI is solely comprised out of these 3 categories. Scaled to a 100%, the indicator category weights are transformed with the following formula, in the table below:

$$\left(\frac{\lfloor Weight\ by\ public\ opinion \rfloor}{\sum weight\ by\ public\ opinion}\right)\ x\ 100\%$$

Figure 19 shows a graphical layout of the indicator category weights scaled to a 100%.

Indicator category	Weight by public opinion[iv]	Scaled to 100%
Land Use, Planning & Zoning	4.0	$\left(\frac{\lfloor 4 \rfloor}{13}\right) x\ 100\% = 31\ \%$
Health	4.0	$\left(\frac{\lfloor 4 \rfloor}{13}\right) x\ 100\% = 31\ \%$
Safety	5.0	$\left(\frac{\lfloor 5 \rfloor}{13}\right) x\ 100\% = 38\ \%$

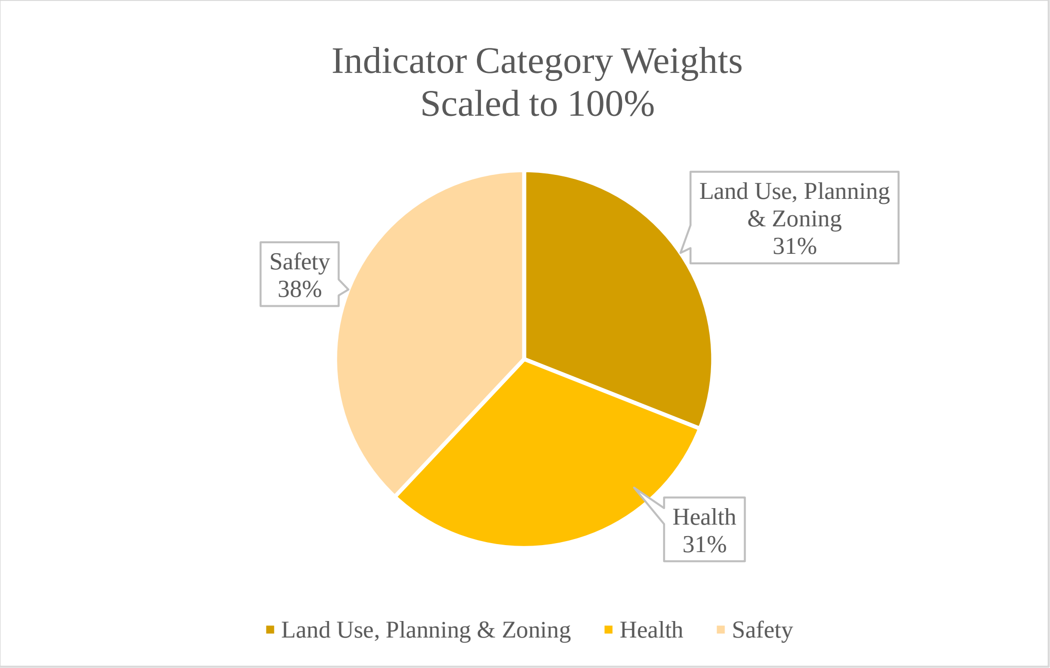


Figure 19 Indicator Category Weights Scaled to 100%

4.2.2 Weight – indicators

The next step to creating the USI is determining how much each of the chosen indicators impacts urban sustainability. As previously stated in paragraph 2.1, sustainability is a healthy balance between its 3 pillars:

- People (Society)
- Planet (Environment)
- Profit (Economy)

[iv] (The Inter-American Development Bank, 2019)

Measuring the indicators against these pillars gives more concise and justifiable results. The grading system used illustrates 3 degrees of influence (1,3 and 5). Each with a mandatory connotation establishing if the influence is negative or positive. This specific grading system was used, due to the range that suggest that an impact can have a low (1), medium (3) or high (5) impact. The degrees are one number apart, in hopes that it is more relatable and less overwhelming (as opposed to a grading system with more numbers e.g., 1, 2, 3… 100).

Matrix below appropriates how much influence each indicator can potentially have on each of the environmental "pillars", through a grading system of:

- High positive influence = 5
- Medium positive influence = 3
- Low positive influence = 1
- Low negative influence = -1
- Medium negative influence = -3
- High negative influence = -5

While conducting this research the following methods were considered to grade the indicators:

- Have the researcher grade each indicator themselves.

Pros	Cons
○ Fastest Method	○ Results would not be representative

- Send out an open survey to the general public with an invite to grade the indicators

Pros	Cons
○ Results are representative to the public	○ The survey is technical and sufficient knowledge about Paramaribo and sustainability is needed to accurately make such an assessment

- Send a closed survey to a medium group (15-30 people) of experts and professionals with a personal invite to grade the indicators

Pros	Cons
○ The survey is technical and sufficient knowledge about Paramaribo and sustainability is needed to accurately make such an assessment	○ There is a risk that the target group would be too small for accurate representative results.

Ultimately it was decided that working knowledge about the survey contents weighed more than the other factors. Experts and professionals were invited to participate in the survey. A total of 19 responses were received. For more details on the survey, see Appendix 2.

The survey results were analyzed and the most often occurring numerical values (statistical mode) were determined per indicator. The statistical mode value was preferred to the statistical mean value, due to the former's similarity with the grading system: this way the survey emits a number that has a known value and known explanation on the grading system.

With the 3 pillars of sustainability in mind, the values derived from the survey are summarized per indicator (people + planet + profit). The results of this summary indicate the degree (1, 3 or 5) and the type (good / bad) of impact each indicator has on urban sustainability[v], the so-called summarized weight.

The following step to developing the USI is scaling the summarized weight to fit the USI 100%. The scaling is done with absolute values[vi], because the target here is to calculate **how big** of an impact the indicators have, and **less if that impact is negative or positive**. The negative and positive connotations are descriptive in this case (stating if the impact is good or bad) and not mathematical. This calculation is done step-by-step:

- First the indicator is scaled to the category in %
  Each indicator is scaled to % importance of the whole category, through the following equation:
  Scaled per category (%) = $\left(\frac{\lfloor Weight\ per\ indicator \rfloor}{Summirized\ weight\ per\ category}\right)\ x\ 100\%$

- Secondly the indicator is called to the USI in %
  After scaling each indicator to the category, the calculation is done on the general weight of each specific indicator in the conceptual USI:

  Indicator weight in USI (%) =

$$\left(\frac{\lfloor category\ weight\ (scaled\ for\ USI)\rfloor}{100}\right)\ x\ indicator\ weight\ (scaled\ per\ category)$$

- Lastly the indicator is scaled to the USI in decimals = this is the value that will be used in the USI

The first and second step could easily be left out to calculate the last value. The choice was made to do this calculation in these specific steps, so it can serve as background information in case further explanation is needed on the final value of the USI (a.k.a. the Rel.USI.Value).

---

[v] As per de indicators of this research thesis
[vi] Absolutes are the non-negative values of numbers, regardless of their sign.

Disclaimer: Appropriation Matrix below gives a general analysis, based on the collective input of several scientists/experts. For a more in-depth calculation, further extensive research is required.

		People	Planet	Profit	Summarized weight	Scaled per category (%)		Indicator weight in USI (%)		Indicator weight in USI (decimals)	
Land Use, Planning & Zoning	Industrial Environment	**-5**	**-5**	**5**	**-5**	-	**13**	-	**3.88**	-	**0.039**
	Green Urban Spaces	**5**	**5**	**5**	**15**	+	**38**	+	**11.63**	+	**0.116**
	Water bodies	**5**	**5**	**5**	**15**	+	**38**	+	**11.63**	+	**0.116**
	Residential Environment	**5**	**-1**	**1**	**5**	+	**13**	+	**3.88**	+	**0.039**
	Category Totals (absolutes)				*40*		*100*		*31*		*0.310*
Health	Life Expectancy	**5**	**-1**	**3**	**7**	+	**47**	+	**14.47**	+	**0.145**
	Hospitals	**5**	**-1**	**3**	**7**	+	**47**	+	**14.47**	+	**0.145**
	Population Density	**1**	**-3**	**3**	**1**	+	**7**	+	**2.07**	+	**0.021**
	Category Totals (absolutes)				*15*		*100*		*31*		*0.310*
Safety	Homicide	**-5**	**-1**	**-1**	**-7**	-	**24.1**	-	**9.2**	-	**0.092**
	Robberies	**-5**	**-1**	**-5**	**-11**	-	**37.9**	-	**14.4**	-	**0.144**
	Fatal Traffic Injuries	**-5**	**-1**	**-5**	**-11**	-	**37.9**	-	**14.4**	-	**0.144**
	Category Totals (absolutes)				*29*		*100*		*38*		*0.380*
							Total		100		1.000

4.3 Development of a conceptual USI

The USI is based on the sustainability indicators seen below:

		Indicator weight in USI (decimals)
Land Use, Planning & Zoning	Industrial Environment	**-0.039**
	Green Urban Spaces	**0.116**
	Water bodies	**0.116**
	Residential Environment	**0.039**
	Category Totals (absolutes)	*0.310*
Health	Life Expectancy	**0.145**
	Hospitals	**0.145**
	Population Density	**0.021**
	Category Totals (absolutes)	*0.310*
Safety	Homicide	**-0.092**
	Robberies	**-0.144**
	Fatal Traffic Injuries	**-0.144**
	Category Totals (absolutes)	*0.380*
		1.000

The USI is calculated in comparison to a referential data.

Each indicator must have 2 sets of Data:

- Data AOI (Area of Interest)
- Data RA (Reference Area)

1) Equation 1

   The first value calculated, is the value per indicators relative to the refence data, henceforth referred to as "$RelValue_i$"

   $RelValue= (Data\ AOI/Data\ RA)_i$

   This calculation is done for each of the indicators.

2) Equation 2

   The relative urban sustainability value (Rel.USI.Value) is calculated by the following equation:

   $Rel.USI.Value = \Sigma\ (RelValue_i \times Weight_i)$

   i = indicator

Equation 1 was not essential to have done separately. It could easily be left out to calculate the last value. The choice was made to do this calculation in these specific steps, so it can serve as background information in case further explanation is needed on the final value of the USI (a.k.a. the Rel.USI.Value).

4.4 Integrating the conceptual USI in GIS

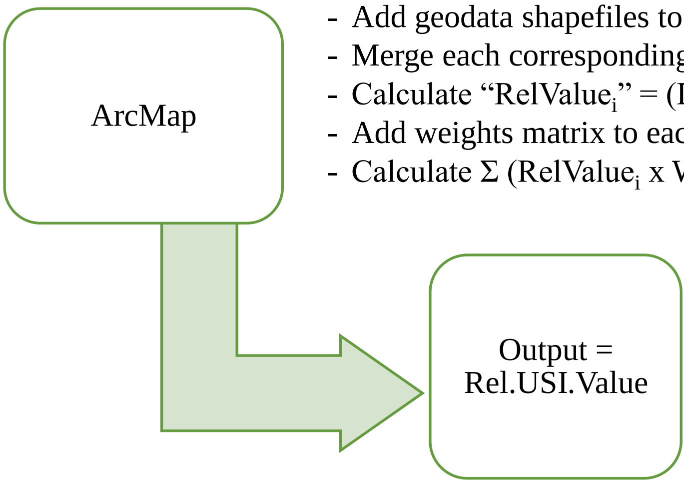
Important note when working in GIS:

The case study Area Paramaribo is the main and only focus of this research. All executions will be demarcated to this area, by defining the Area Of Interest (AOI) in ArcMap to Paramaribo in the form of a shapefile (retrieved from GLISS). The AOI is demonstrated in Figure 20.

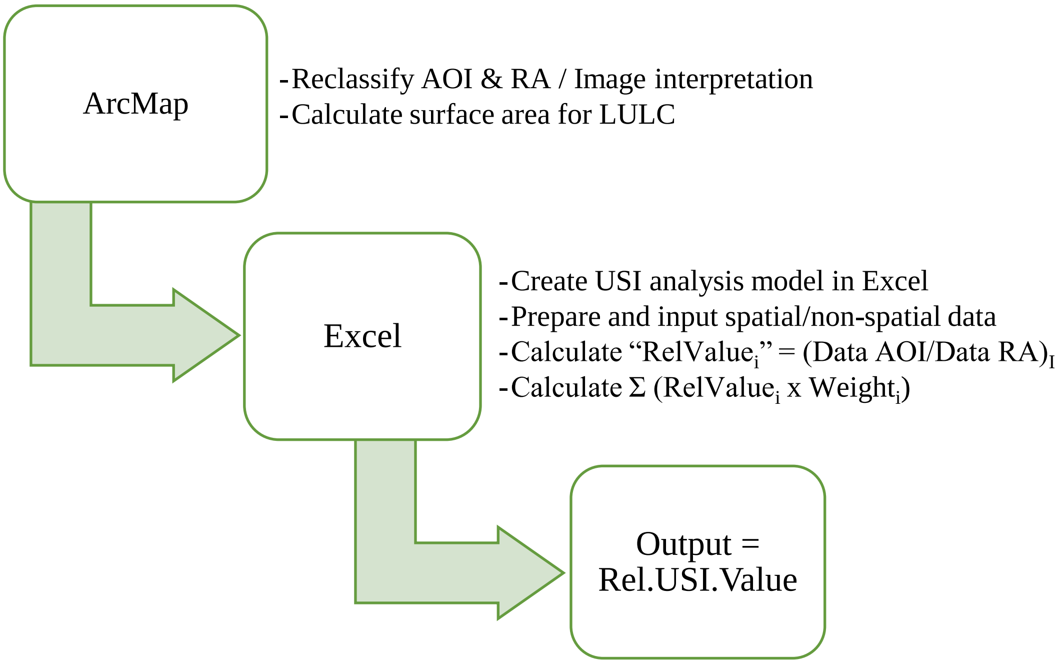
Figure 20 AOI - Paramaribo

❖ Method A – Integrate the model in its entirety in GIS
This method is effective if working exclusively with spatial data.

- Activate ArcGIS Model Builder
- Add geodata shapefiles to the ArcMap document
- Merge each corresponding AOI and RA
- Calculate “RelValue$_i$” = (Data AOI/Data RA)$_I$
- Add weights matrix to each RelValue
- Calculate Σ (RelValue$_i$ x Weight$_i$)



❖ Method B – Integrate the model through a combination of GIS and Excel
  This method is ideal if working with combined data types, such as a combination of spatial and numerical data.



4.5 Gather empirical geodata of Paramaribo for the conceptual USI

The following requirements apply for empirical data for the GIS USI:
❖ The data must have a geographical dimension.
❖ The data must be logical.
❖ The data must be complete.
❖ The data must be thematically accurate.
❖ The data must be legal.
❖ The data must be authentic.

Unlike most indices, this thesis chooses not to integrate specific reference data in the model. This model is flexible and open to data that is continually changing and updating. Some examples on how this USI can be used, is to calculate the relative USI Value between:
- Suriname and the Caribbean
- Suriname and any continent/country
- Paramaribo 2020 and Paramaribo 2000

This research thesis focusses on the latter: Paramaribo 2020 in relation to Paramaribo 2000
Henceforth the following references will be made:
AOI: Paramaribo 2020
RA: Paramaribo 2000

During the thematic data gathering phase the unavailability of (complete) data was a limitation/weakness. There was no spatial data readily available for the Land Use and Land Cover (LULC) indicators: Industrial Environment, Green Urban Spaces, Water bodies, Residential Environment. The data for the remaining indicators is (currently) only available in a numerical format. The data gathering plan was adjusted by:

- Choosing numerical data of the closest surrounding years.
- Calculating the LULC spatial data from satellite images (for category Land Use Planning & Zoning)

A distinction was made between:

- Data for the industrial area
- Data for greenery, water bodies and residential environment

The calculation is done in GIS via the methods: satellite image interpretation and image reclassification in paragraph 4.5.i Spatial indicators.

De data of the remaining (non-spatial) indicators will be collected in a textual format in paragraph 4.5.ii.

4.5.1 Spatial indicators

The first step for the GIS analysis is assigning a coordinate system.
This research uses:

WGS_1984_UTM_Zone_21N
WKID: 32621 Authority: EPSG

Projection: Transverse_Mercator
False_Easting: 500000.0
False_Northing: 0.0
Central_Meridian: -57.0
Scale_Factor: 0.9996
Latitude_Of_Origin: 0.0
Linear Unit: Meter (1.0)

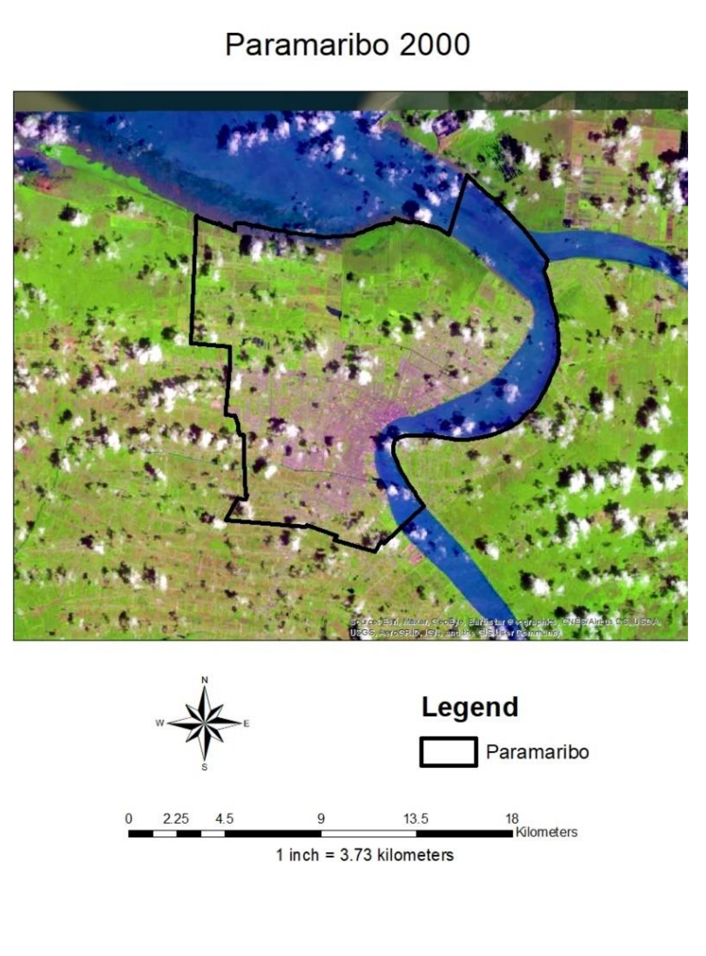
Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree (0.0174532925199433)
Prime Meridian: Greenwich (0.0)
Datum: D_WGS_1984
Spheroid: WGS_1984
Semimajor Axis: 6378137.0
Semiminor Axis: 6356752.314245179
Inverse Flattening: 298.257223563

The satellite image (GeoTIFF file) is downloaded from USGS Landlook Viewer (USGS, 2000 - 2020) from the Landsat satellites and added to ArcMap (Figure 21).

Paramaribo barely houses any industrial areas. Through the Image Interpretation technique, an analysis can be made about an aerial image. Setting firm conditions on what may look like an industrial area from a satellite image, proposes the opportunity to make an independent objective analysis.
Since greenery, water bodies and residential environment can be recognized by the GIS program, it would stand to reason that an automatic analysis would be more efficient than a manual one. If the satellite image has clouds in the area of interest, these should be factored in the reclassification. This is the easiest method to remove unnecessary data from the image, such as clouds. An important extra step here is to remove the pieces of land previously classified as industrial area, so it doesn’t merge with the residential areas.

As the case study area is Paramaribo, it is essential that the shapefiles are demarcated to this area before the calculations of the surface area.

For both the industrial area, as the other LULC indicators, the surface area is calculated via the geometry calculator in the attribute table.



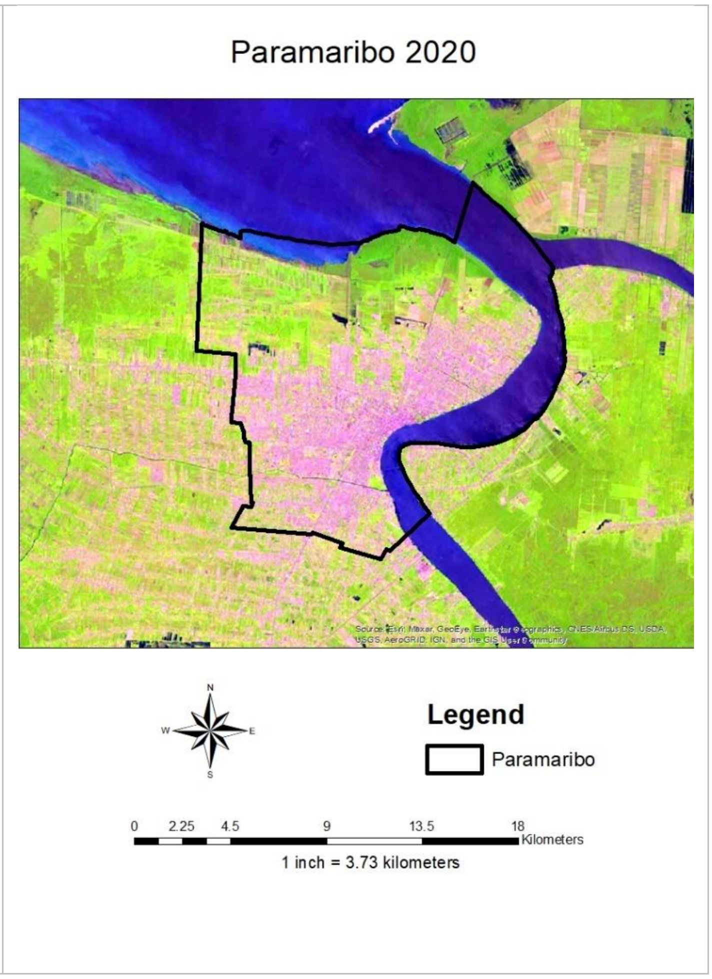


Figure 21 Satellite (base) image Paramaribo 2000 & 2020 downloaded from USGS Landlook (USGS, 2000 - 2020)

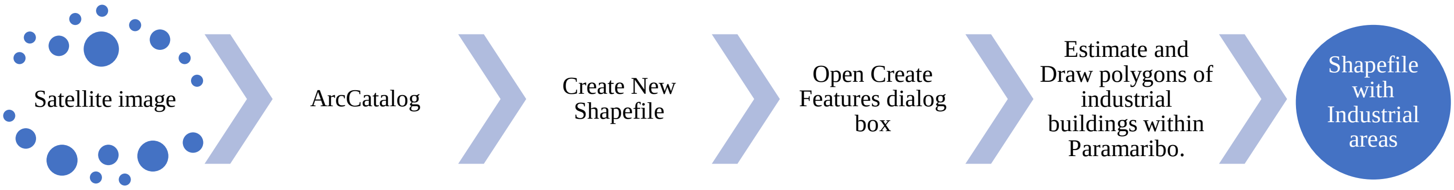
Satellite Image Interpretation

1) Looking at the AOI and RA satellite images, it can be speculated which buildings to categorize as industrial environment, by looking at:

- ❖ Their size and built.
- ❖ Their surrounding environment:
  - o Presence of a port
  - o Large property
  - o Large parking spaces

2) Once the industrial areas are determined, they can be clustered in a shapefile.

The guidelines for this action are:



This action is done for both the AOI as the RA. See Figure 22 below for the ***estimated*** results.

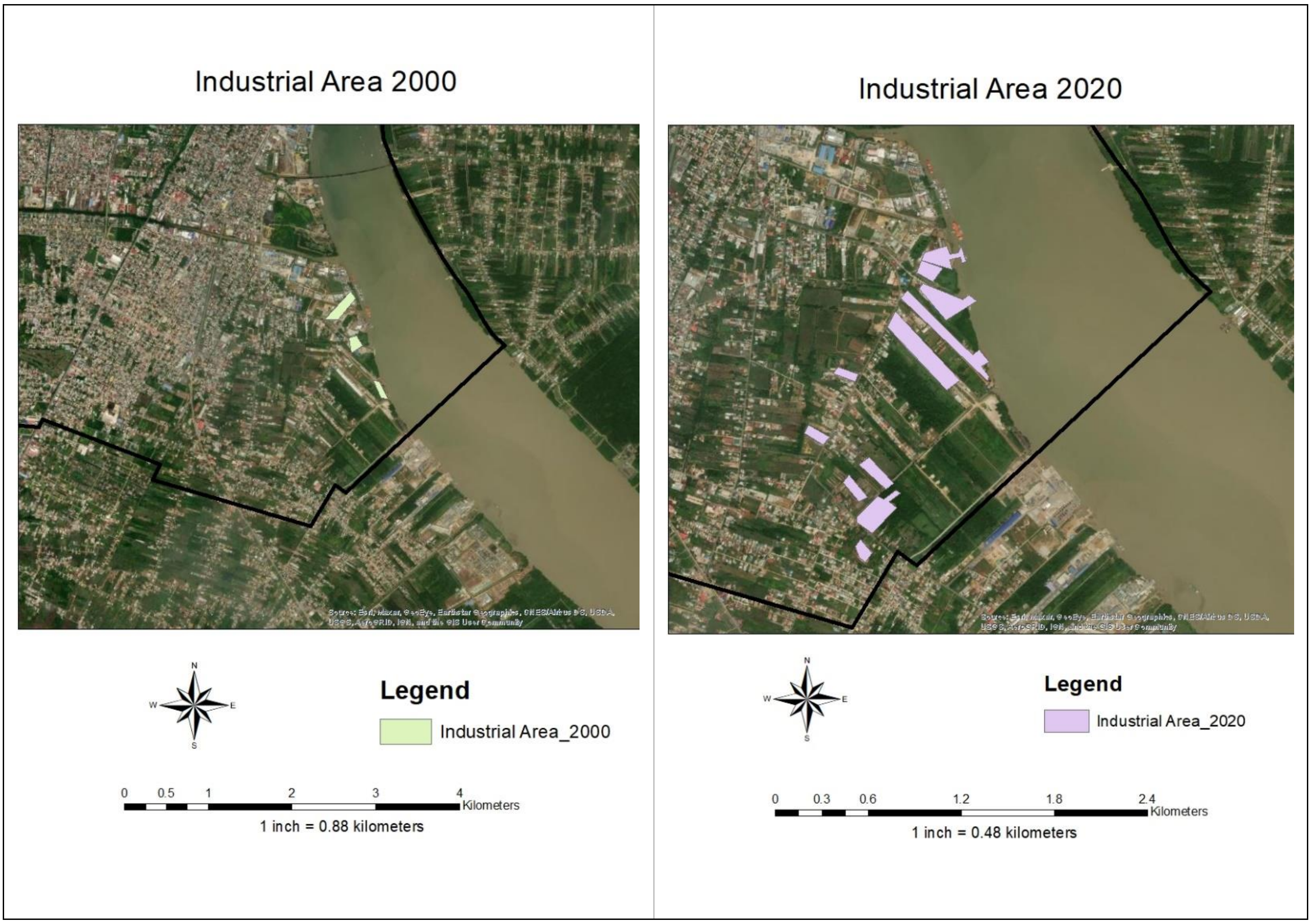
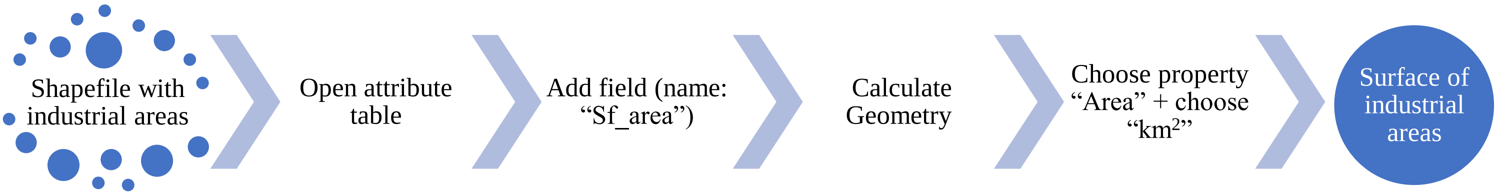


Figure 22 Industrial areas 2000 & 2020 through Satellite image interpretation in ArcMap

3) The next step is calculating the surface industrial area of each polygon through the following steps ArcMap:



This action is done for both the AOI as the RA. See Figure 23 below for the results.[vii]

[vii] Sf_area = surface area

Industrial Area_2000

FID	Shape *	Id	LULC	Sq_Area
0	Polygon	0	Industrial Area	0.019545
1	Polygon	0	Industrial Area	0.046229
2	Polygon	0	Industrial Area	0.015317

Total industrial area Paramaribo 2000 = 0.081 km^2

Industrial Area_2020

Shape *	Id	LULC	Sq_Area
Polygon	0	Industrial Area	0.063649
Polygon	0	Industrial Area	0.048569
Polygon	0	Industrial Area	0.017256
Polygon	0	Industrial Area	0.008978
Polygon	0	Industrial Area	0.010818
Polygon	0	Industrial Area	0.008311
Polygon	0	Industrial Area	0.035167
Polygon	0	Industrial Area	0.007391
Polygon	0	Industrial Area	0.013098
Polygon	0	Industrial Area	0.036199
Polygon	0	Industrial Area	0.0219

Total industrial area Paramaribo 2020 = 0.271 km^2

Figure 23 Surface area of each polygon that represents an industrial building for Paramaribo 2000 & 2020. Results in km2.

Reclassification of Remote Sensing Data

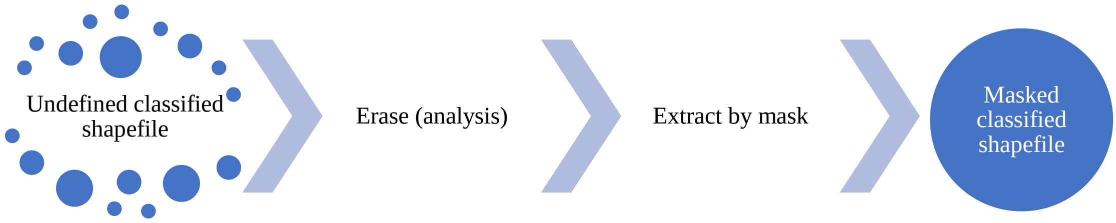
Reclassification of a satellite image can categorize the images in different geographical values, in this case: greenery, water bodies and built areas. ArcGIS offers the **Interactive Supervised Classification**.

The presence of clouds can pose a risk to inconclusive classification results. One method to minimalize the impacts clouds have, is to classify them along with the other spatial indicators. For supervised classification, a signature file is created using training samples through the Image Classification toolbar. The training samples for these LUC consist of drawn polygons for greenery, built areas, water bodies and (where applicable) clouds. The data for the clouds will be excluded from the USI. The Interactive Supervised Classification transforms the satellite image in the classes that were specified in the training samples. The result is an undefined classified shapefile across the entire satellite image. The data needed for this research needs to be demarcated to the case study area: Paramaribo, which will be done in step 2 below.

1) The Interactive Supervised Classification is executed as below.

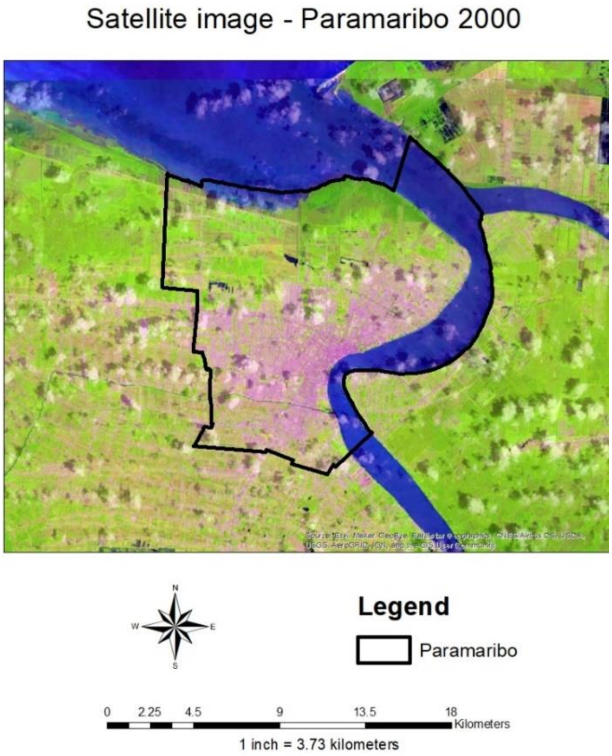
2) It is important that the industrial areas are separate from this classification, so they don’t overlap. Therefore, the end results will be masked with the shapefiles of the industrial areas via the “**erase (analysis)**” tool and then the “**extract by mask**” tool in ArcMap.

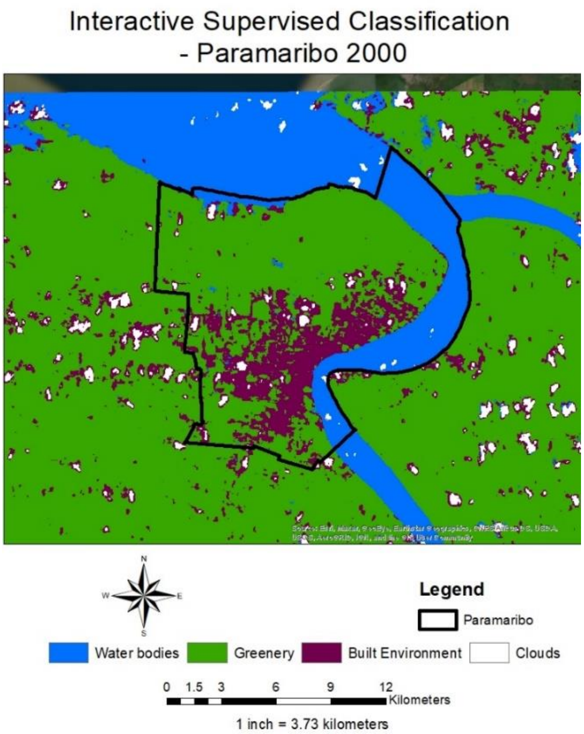
   The classification will also be demarcated to Paramaribo via the “**extract by mask**” tool.



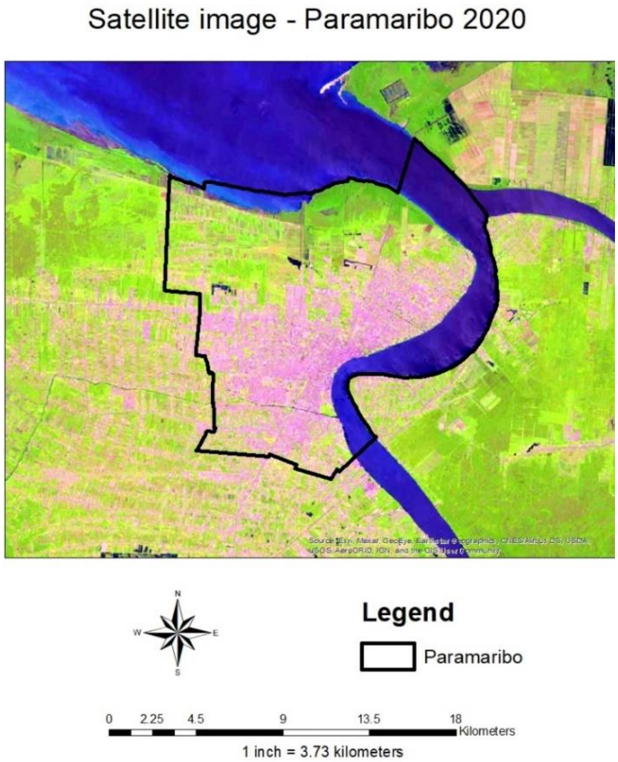
Images below (Figure 24) show the process from raw data (satellite image) to classified “clean” data, as described in step 1 and 2 above.

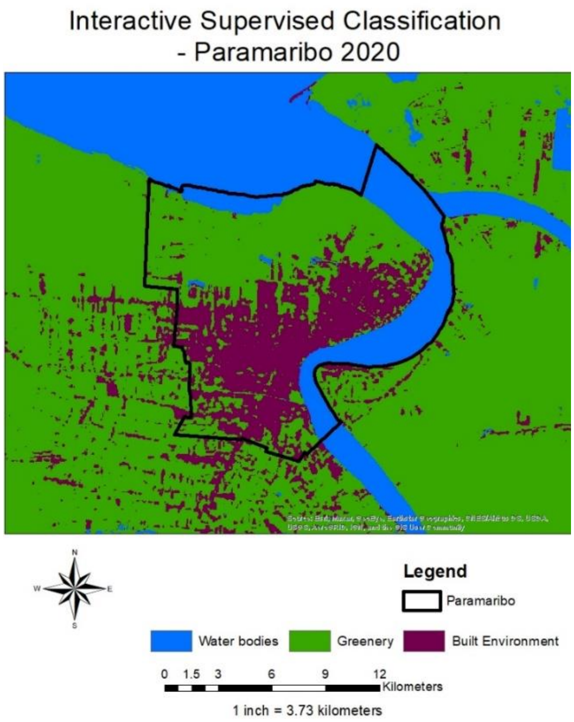
Paramaribo 2000





Paramaribo 2020





Paramaribo 2000	**Paramaribo 2020**

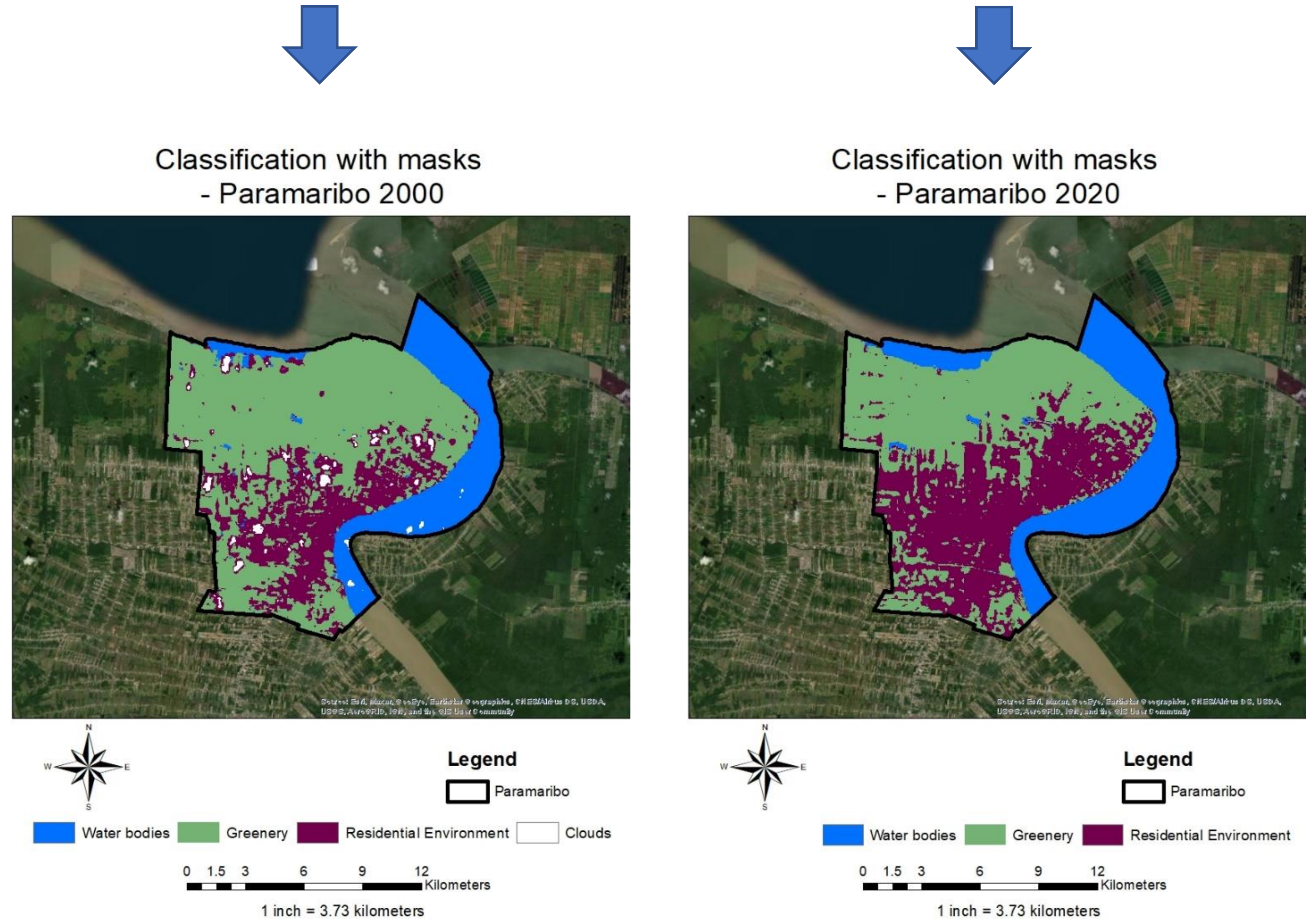
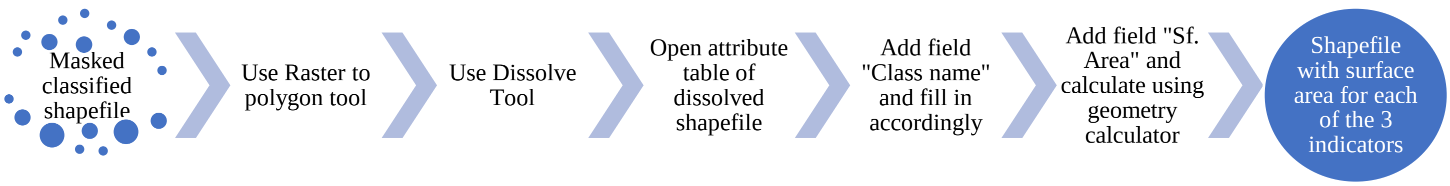


Figure 24 Reclassification and masking process for Paramaribo 2000 & 2020

3) The next step is calculating the surface area of these Land Use and Land Cover indicators through the following steps ArcMap:



Through the above method, the following results were calculated (Figure 25, Figure 26)

Table

c2000_Raster2Polygon_Dissolv1

FID *	Shape *	gridcode	Shape_Length	Shape_Area	Class_name	Sf_Area_LULC_2000
1	Polygon	1	99165.355662	40080615.07813	Water bodies	40.080615
2	Polygon	15	424190.903967	110458971.02252	Greenery	110.458971
3	Polygon	36	435420.81844	42369002.287253	Residential Env.	42.369002
4	Polygon	53	48899.106051	2841671.974069	Clouds	2.841672

Figure 25 Surface area of water bodies, greenery, and residential areas for Paramaribo 2000 (last column)

Table

c2020_Raster2Polygon_Dissolv

FID *	Shape *	gridcode	Shape_Length	Shape_Area	Class_name	Sf_Area_LULC_2020
1	Polygon	1	89990.607602	42716630.233709	Water bodies	42.71663
2	Polygon	18	437173.688331	84330495.626317	Greenery	84.330496
3	Polygon	34	396570.668073	68492400.295218	Residential Env.	68.4924

Figure 26 Surface area of water bodies, greenery, and residential areas for Paramaribo 2020 (last column)

4.5.2 non-Spatial indicators

- Life Expectancy

  AOI:

  There is no data available for the year 2020.

  The closest data to that year is of 2019.

  In 2019 the life expectancy number was 71.7 years.

  (Life expectancy at birth, total (years) - Suriname, 2019)

  RA:

  In 2000 the life expectancy number was 67.8

  (Life expectancy at birth, total (years) - Suriname, 2019)

- Hospital bed density

  AOI:

  There is no data available for the year 2020.

  The closest data to that year is of 2017.

  In 2017 the number of hospital beds was 3 per 1000 people.

(Hospital beds (per 1,000 people) - Suriname, n.d.)

RA:
In 2000 the number of hospital beds was 3.9 per 1000 people.
(Hospital beds (per 1,000 people) - Suriname, n.d.)

- Population Density
  AOI:
  There is no data available for the year 2020.
  The closest data to that year is of 2012.
  In 2012 the population of Paramaribo was 240,924 persons.
  The surface area of Paramaribo is 182 km^2.
  Population density: 240,924 / 182 = 1,323.76 people/km^2
  (Censusstatistieken 2012, 2012)

  RA:
  There is no data available for the year 2000.
  The closest data to that year is of 2004.
  In 2004 the population of Paramaribo was 242,946 persons.
  The surface area of Paramaribo is 182 km^2.
  Population density: 242,946 / 182 = 1,334.87 people/km^2
  (Censusstatistieken 2004, 2004)

- Homicide
  AOI:
  There is no data available for the year 2020.
  The closest data to that year is of 2017.
  In 2017 the homicide rate was 5.4.
  (Intentional homicides (per 100,000 people) - Suriname, n.d.)

  RA:
  In 2000 the homicide rate was 14.4
  (Intentional homicides (per 100,000 people) - Suriname, n.d.)

- Robberies
  AOI:
  In 2020 the robbery rate of Paramaribo was 636 per 100,000 people.
  (Korps Politie Suriname, 2021)

  RA:
  There is no data available for the year 2000.
  The closest data to that year is of 2004.
  In 2004 the robbery rate of Paramaribo was 442.1 robberies per 100,000 people.
  (Suriname Crime Stats, n.d.)

- Fatal Traffic Injuries
  AOI:
  There is no data available for the year 2020.
  The closest data to that year is of 2019.
  In 2019 the number of fatal traffic injuries of Paramaribo was 22.
  (Algemeen Bureau voor de Statistiek (ABS), 2020)

  RA:
  In 2000 the number of fatal traffic injuries of Paramaribo was 23.
  (Anda Suriname, n.d.)

4.6 Validation of USI model with case study area: Paramaribo

Validation of USI model with case study area: Paramaribo
Due to the nature of the gathered data, being both non spatial and spatial, the USI was processed in both GIS and in Excel (as per method B in paragraph 4.4 .)
Via the following ArcMap calculations/tools, satellite images were reclassified in the LULC indicators (Industrial Environment, Green Urban Spaces, Water bodies, Residential Environment):

- Satellite image interpretation
- Reclassification of remote sensing data
- Interactive Supervised Classification
- Training samples
- Extract by mask
- Erase
- Raster to Polygon
- Dissolve
- Geometry Calculator

After determining the surface area of aforementioned indicators through ArcMap in the previous paragrapgh, the USI is continued in Excel. The remaining calculations were conducted in this platform. The final deliverable of the USI is the Relative USI Value (Rel.USI.Value).

Summary of the data gathered in the previous paragraph:

		Reference Area	**Area of Interest**		
	Indicator	**Paramaribo 2000**	**Paramaribo 2020**	**Unit**	**Note**
Land Use, Planni	Industrial Environment	0.081	0.271	km^2	

	Green Urban Spaces	110.46	84.33	km^2	
	Water bodies	40.08	42.72	km^2	
	Residential Environment	42.37	68.5	km^2	
Health	Life Expectancy	67.8	71.7	years	Origin AOI data: 2019
	Hospitals	3.9	3	#beds / 1000 people	Origin AOI data: 2017
	Population Density	1334.87	1323.76	people/km^2	Origin AOI data: 2012; Origin RA data: 2004
Safety	Homicide	14.4	5.4	per 100,000 people	Origin AOI data: 2017
	Robberies	442.1	636	per 100,000 people	Origin RA data: 2004
	Fatal Traffic Injuries	23	22	#	Origin AOI data: 2019

USI calculations (Figure 27 below):

1) Equation 1: The first value calculated, is the value per indicators relative to the refence data, henceforth referred to as "RelValue$_i$" = (Data AOI/Data RA)$_i$ This calculation is done for each of the indicators.

2) Equation 2: The relative urban sustainability value (Rel.USI.Value) is calculated by the following equation:

Σ (RelValue$_i$ x Weight$_i$)

i = indicator

		Reference Area	*Area of Interest*			
		Paramaribo 2000	**Paramaribo 2020**	**EQUATION 1 "RelValue$_i$" = (Data AOI/Data RA)$_i$**	**Weight + neg/pos conotation**	**(RelValue$_i$ x Weight$_i$)**
Land Use, Planning & Zoning	Industrial Environment	0.081	0.271	3.345679012	-0.039	**-0.130**
	Green Urban Spaces	110.46	84.33	0.763443781	0.116	**0.089**
	Water bodies	40.08	42.72	1.065868263	0.116	**0.124**
	Residential Environment	42.37	68.5	1.616709936	0.039	**0.063**
Health	Life Expectancy	67.8	71.7	1.057522124	0.145	**0.153**
	Hospitals	3.9	3	0.769230769	0.145	**0.112**
	Population Density	1334.87	1323.76	0.991677092	0.021	**0.021**
Safety	Homicide	14.4	5.4	0.375	-0.092	**-0.035**
	Robberies	442.1	636	1.438588555	-0.144	**-0.207**
	Fatal Traffic Injuries	23	22	0.956521739	-0.144	**-0.138**
			EQUATION 2	**Rel.USI.Value = Σ (RelValuei x Weighti)**		**0.051078909**

Figure 27 Results of Equation 1 and 2 of USI

Paramaribo 2020, compared to Paramaribo 2000, delivers a Relative USI Value of 0.051.
This number can be interpreted as follows:
The value is positive, meaning Paramaribo 2020 is more urban sustainable than Paramaribo 2000, according to the parameters of this USI.
Looking at Equation 1, Paramaribo 2020 differs the most from Paramaribo 2000 on the following indicators:

- Most prominent positive influences: life expectancy increased with factor 1.05.
- Most prominent negative influences: robberies rate increased with factor 1.44.

Targeting sustainability, the indicators with a negative weight should, in theory, drop while those with a positive weight should rise.

The Relative USI Value can currently only be interpreted in terms of absolutes:

- The AOI is more urban sustainable than the RA
- The AOI is less urban sustainable than the RA

No statement can be made on how much more/less sustainable the AOI is.
In order to make such an analysis, another research must be done with this same USI, valued against an RA of ideal data.

Limitations

The limitations encountered throughout this research:

- There was hardly any spatial data available for Paramaribo. Satellite images were the only source of spatial data. GIS is a platform based on geographic data and will not work to its full potential when spatial data is not available.
- To reiterate, it was decided that the validation would be done for Paramaribo 2020 in comparison to Paramaribo 2000. However, this data was also unavailable for many indicators, even in numerical format. This resulted in the available data for the AOI and the RA indicators being of neighboring years, instead of respectively 2020 and 2000.

5. Conclusion

Sustainability is meeting present and future generations' resource and service needs without jeopardizing the health of the ecosystems that sustain them (Morelli, 2011). Sustainability is achieved when its 3 pillars: people, planet, and profit are in balance with each other. However, there are limited resources available to accommodate everyone sustainably. This is especially concerning for densely populated urban cities, such as the case study area of this research thesis: Paramaribo.

Paramaribo is home to most habitants of Suriname. It houses 10 resorts, each with their own unique characteristics. Traffic congestion are often common in Paramaribo during rush hour.

The city is generally quiet after regular business hours. Flooding is a regular occurrence during the rainy seasons and can hinder vehicles to navigate through the flooded road. Suriname has a tradition of building homes/houses from the ground up on their own land, which can contribute to urban sprawl.

The objective of this research thesis to develop a (GIS) framework of inclusive and sustainable urban development factors to be used as a legislative tool for policymakers.
By first dividing the thesis objective in research sub questions and then analyzing these questions, the development of the conceptual USI was accomplished. Due to spatial data limitations, a USI framework integrated exclusively in GIS was impossible. Therefore, the USI was adjusted to range across two platforms, GIS and Excel. The following results were acquired when answering the thesis research question:

What are the building blocks and the thereby corresponding GIS technical applications for a conceptual Urban Sustainability Index for Suriname to transfer the existing urban environment to an inclusive and sustainable urban environment through sustainable spatial planning policy?

1. Urban Sustainability Indicator Selection
   The first building block is establishing which indicators are 1) specific to Suriname and 2) relevant to the USI framework.
   Each area is unique in their social customs, business ethics, government, etc. Using data from a previous study, done by an external organization ((The Inter-American Development Bank, 2019)), it's determined that the Surinamese society holds the following indicator categories in high esteem: Land Use Planning and Zoning, Health and Security.
   Through thorough research, the following indicators were chosen for each of these indicator categories:
   - Land Use Planning & Zoning
     - Industrial Environment
     - Green Urban Spaces
     - Water bodies

    - Residential Environment
  - Health
    - Life Expectancy
    - Hospitals
    - Population Density
  - Security
    - Homicide
    - Robberies
    - Fatal Traffic Injuries

2. Indicator analysis & correlation
   The second building block is analyzing how the indicators compare between themselves in terms of importance and how much impact each of these indicators have on sustainability, through a cross analysis with the 3 pillars of sustainability: people, planet, and profit.
   Through a survey, followed by a mathematical analysis, the indicators above were determined to have the following weight in the USI (in decimals):
    - Industrial Environment = - 0.039
    - Green Urban Spaces = + 0.116
    - Water bodies = + 0.116
    - Residential Environment = + 0.039
    - Life Expectancy = + 0.145
    - Hospitals = + 0.145
    - Population Density = + 0.021
    - Homicide = - 0.092
    - Robberies = - 0.144
    - Fatal Traffic Injuries = - 0.144

3. Develop a conceptual urban sustainability index
   The third building block is cross analyzing the indicators and integrating them in a conceptual USI.
   Each indicator must have 2 sets of Data, that will be measured against each other: Data AOI (Area of Interest) and the Data RA (Reference Area).
   The 1st equation: "$RelValue_i$" = $(Data\ AOI/Data\ RA)_i$
   ↳ measuring the increase/decrease in the indicator's values in comparison to the RA.
   The 2nd equation: $\Sigma\ (RelValue_i \times Weight_i)$
   i = indicator
   ↳ measuring the relative urban sustainability value

4. Implementation guidelines for the USI in GIS
   The fourth building block is deciding on which platform the USI will be executed and then developing a matrix based on the USI.

The intent was to develop a USI fully integrated in GIS. While conducting research, it became evident that Suriname does not possess the data type necessary for integrating in this platform, because GIS, or Geographical Information Systems, work exclusively with spatial data. The indicators chosen for the USI either did not have the data available in a spatial format, or the data did not exist (yet).

Due to this unforeseen discovery, the integration method had to be adjusted. Straying away from a complete integration in GIS, it was decided to develop a hybrid integration system: GIS and Excel.
GIS (ArcMap) for calculating the indicator values of the category "Land Use Planning & Zoning". Subsequently Excel is used to determine the values of above equations.

5. Gather empirical geodata of Paramaribo for the conceptual USI
   The fifth building block is gathering data to submit in the USI.
   For this research thesis, it was decided to conduct the USI for Paramaribo 2020 in comparison to Paramaribo 2000.
   The spatial data was prepped in ArcMap via the Reclassification tool and the Image Interpretation. Via extensive analysis of satellite images in ArcMap, including using features such as reclassification, masking, and erase analysis, the surface areas were calculated for the indicators: Industrial Environment, Green Urban Spaces, Water bodies and Residential Environment.
   The remaining indicators were numerical in value.
   Afterward the values of Equation 1 and Equation 2 will be calculated in Excel.

6. Validation of USI model with case study area: Paramaribo
   The sixth and final building block is testing the model.
   Paramaribo 2020, compared to Paramaribo 2000, delivers a Relative USI Value of 0.051. The value is positive, meaning Paramaribo 2020 is more urban sustainable than Paramaribo 2000, according to the parameters of this USI.
   Ideally, the indicators with a negative weight should decrease and those with a positive weight increase.

For cities to achieve true sustainable development, urban governance must monitor urban development trends, address unsustainable urban development issues, and create a system to assess urban sustainability (Huang, C.T, & Che, 2005). The USI created in this research thesis can potentially serve as a foundation for developing a broader USI to be used at national level.

Recommendations

The recommendations for this research thesis:

- When using satellite images, it is highly recommended to use those with limited cloud exposure. The clouds can cover valuable data, and if in large quantities can be responsible for inconclusive results.

- Use a computer or laptop with the recommend specifications to run ArcGIS ArcMap, because this application needs sufficient RAM when using for longer periods.
- As stated before, this research used a survey aimed at experts and professionals in the field, to determine the correlation between the indicators and the 3 pillars of sustainability. For more accurate result, extensive research is required.
- To get a better indication about the obtained USI value, a baseline study must be conducted with indicator values that are ideal for Suriname. This type of baseline study can offer more insight in the general trend Suriname should be heading in to achieve true sustainability.
- In order to finetune this USI model and subsequently improve the urban planning, it is important that the USI is put to use. This will ensure potential flaws and limitations are discovered early on, which will only lead to the betterment of this USI.

6. Timetable

As per the student handbook of the Environmental Sciences Department, this research must be conducted in max. 17.5 workweeks. The study load must be 700 sbu.

Richting	Sbu	Sp	Werkdagen	Werkweken
Milieuwetenschappen	700	25	88	17.5

Table 1 FTeW. (n.d.). Studiebelasting voor de individuele richtingen van de FTeW. In Afstudeerreglement voor de 3-jarige Bacheloropleiding. Source: (FTeW)

Research timetable

Literature study	2 weeks
Information gathering	2 weeks
Method & Analysis	3 weeks
Developing USI	3 weeks
Subtotal 1	10 weeks
Completing the 1st draft	2 weeks
Consultations with supervisors + revision draft	2 weeks
Subtotal 2	4 weeks
Completing the 2nd draft + 2nd revision with supervisors	2 weeks
Finalizing thesis	1.5 weeks
Subtotal 3	3.5 weeks
TOTAL	17.5 weeks

References

Tier 1—Life expectancy and wellbeing—1.19 Life expectancy at birth. (2012). Retrieved May 07, 2021, from Department of Health : https://www1.health.gov.au/internet/publications/publishing.nsf/Content/oatsih-hpf-2012-toc~tier1~life-exp-wellb~119

Adel, H. S. (2016). Crime in relation to urban design. Case study: The Greater Cairo Region. *Ain Shams Engineering Journal*. Retrieved May 8, 2021

Algemeen Bureau voor de Statistiek (ABS). (2020). *9de Milieustatistieken Publicatie/ 9th Environment Statistics Publication.* Retrieved July 4, 2021

Anda Suriname. (n.d.). Retrieved july 4, 2021, from Statistieken van 1995 - 2000: https://www.suriname.nu/101alg/statis10.html

Bindu, C. A. (2016). Water bodies as a catalyst to growth and development-The case of Kodungallur town, Kerala. *Procedia Technology, 24*, 1790 - 1800. doi:https://doi.org/10.1016/j.protcy.2016.05.222

Braubach, M. E. (2017). Effects of urban green space on environmental health, equity and resilience. *Nature-based solutions to climate change adaptation in urban areas*. doi:https://doi.org/10.1007/978-3-319-56091-5_11

Censusstatistieken 2004. (2004). Retrieved July 4, 2021, from Algemeen Bureau voor de Statistiek: https://www.statistics-suriname.org/wp-content/uploads/2019/03/district-profiel-census.xls

Censusstatistieken 2012. (2012). Retrieved July 4, 2021, from Algemeen Bureau voor de Statistiek: https://www.statistics-suriname.org/wp-content/uploads/2019/03/census8etn.pdf

CNN. (2008, December 7). Urban densification: Creating space to live. Retrieved July 20, 2021, from http://edition.cnn.com/2008/WORLD/asiapcf/12/03/eco.denseliving/

CR, S., Anantram, K., & Venkataramani, V. (2012). *USI: URBAN SUSTAINABILITY INDEX*. Retrieved March 13, 2021, from LEAD: https://ifmrlead.org/usi-urban-sustainability-index/#:~:text=The%20Urban%20Sustainability%20Index%20(USI,Roads%20and%20Water%20Quality%20%26%20Supply.

Dissolve. (2016, August 11). Retrieved July 24, 2021, from https://desktop.arcgis.com/en/arcmap/10.3/tools/data-management-toolbox/dissolve.htm

Division, U. N. (2019). *Make cities and human settlements inclusive, safe, resilient and sustainable*. Retrieved November 24, 2020, from United Nations: //unstats.un.org/sdgs/report/2019/goal-11/

Ecological Footprint. (2016, October 19). Retrieved March 15, 2021, from Global Footprint Network: https://www.footprintnetwork.org/our-work/ecological-footprint/

Eom, S. Y. (2018). ealth effects of environmental pollution in population living near industrial complex areas in Korea. *Environmental health and toxicology, 33*(1). doi:10.5620/eht.e2018004

Erase (Analysis). (2021, April 18). Retrieved July 24, 2021, from ESRI: https://pro.arcgis.com/en/pro-app/latest/tool-reference/analysis/erase.htm

Extract by Mask (Spatial Analyst). (2021, May 3). Retrieved July 24, 2021, from ESRI: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/extract-by-mask.htm

F, K., & K., K. (2018). How to Contextualize SDG 11? Looking at Indicators for Sustainable Urban Development in Germany. *ISPRS International Journal of Geo-Information*. doi:https://doi.org/10.3390/ijgi7120464

FTeW. (n.d.). Studiebelasting voor de individuele richtingen van de FTeW. In *Afstudeerreglement voor de 3-jarige Bacheloropleiding.*

Galanis, T. (2017, January 2). Environmental Problems of Modern Cities. Retrieved April 8, 2021, from https://www.linkedin.com/pulse/environmental-problems-modern-cities-theodoros-galanis

GISSAT via ESRI ArcGIS. (n.d.). Retrieved July 20, 2021

Glossary of Statistical Terms. (2001, September 25). Retrieved July 23, 2021, from OECD: https://stats.oecd.org/glossary/detail.asp?ID=830

Greenhouse Gas Emissions. (2021, April 14). Retrieved May 15, 2021, from United States Environmental Protection Agency: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Gupta, B. L. (2016). Impact of Urban Built Environment on Health of Women: A Pilot Study. *Khoj: An International Peer Reviewed Journal of Geography, 3*(1), 48-59. doi:10.5958/2455-6963.2016.00006.0

Health is a fundamental human right. (2017, December). Retrieved July 24, 2021, from WHO: https://www.who.int/news-room/commentaries/detail/health-is-a-fundamental-human-right

Healthcare Disparities & Barriers to Healthcare. (2018, August 24). Retrieved July 24, 2021, from Stanford Medicine: https://webcache.googleusercontent.com/search?q=cache:3bHtK0C8T6EJ:https://med.stanford.edu/ruralhealth/health-pros/factsheets/disparities-barriers.html+&cd=2&hl=en&ct=clnk&gl=sr&client=firefox-b-d

Hospital beds (per 1,000 people) - Suriname. (n.d.). Retrieved July 4, 2021, from The World Bank: https://data.worldbank.org/indicator/SH.MED.BEDS.ZS?end=2017&locations=SR&start=1960

Huang, S., C.T, & Che, L. (2005). A Review of Urban Sustainability Indicators: Systems Framework and Policy Evaluation. *City Plan*, 227-251. Retrieved March 13, 2021

I., B. (2013). Road traffic injuries: social change and development. *Medical history,*(57). doi:10.1017/mdh.2012.83

Ibraheem, A., & Daham, A. (2011). Development and Use of Large-Scale Land Information System (LIS) by Using Geographic Information System (GIS) and Field Surveying. *Iraqi Journal of Civil Engineering*(8), 29-43. doi:10.4236/eng.2012.42014

Intentional homicides (per 100,000 people) - Suriname. (n.d.). Retrieved July 4, 2021, from The World Bank: https://data.worldbank.org/indicator/VC.IHR.PSRC.P5?end=2017&locations=SR&start=2000&view=chart

Interactive Supervised Classification. (n.d.). Retrieved July 24, 2021, from https://sites.google.com/site/gis520ince/image-classification/interactive-supervised-classification

Ivan Turok, G. M. (2013, June 28). Urbanization and economic growth: the arguments and evidence for Africa and Asia. *Sage Journal*. doi:https://doi.org/10.1177%2F0956247813490908

Kaushal, S. S. (2015, July 27). Urban Evolution: The Role of Water . *Urban evolution: The role of water. Water, 7*(8), 4064. doi:https://doi.org/10.3390/w7084063

Korps Politie Suriname. (2021). *Statistieken.* Retrieved July 5, 2021

Life expectancy at birth, total (years) - Suriname. (2019). Retrieved July 4, 2021, from The World Bank: https://data.worldbank.org/indicator/SP.DYN.LE00.IN?end=2003&locations=SR&start=1960&view=chart

Lithmee. (2019, March 1). *What is the Difference Between Raster and Vector Data*. Retrieved April 9, 2021, from PEDIAA: https://pediaa.com/what-is-the-difference-between-raster-and-vector-data/

McKee, M. &. (2004). *Reducing hospital beds: what are the lessons to be learned?* Retrieved May 07, 2021, from https://www.euro.who.int/__data/assets/pdf_file/0011/108848/E85032.pdf

MI-GLISS. (n.d.).

Mohamadzadeh, P., Pourmoradian, S., Feizizadeh, B., Sharif, A., & Vogdrup-Schmidt, M. (2020). A GIS-Based Approach for Spatially-Explicit Sustainable Development Assessments in East Azerbaijan Province, Iran. *Sustainability, 12(24)*. doi:10.3390/su122410413

Morelli, J. (2011). Environmental Sustainability: A Definition for Environmental Professionals. *Journal of Environmental Sustainability, Volume 1*(1, Article 2). doi:10.14448/jes.01.0002

Office of the Director of National Intelligence USA. (2013). Natural Resources in 2020, 2030, and 2040: Implications for the United States. *NATIONAL INTELLIGENCE COUNCIL REPORT*. Retrieved March 14, 2021, from https://www.dni.gov/files/documents/NICR%202013-05%20US%20Nat%20Resources%202020,%202030%202040.pdf

Organization of American States. Department of Regional Development and Environment, United States. Agency for International Development. Office of U.S. Foreign Disaster Assistance. (1991). *Primer on Natural Hazard Management in Integrated Regional Development Planning.* Department of Regional Development and Environment, Executive Secretariat for Economic and Social Affairs, Organization of American States. Retrieved April 7, 2021, from https://pdf.usaid.gov/pdf_docs/Pnabj801.pdf

Pettinger, T. (2019). *Factors that affect population size and growth*. Retrieved from Economics Help: https://www.economicshelp.org/blog/469/development/factors-effect-population-size-and-growth/

Purvis, B. M. (2019). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science, 14*, 681–695. doi:10.1007/s11625-018-0627-5

Radzi, A. (2018). The 100% renewable energy metropolis: governing the design of cities for renewable energy infrastructures. *Urban energy transition (pp. 85-113)*, 85-113. doi:https://doi.org/10.1016/B978-0-08-102074-6.00023-1

Reclass by ranges of values. (2021, April 18). Retrieved July 24, 2021, from ESRI: https://pro.arcgis.com/en/pro-app/latest/tool-reference/3d-analyst/reclass-by-ranges-of-values.htm

Residential Pollution. (n.d.). Retrieved July 24, 2021, from Environmental Pollution Centers: https://www.environmentalpollutioncenters.org/residential/

Ritchie, H. (2018, September 18). *How urban is the world?* Retrieved April 8, 2021, from Our World in Data: https://ourworldindata.org/how-urban-is-the-world

Santana, P. S. (2010). Crime: impacts of urban design and environment. *TRIA-Rivista internazionale di cultura urbanistica*(5). doi:10.6092/2281-4574/1788

Suriname Crime Stats. (n.d.). Retrieved July 4, 2021, from NationMaster: https://www.nationmaster.com/country-info/profiles/Suriname/Crime

Tanguay, G. A., Rajaonson, J., Lefebvre, J.-F., & Lanoie, P. (2009). Measuring the Sustainability of Cities: A Survey-Based Analysis of the Use of Local Indicators. *SSRN Electronic Journal*. doi:10.2139/ssrn.1336649

Tasdemir, C. &. (2020). Sustainability benchmarking tool (SBT): theoretical and conceptual model proposition of a composite framework. *Environment, Development and Sustainability., 22*. doi:10.1007/s10668-019-00512-3.

The Global Health Observatory. (2021, May 07). Retrieved from World Health Organization: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3119

The Inter-American Development Bank. (2019). *Emerging And Sustainable Cities Program - Action Plan For Paramaribo.* Retrieved March 12, 2021

Topic 5: Air Photo Interpretation. (n.d.). Retrieved July 24, 2021, from http://hosting.soonet.ca/eliris/remotesensing/bl130lec5.html

United Nations. (2016). *THE 17 GOALS*. Retrieved November 24, 2020, from The Division for Sustainable Development Goals (DSDG) in the United Nations Department of Economic and Social Affairs (UNDESA): https://sdgs.un.org/goals

USGS. (2000 - 2020). USGS LandLook. Retrieved June 6, 2021, from https://landlook.usgs.gov/landlook/viewer.html

World Health Organization. (2015). *Violence Info - Homicide*. Retrieved May 8, 2021, from World Health Organization: https://apps.who.int/violence-info/homicide/#:~:text=Poverty%2C%20economic%20inequality%2C%20ethnic%20fractionalization,also%20risk%20factors%20for%20homicide.

Appendix 1 – IDB Indicator Explanation

Appendix 1 THE INTER-AMERICAN DEVELOPMENT BANK. (2019). EMERGING AND SUSTAINABLE CITIES PROGRAM – "ANNEX 2"

II. Urban Sustainability

# Topics	# Subtopic	# Indicator	Unit of Measurement	Description	Benchmarks		
I Land Use, Planning, and Zoning	I.1 Density	41 Annual growth rate of the urban footprint	% annual	Average annual growth rate of the areal urban footprint within the city's official limits (minimum last five years or last time period available)	<3%	3–5%	>5%
		42 (Net) urban population density	residents/km²	People who live in the urbanized area of the municipality, per km² of urbanized area of the municipality	7,000–20,000	4,000–7,000, 20,000–25,000	<4,000 >25,000
	I.2 Housing	43 Substandard housing	%	Percentage of homes that do not meet the habitability standards defined by the country	<10%	10–25%	>25%
		44 Quantitative housing shortage	%	(Number of households – number of homes (housing units))/Number of households	<10%	10–20%	>20%
	I.3 Green and recreational areas	45 Green area per 100,000 residents	hectares/ 100,000 residents	Hectares of permanent green space per 100,000 city residents	>50	20–50	<20
		46 Public recreational area per 100,000 residents	hectares/ 100,000 residents	Hectares of publicly accessible, open air recreational space per 100,000 city residents	>10	7–10	<7
	I.4 Land use planning	47 Existence and active implementation of a land use plan	Yes/No and implementation	The city has a land use plan that includes zoning with environmental protection and preservation zones, and it is actively implemented.	Sole master plan with ecological components; city actively implements it.	Master plan exists but without ecological components, there are no steps toward implementation.	There is no master plan or the plan is over 10 years old.
		48 Up-to-date, legally binding master plan	Yes to both criteria/ yes to only one criterion/ no to both criteria	Existence and active implementation of a legally binding, comprehensive master plan dated or updated within the last 10 years	The city has a master plan that is legally binding and has been updated within the last 10 years, and actively implements it.	Either: (a) the city has a master plan and it is legally binding but has not been updated in the last 10 years or (b) the city has a master plan that has been updated within the last 10 years but it is not legally binding.	The city does not have a master plan, or it has a master plan but it is neither legally binding nor has it been updated within the last 10 years.
J Urban Inequality	J.1 Poverty	49 Percentage of the population below the poverty line	%	The number of persons in the city living below the national urban poverty threshold (the numerator), divided by the total current population of the city (the denominator), expressed as a percentage	<15%	15–25%	>25%
	J.2 Socio-spatial segregation	50 Percentage of housing located in informal settlements	%	Percentage of dwellings located in informal settlements	<20%	20–30%	>30%
	J.3 Income inequality	51 Income Gini coefficient		Measure of inequality in which 0 corresponds to perfect equality in income and 1 corresponds to perfect inequality in income	<0.40	0.40–0.49	>0.49

(continued on next page)

II. Urban Sustainability *(continued)*

# Topics	# Subtopic	# Indicator	Unit of Measurement	Description	Benchmarks		
K Mobility/ Transportation	K.1 Balanced transportation infrastructure	52 Kilometers of road per 100,000 population	km	The total lane kilometers of public roads within the city (the numerator), divided by 100,000th of the city population, expressed as kilometers per 100,000 population	<300	300–400	>400
		53 Kilometers of roads dedicated exclusively to public transit per 100,000 population	km	The total centerline kilometers dedicated exclusively to bus way and centerline kilometers of passenger rail (the numerator), divided by 100,000th of city population, expressed as kilometers of transportation system per 100,000 population	>40	10–40	<10
		54 Kilometers of bicycle path per 100,000 population	km	The centerline kilometers of way dedicated to bicycles within the city (the numerator), divided by 100,000th of city population, expressed as kilometers per 100,000 population	>25	15–25	<15
		55 Kilometers of sidewalk and pedestrian path per 100,000 population	km	The total walkway kilometers of dedicated pedestrian paths within the city (the numerator), divided by 100,000th of city population, expressed as kilometers per 100,000 population	More than four times the length of road network	Between two and four times the length of road network	Less than two times the length of road network
		56 Modal split (specifically public transport))	%	The number of commuters working in the subject city who typically use public transport (including taxis) as their primary way to travel to work (the numerator), divided by all trips to work (the denominator)	>65%	50–65%	<50%
	K.2 Clean transportation	57 Average age of public transport fleet	years	Average age of the public transport fleet (in years)	<6	6–12	>12
	K.3 Safe transportation	58 Transportation fatalities per 1,000 population	deaths per 1,000 population	The annual number of fatalities related to transportation of any kind (the numerator), divided by 1,000th of city population (the denominator), expressed as number of transportation deaths per 1,000 population	<0.1	0.1–0.2	>0.2
	K.4 Reduced congestion	59 Average travel speed on primary thoroughfares during peak hours	km/h	The average travel speed for all private motorized vehicles and public transit vehicles that use roads (e.g., excluding trams or trolleys), across all locally defined "thoroughfares," during the peak commuter hours (typically, morning and evening)	>30	15–30	<15
		60 Number of automobiles per capita	vehicles per capita	Number of personal automobiles per capita	<0.3	0.3–0.4	>0.4

(continued on next page)

II. Urban Sustainability *(continued)*

#	Topics	#	Subtopic	#	Indicator	Unit of Measurement	Description	Benchmarks		
K	Mobility/ Transportation *(continued)*	K.5	Planned and managed transportation	61	Transportation planning and management system	Yes/No	This indicator is aimed at establishing whether or not a city has a sound transportation planning and management system. The indicator is measured by the answers to three questions: 1. Is there a recent (maximum two years old) origin/destination survey covering the urban or metropolitan area? 2. Is there a published transport master plan based on the results of the survey and other supporting studies? 3. Has the city implemented a transport management system, including various indicators for measuring and monitoring the transportation system?	The city has the three elements.	The city has a recent origin/destination survey and has or is in the process of designing and publishing a transportation master plan based on this and other supporting documents.	The city does not have an origin/destination survey that is not older than two years at the time of measuring the indicator.
		K.6	Affordable transportation	62	Affordability index	%	(Number of trips x average cost per trip)/(Per capita income of the bottom quintile of the population)	up to 5%	5–10%	>10%
		K.7	Balanced demand	63	Jobs-to-housing ratio	ratio	The jobs-to-housing ratio refers to the approximate distribution of employment opportunities and workforce population across a geographic area. It is usually measured in terms of the proportion of jobs per household.	1.3:1 to 1.5:1	1.5:1 to 1.7:1	<1.3:1 and >1.7:1
L	Competitiveness of the Economy	L.1	Regulation of business and investment	64	Days to obtain a business license	# of days	Time required to obtain an initial business license (not total time required to open a business)	<12	12–20	>20
		L.2	Strategic infrastructure	65	Existence of a logistics platform	Yes/No	The city provides specialized facilities exclusively to logistics operators in diverse activities.	There is a logistics platform designed and implemented for maritime, air, and land transport.	A logistics platform has been designed for at least one type of transport (maritime, air, or land).	No logistics platform has been designed.
		L.3	Gross product	66	GDP per capita of the city	US$ per capita	Per capita measurement of economic performance. GDP of the city divided by population of the city. The GDP of the city is the total product of the city as defined in national accounts procedures. It may be taken as the total income or value-added income (wages plus business surplus plus taxes plus imports) or the total final demand (consumption plus investment plus exports). The city product expressed in current US dollars (the numerator), divided by the city population (the denominator), expressed in US dollars.	>9,000	9,000–3,000	<3,000

(continued on next page)

II. Urban Sustainability *(continued)*

#	Topics	#	Subtopic	#	Indicator	Unit of Measurement	Description	Benchmarks		
M	Employment	M.1	Unemployment	67	Average annual unemployment rate	%	The total number of unemployed persons, divided by the total labor force. The unemployment rate is the percentage of the labor force that actively seeks work but is unable to find work at a given time.	<7%	7–12%	>12%
		M.2	Informal employment	68	Informal employment as a percentage of total employment	%	The percentage of the economically active population engaged in informal employment as defined by the International Labour Organization	<20%	20–35%	>35%
N	Connectivity	N.1	Internet	69	Fixed broadband Internet subscriptions per 100 inhabitants	# of subscriptions per 100 residents	Number of fixed access Internet subscriptions (for every 100 residents) with speeds of 256 kbit/s or greater. These include DSL, fiber optic, and cable modem fixed connections, and exclude mobile phone connections.	>15%	7–15%	<7%
				70	Mobile broadband Internet subscriptions per 100 inhabitants	# of subscribed mobile phones per 100 residents	Number of mobile devices (such as cell phones, tablets, and smartphones) with a data subscription plan to access the Internet with speeds of 256 kbit/s or greater, per 100 people. This excludes mobile subscriptions via data cards or USB modems.	>20%	10–20%	<10%
		N.2	Telephones	71	Mobile cellular phone subscriptions per 100 inhabitants	# of subscriptions per 100 residents	Number of mobile cellular phone subscriptions for every 100 residents. (This includes pre-paid and post-pay subscriptions.)	>90%	60–90%	<60%
O	Education	O.1	Quality of education	72	Adult literacy rate	%	Percentage of the adults 15 years and older (unless defined otherwise by the country) in the city who can, with understanding, read and write a short, simple statement about their everyday life	>95%	90–95%	<90%
				73	Percentage of students passing standardized reading tests	%	Percentage of students in grade x in primary school with a passing/satisfactory grade on national (or state) standardized reading achievement tests, disaggregated by gender	Similar to exemplary cities in the country	Similar to peer cities in the country	Lower in comparison to peer cities
				74	Percentage of students passing standardized math tests	%	Percentage of students in grade x in primary school with a passing/satisfactory grade on national (or state) standardized math achievement tests, disaggregated by gender	Similar to exemplary cities in the country	Similar to peer cities in the country	Lower in comparison to peer cities

(continued on next page)

II. Urban Sustainability *(continued)*

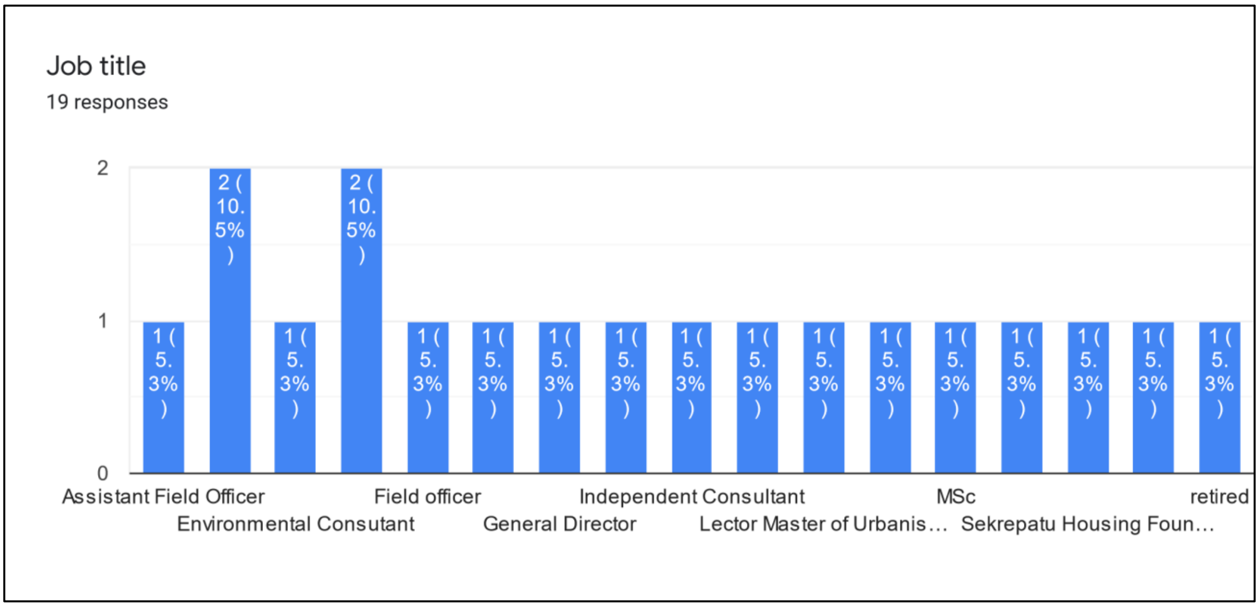
# Topics	# Subtopic	# Indicator	Unit of Measurement	Description	Benchmarks		
O Education *(continued)*		75 Student-teacher ratio	students/ teachers	The number of enrolled primary school students (the numerator), divided by the number of full-time equivalent primary school classroom teachers (the denominator), expressed as a ratio. Primary school refers to elementary school, generally for children aged six to 12 years, or first grade through to fifth grade, though in some school systems it may extend to sixth grade.	<15:1	Between 15:1 and 25:1	>25:1
	O.2 Attendance	76 Percentage of three- to five-year-olds receiving comprehensive early childhood development services	%	Percentage of the population from three to five years old receiving comprehensive early childhood development services	>80%	60–80%	<60%
		77 Percentage of six- to 11-year-olds enrolled in school	%	Percentage of the population from six to 11 years old that is enrolled in school	98–100%	95–98%	<95%
		78 Percentage of 12- to 15-year-olds enrolled in school	%	Percentage of the population from 12 to 15 years old that is enrolled in school	97–100%	90–97%	<90%
		79 Percentage of 16- to 18-year-olds enrolled in school	%	Percentage of the population from 16 to 18 years old that is enrolled in school	80–100%	60–80%	<60%
	O.3 Higher education	80 University seats per 100,000 people	# per 100,000 residents	Number of university seats for every 100,000 residents	>5,000	2,500–5,000	<2,500
P Security	P.1 Violence	81 Homicides per 100,000 residents	# per 100,000 residents	Annual number of homicides for every 100,000 residents	<10	10–25	>25
		82 Prevalence of partner violence – last 12 months	%	Number of ever-partnered women between 15 and 49 years old who have suffered physical violence from an intimate partner or ex-partner in the last 12 months/Total number of ever-partnered women between 15 and 49 years old, expressed as a percentage	<6%	6–9%	>9%
		83 Prevalence of partner violence – lifetime	%	Number of ever-partnered women between 15 and 49 years old who have ever suffered physical violence from an intimate partner or ex-partner, divided by the total number of ever-partnered women between 15 and 49 years old, expressed as a percentage	<14%	14–25%	>25%
		84 Robberies per 100,000 residents	# every 100,000 residents	Annual number of robberies (theft with violence or threat of violence) for every 100,000 residents	<300	300–1,000	>1,000
		85 Larcenies per 100,000 residents	# every 100,000 residents	Number of larcenies (nonviolent thefts) for every 100,000 residents	<3,000	3,000–5,000	>5,000

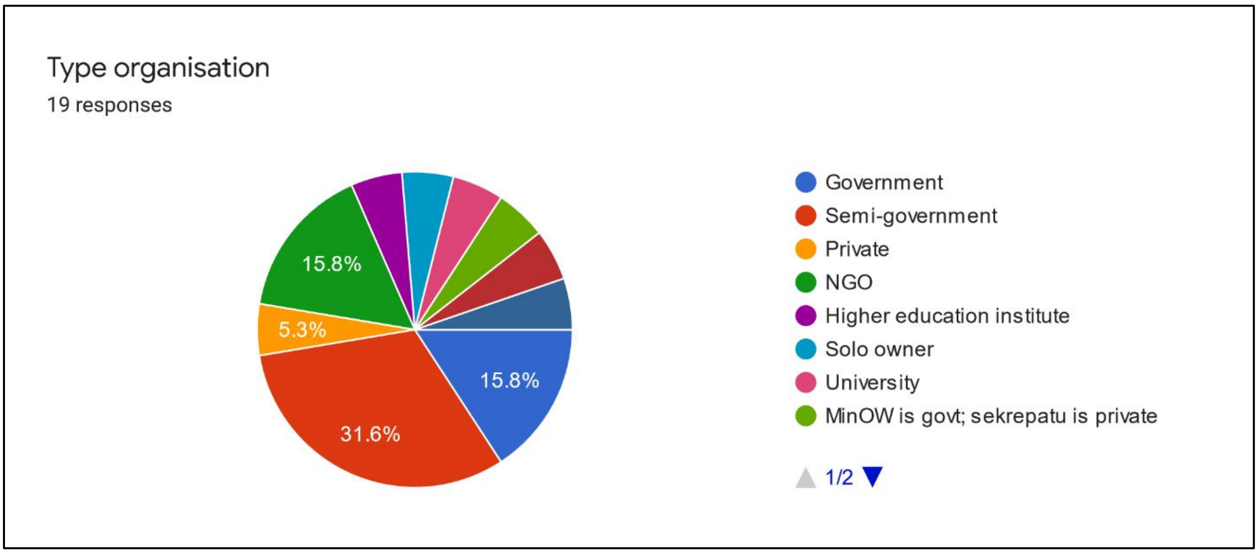
(continued on next page)

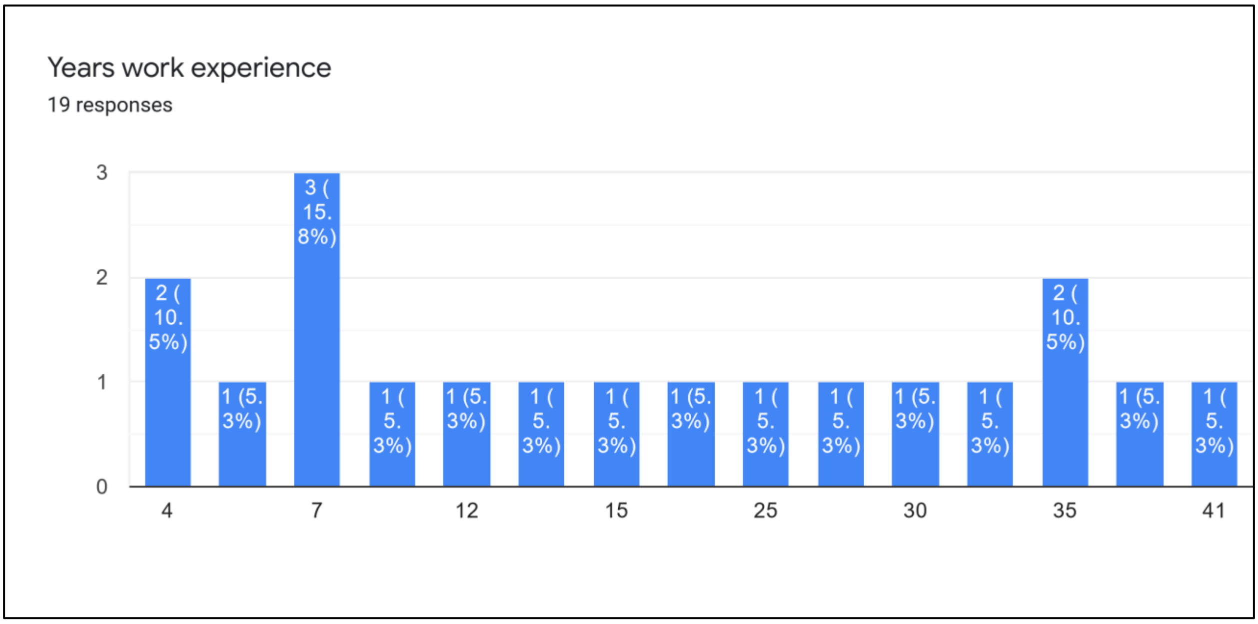
II. Urban Sustainability *(continued)*

# Topics	# Subtopic	# Indicator	Unit of Measurement	Description	Benchmarks		
P Security *(continued)*	P.2 Citizens' confidence in security	86 Percentage of citizens who feel safe	%	Percentage of citizens who respond that they feel safe or very safe	>60%	30–60%	<30%
		87 Victimization rate	%	The percentage of people who respond "yes" to the question "Have you been a victim of a crime in the last 12 months?" (Determined through a survey.)	<10%	10–30%	>30%
Q Health	Q.1 Level of health	88 Life expectancy at birth	years	The average number of years to be lived by a group of people born in the same year, if health and living conditions at the time of their birth remained the same throughout their lives. (CIA Fact Book and OECD definition, also used by GCIF.)	>74	70–74	<70
		89 Male life expectancy at birth	years	Average life expectancy at birth of the city's male population	>70	64–70	<64
		90 Female life expectancy at birth	years	Average life expectancy at birth of the city's female population	>76	70–76	<70
		91 Under-five mortality rate (per 1,000 live births)	deaths/1,000 live births	The probability of a child born in a specified year dying before reaching the age of five, expressed as a rate per 1,000 live births	<20	20–30	>30
	Q.2 Provision of health services	92 Doctors per 100,000 residents	doctors/ 100,000 residents	The number of physicians whose workplace is in the city, expressed as the number of physicians per 100,000 of the city population	>200	75–200	<75
		93 Hospital beds per 100,000 residents	beds/100,000 residents	The number of in-patient hospital beds in the city, expressed as the number of hospital beds per 100,000 of the city population	>100	50–100	<50

Appendix 2 – Survey Results







How big is the impact each of these indicators has on: the people (society)?

Industrial Environment	Green Urban Spaces	Water Bodies	Residential Environment	Life Expectancy	Hospitals	Population Density	Homicide	Robberies	Fatal Traffic Injurie
5	5	5	3	5	5	5	3	3	5
5	3	3	5	5	5	1	-1	-5	-5
5	5	5	3	5	5	5	3	3	5
-1	3	1	3	1	1	1	-1	-3	-1
-3	5	3	5	5	3	1	-5	-5	-5
-5	5	5	-1	-1	5	-3	-5	-5	-5
-5	5	5	5	5	3	-3	-5	-5	-5
-5	-3	-3	1	3	3	-5	3	3	-5
-1	5	5	5	3	3	-1	-5	-5	-5
-3	3	5	3	1	5	1	5	3	-1
3	5	5	5	5	5	3	-5	-3	-3
-5	5	5	1	5	5	-1	-5	-5	-5
-3	3	-3	1	3	3	3	-1	-3	-3
-5	5	3	5	1	3	-3	-5	-5	-5
-5	5	-1	5	3	3	3	-3	-3	-3
-5	3	3	3	1	3	-1	-5	-5	-3
-3	5	1	1	5	1	1	3	3	3
-3	5	3	5	5	5	3	-3	-5	-5
3	5	5	5	3	5	3	-5	-5	-5

Explain your answer of the previous question
People like to live in a peaceful environment and therefore everything that has to do with disturbing peace is not welcome.
Because of lack and or shortcomings in spatial planning as a result of outdated or missing legislation

People are highly impacted by personal loss, hospitals and life expectancy are very positive but pop d is in between, because it depends, industry should not be close to people and env green and water bodies have positive impacts.
People are more affected by their environment than they think. Industrial pollution has been shown to affect health in higly negative ways including possibly increasing dementia. On the other hand, green spaces and bodies of water can provide recreational space, encourage love of nature and walks, all of which have positive impact.
The urban development of Paramaribo is far off satisfactorily despite its favorable statistics such as the relatively low population and low crime rate. The city's unplanned structure results in many urban problems, such as traffic jams, long displacements of population from home to their working place, etc. For this low population number of nearly 250.000 inhabitants, Paramaribo should offer much higher positive impact on living conditions.
Most of the themes, with exception of homicide, robberies end traffic injuries can have both negative or positive impact on society. It depends on the spatial, social and environmental quality of the industry and the residential environments. Also a neighbourhood with a high population density can be both negative and positive for the residents. Negative when it is e.g. an informal settlement with high population density in unhealthy houses. Positive when it is a high quality neighborhood with high population density in healthy houses and with a lot of amenities on walking distance because this encourages residents to daily physical exercise. Also a water body can have both positive and negative impact. An example for the first is when it is buffering rainwater and protecting against flooding. An example for the latter is when the water body is polluted, or when it it's the biotope of disease spreading insects and other animals.
Water bodies: langs een meer wonen is prettig. Life expectancy: voor mij is levensduur een positief impact als mens, zolang ik maar gezond blijf.
I have based the impact indicators of the people on the standards of spatial planning for urban cities
industrial activities will always have an effect on people. Most of the time its a bad impact, due to nuisance created by these activities.
all answers can either have a positive impact. It depends on how you interpret them. In my perception it was: industrial environment close to peoples living environment, sufficient green urban spaces, sufficient water bodies, qualitative residential environment, good life expectation, sufficient and qualitative hospitals, acceptable population density (not to low, not to high), high amount of homoside cases, high amount of roberies, too many fatal traffic injuries.

How big is the impact each of these indicators has on: the planet (environment)?

Industrial Environment	Green Urban Spaces	Water Bodies	Residential Environment	Life Expectancy	Hospitals	Population Density	Homicide	Robberies	Fatal Traffic Injuries
5	5	5	3	-1	-1	5	-1	-1	-1
-3	5	5	-1	-3	-1	-3	-1	-1	-1
5	5	5	3	-1	-1	5	-1	-1	-1
-3	3	1	1	1	1	1	-1	-1	-1
-5	5	5	1	1	1	-5	-1	-1	-1
-5	5	5	-3	-1	5	-3	-5	-5	-5
-5	5	5	-5	-3	-3	-3	-3	-3	-3
-5	-3	-3	-1	3	3	3	3	3	-5
-3	5	5	-1	-1	-1	-3	-1	-1	-1
-3	5	5	-3	-1	-3	-3	1	1	-1
-3	5	5	-3	-1	-1	-1	1	-1	1
-1	5	5	-1	-3	-1	-3	-1	-1	-1

-1	1	-1	1	1	3	3	-1	-3	-3
-5	5	5	-5	-5	-1	-5	-5	-5	-5
-5	5	3	-3	3	3	-5	-1	-1	-1
-5	5	5	-1	-1	1	-3	-1	-1	-1
-5	5	5	-1	1	-3	-5	-1	-1	-1
-3	5	5	1	1	1	5	1	1	1
-5	5	5	5	5	5	3	-5	-5	-5

Explain your answer to the previous question
All indicators that cause the planet to suffer is not sustainable. There must be a balance in the three pillars.
Human activities not based on sustainabillity and protection of the environment will more and more lead to man induced natural disasters and running out of natural resources.
Homocides, robberies and fatal injuries are social problems Pop end industry have very negative impact because of carbon footprints etc residents etc might contribute to peaceful living and healthy people reason better Green spaces and waterbodies are important for the environment
This question was hard to understand. For example I am not sure how to evaluate the impact of hospitals on the environment, or of homicides, robberies and traffic injuries. Industry and its waste have negative impact. Green spaces and water have positive impact. the longer people live and the higher human densitiy may have negative effect on the environment. The presence of hospitals, as with residences will increase waste in the environment. As for homicides, robberies and traffic accidents I assume that they will impact environment negatively but indirectly; people who are subject to high crime and other insecurity in life are less likely to take care of the enviornment.
Due to the unplanned structure and development of the city, the environment suffers a lot of untreated water disposal, traffic jams, uncontrolled processing of mercury, etc.
I am not sure if homocides, robberies and fatal traffic injuries would be negative or positive, but you do not have an option for a neutral score
Many of these themes can have a big negative or small negative impact impact on the planet. It depends on the environmental quality of the industrial and the residential developments and of the hospitals. High population density in cities can be positive because it keeps the degree of urban sprawl low. I was puzzled about the impact of homicide, robberies and traffic injuries. I think that there no impact on the planet because but this answer is not possible. That's why I choose -1 or 1. As for the life expectancy I think that the longer people live the bigger the world population will grow, thus also a small negative impact.
The score is based on the effects of the indicators on the environment of Paramaribo and not on the environment of the planet, because this is negligible
I Think my answers speak for themselfs
if it is a green circular industrial environment, then the impact is positive but generally the impact of a regular industrial environment is negative for the planet. Lack of green spaces is bad for the planet while a sufficient amount of green spaces is postive. A resendetial area can either be a green sustainable residential environment or it can be very unsustainable residential environment. So impact can vary. Hospitals, roberies, homocide and fatal traffic injuries are all people related, so they have few impact on the planet.

How big is the impact each of these indicators has on: the profit (economy)?									
Industrial Environment	Green Urban Spaces	Water Bodies	Residential Environment	Life Expectancy	Hospitals	Population Density	Homicide	Robberies	Fatal Traffic Injuries
5	5	5	3	-1	5	5	-5	-5	-5
5	5	5	1	3	1	-1	-1	-1	-3
5	5	5	3	-1	5	5	-5	-5	-5
3	1	3	1	3	1	3	1	3	1
5	1	1	1	3	3	3	-3	-3	-3
5	1	1	5	-3	5	3	-1	-5	-3
3	5	5	5	5	5	3	-5	-5	-5
1	-1	-1	1	3	3	-3	3	3	-5
5	5	5	1	3	3	1	-3	-5	-3
3	-1	3	3	3	3	3	-1	-1	-1
5	3	3	3	1	1	1	-1	-1	-1
5	5	5	5	5	5	3	-5	-5	-5
1	1	-1	1	3	3	3	-1	-3	-3
5	5	5	5	1	3	-1	3	-5	-5
5	5	1	-5	-3	3	1	-1	-3	-1
3	1	1	1	1	1	1	-3	-3	-3
5	1	3	1	5	5	5	-1	-1	-1
5	1	3	1	3	3	3	-3	-3	-3
5	5	5	5	5	5	-5	-5	-5	-5

Explain your answer to the previous question
The economy depends how you look at the indicators.
Ecomic activities in general aim at increasing profit and subsequently wealth for societies if focused on sustainable development of the societies
homocides etc zijn sociale problemen en slecht voor productiebedrijven pop d, hospitalen en life exectancy zijn goed for human capital onder gezond omstandigheden. urban, water en residential env dragen niet als zodanig bij aan profit, maar de urban env kan wel consumptie gedrag aansturen.
Typically industry has a positive effect on the economy but longterm may be negative as the industry can destroy the land and overuse resources. Green urban spaces, water, more people, hospitals and a good place to live (residential environment).
The city's economy would be much more development and efficient if the city had a planned development. As there is no healthy urban structure, the economy suffers a lot and the production loses in competitiveness.
Green urban spaces can make industrial zones more healthy and more attractive for workers. Water bodies can protect against flooding and can deliver water for the production process. Good residential environments attract workers and keep them healthy and in good shape. Economic growth is affected by a shrinking working population and by a larger proportion of available resources being spent on elderly care(Hospitals and high life expectancy). A high population density can sustain short chain production and lower the cost of transport.
The score is based on the effects the indicators have on the profit in Paramaribo

Industrial environment are mostly economically profitable areas, sustaining and maintenance of green spaces is costly but is they are part of transferable carbonoxide rights, then they become profitable. I the people are not physically and mentally healthy or safe, then it affects their economic performance. Which results in an negative impact on the profit.