

**T.C.**  
**ANTALYA BILIM UNIVERSITY**  
**INSTITUTE OF POSTGRADUATE EDUCATION**

**CIVIL ENGINEERING**  
**MASTER'S THESIS**

**BARRIERS TO SUSTAINABLE PARKING SYSTEM OF ISLAMABAD**

**Tabish HASSAM**

**JANUARY 2023**

**ANTALYA**



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This thesis was accepted by the jury (with unanimous vote/majority vote) on the date  
19/01/2023 in BARRIERS TO SUSTAINABLE PARKING SYSTEM OF  
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## **DECLARATION**

Master thesis of this study named “Barriers to sustainable parking system of Islamabad”, which I presented, I declare that scientific moral principles were followed in the preparation of this study, in case of benefiting from the works of others, reference is made by scientific norms, no falsification has been made in the data used, and that any part of this study is not presented as another academic study.

\_\_ / \_\_ / 2023

Tabish Hassam

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## **ABSTRACT**

### **BARRIERS TO SUSTAINABLE PARKING SYSTEM OF ISLAMABAD**

**Tabish HASSAM**

**MSc Thesis in Civil Engineering**

**Supervisor: Assistant Prof. Dr. Emre DEMİR**

**Co-Supervisor: Assistant Prof. Dr. Şenay SADIÇ**

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The sustainability of transportation is highly affected by urbanization and industrialization which cause pollution and emission due to mobility. When considering the sustainability of the transportation system, parking is a core part of mobility. By providing users with parking spots close to their desired destinations, parking facilities serve as components of the built environment, economy, and social aspects of sustainability and serve as a source of income for the government. However, it has become extremely difficult to locate a free parking spot, especially during busy hours. For parking places, drivers would spend a lot of time cycling back and forth. As a result, there is an increase in fuel consumption, air pollution, the probability of accidents, as well as other major issues. This main research goal was to identify the major barriers to achieving a sustainable parking system in Islamabad. The AHP approach is utilized to identify the best strategies to overcome the barriers to the parking system in Pakistan and according to the results, Off-street & On-street parking is proved to be the best strategy among other strategies.

**KEYWORDS:** - Sustainable parking system, Decision makers, Environmental pollution, Smart parking system.

**COMMITTEE:** Assistant Prof. Dr. Emre DEMİR

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## ÖZET

### İSLAMABAD'IN SÜRDÜRÜLEBİLİR OTO PARK SİSTEMİNİN ÖNÜNDEKİ ENGELLER

Tabish HASSAM

İnşaat Mühendisliği Yüksek Lisans Tezi

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Ulaşımın sürdürülebilirliği, yoğunluğa bağlı olarak kirlilik ve emisyonla neden olan kentleşme ve sanayileşmeden oldukça etkilenmektedir. Ulaşım sisteminin sürdürülebilirliği düşünüldüğünde, park sorunu sürdürülebilirliğin yapı taşı oluşturmaktadır. Kullanıcılara ulaşacakları yere yakın park alanları sağlanabilir. Bu noktada otopark tesisleri ulaşımda ekonomi ve sosyal sürdürülebilirliğin bileşenleri olarak hizmet verebilir ve hükümet için ayrıca gelir kaynağı olarak katkı sağlayabilir. Ancak günümüzde özellikle yoğun saatlerde ücretsiz park yeri bulmak son derece zorlaşmıştır. Sonuç olarak, yakıt tüketiminde, hava kirliliğinde, kaza olasılığında ve diğer önemli konularda gözle görülür artışlar yaşanmıştır. Araştırma'nın ana hedefi olarak İslamabad'da sürdürülebilir bir park sistemine ulaşmanın önündeki başlıca engelleri belirlemektir. AHP yaklaşımı, Pakistan'daki park sisteminin engellerini aşmak amacıyla en iyi stratejileri belirlemek adına kullanılmıştır. Sonuçlara ise şunu gösteriyor ki; Sokak Dışı ve Sokak İçi park etme ve diğer stratejilerin en iyi konumda olduğu kanıtlanmıştır.

**ANAHTAR KELİMELER:** - Sürdürülebilir otopark sistemi, Karar vericiler, Çevre kirliliği, Akıllı otopark sistemi

**JÜRİ:** Dr. Öğr. Üyesi Emre DEMİR

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Prof. Dr. Niyazi Uğur KOÇKAL

## **SYMBOLS AND ABBREVIATIONS**

AHP	: Analytic hierarchy process
API	: Application programming interface
BRT	: Buses rapid transit
CBD	: Central business district
CDA	: Capital development authority
CI	: Consistency index
CR	: Consistency ratio
GHG	: Greenhouse gases
GIS	: Geographic information system
GPS	: Global positioning system
IoT	: Internet of things
ITS	: Intelligent transportation system
LPG	: Liquefied petroleum gas
MCDM	: Multicriteria decision method
NGO	: Non-governmental organization
PMS	: Parking management system
RI	: Random index
ST	: Sustainable Transportation
SUMP	: Site Utilization and Management Plan
SUT	: Sustainable urban transportation

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## **PREFACE**

First of All, I would like to thank ALLAH Almighty who give me the strength and resources to accomplish this research work.

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Thanks to all of you who helped me to achieve my goals

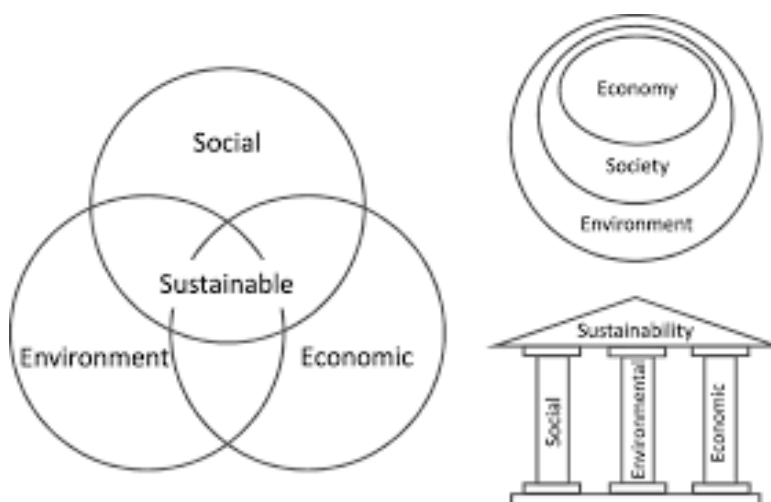
## 1. INTRODUCTION

Transportation plays a crucial role in our daily lives, connecting people to places, and enabling economic and social activities. However, the transportation sector is also a significant contributor to global greenhouse gas emissions, air pollution, and other environmental problems (Schiller & Kenworthy, 2017). The traditional transportation system, which is primarily based on the use of fossil fuels, is not sustainable in the long term (Jeon & Amekudzi-Kennedy, 2005). Therefore, there is an urgent need to transition to a sustainable transportation system that reduces negative environmental, social, and economic impacts while meeting the needs of all stakeholders (D. Banister, 2007).

Sustainable transportation refers to the use of modes of transport that are environmentally friendly, socially responsible, and economically viable (Roman, 2022). This includes transportation options that reduce greenhouse gas emissions, improve public health, and promote equity and affordability (Conference, 1996). Sustainable transportation options include walking, cycling, public transportation, and electric vehicles powered by renewable energy sources (Schiavo et al., 2021). Implementing sustainable transportation can help to reduce traffic congestion, air pollution, and carbon emissions, and promote more livable and sustainable communities (Schweddes & Hoor, 2019).

### 1.1. Sustainable Transportation

The concept of sustainable transportation is closely related to the development of sustainable transport modes, infrastructures, and operations. Three main dimensions are taken into consideration. Figure 1.1 represents the three main pillars of sustainability, which are social, economic, and environmental. These pillars are interconnected and equally important for a sustainable transportation system.



**Figure 1.1.** Three pillars of sustainability

**Source:** (Zako & Moore,2014)

## **Environment**

The environmental aspect of sustainable transportation refers to the reduction of negative impacts on the environment caused by traditional forms of transportation, such as cars and buses that rely on fossil fuels (D. Banister et al., 2011). This includes reducing greenhouse gas emissions, air pollution, and noise pollution (Zhu et al., 2021).

Examples of sustainable transportation options that have a lower environmental impact include walking, cycling, electric vehicles, and public transportation powered by renewable energy sources (Wu et al., 2021). These modes of transportation can help to reduce emissions of carbon dioxide and other pollutants and can contribute to the fight against climate change (Pipitone et al., 2021). Additionally, sustainable transportation options such as biking and walking can also help to reduce dependence on fossil fuels, which can help to reduce air pollution and other environmental impacts (Miller et al., 2016).

## **Economy**

The economic aspect of sustainable transportation refers to the financial and economic benefits and costs associated with different transportation options (Ševčenko-Kozlovská & Čižiūnienė, 2022). Sustainable transportation options, such as public transportation, walking, and biking, can have a positive impact on the economy by reducing congestion, increasing mobility, and supporting local businesses (Garrett, 2014). Additionally, the use of sustainable transportation options can also reduce dependence on fossil fuels, which can help to reduce the cost of transportation and decrease the volatility of fuel prices (Sheth & Sarkar, 2020).

On the other hand, the implementation of sustainable transportation infrastructure and policies can be costly, and there may be economic challenges associated with the transition to more sustainable transportation systems (Bamwesigye & Hlavackova, 2019). Therefore, it is important to consider the economic feasibility and cost-effectiveness of different sustainable transportation options.

## **Social**

The social aspect of sustainable transportation refers to the impact that different transportation options have on society, including issues related to accessibility, equity, and community livability (Zijlstra & Vanoutrive, 2018).

Sustainable transportation options such as walking, biking, and public transportation can increase accessibility by providing transportation options for people who may not have access to a car, such as children, elderly people, and low-income individuals. Additionally, sustainable transportation options can also promote equity by providing transportation options that are affordable and accessible to all members of society (Vale et al., 2016).

Furthermore, sustainable transportation options can contribute to the development of livable communities by encouraging active transportation, reducing dependence on cars and promoting social interactions among people. This can lead to

increased physical activity, improved public health, and a more vibrant community (Geurs et al., 2009).

On the other hand, the lack of sustainable transportation options can lead to social inequality, as certain groups may be disproportionately impacted by poor transportation infrastructure, leading to limited access to jobs, education and basic services.

### **1.1.1. Need for Transportation**

The need for sustainable transportation has become increasingly pressing in recent years as the negative impacts of traditional transportation systems based on personal cars and fossil fuels have become more apparent (Roman, 2022). These impacts include air pollution, climate change, and congestion, which not only affect the environment but also public health and economic activity (Abraham et al., 2012).

Sustainable transportation options, such as public transportation, and electric vehicles, can help to address these challenges by reducing dependence on fossil fuels, decreasing air pollution, and improving public health (Badassa et al., 2020). Additionally, sustainable transportation options can also promote social equity by providing transportation options for all members of society, regardless of income or ability.

Therefore, it is important for transportation planning and policy to consider the full range of impacts associated with different transportation options and to prioritize sustainable transportation options that can meet the mobility needs of society while minimizing negative environmental and social impacts.

In industrialized countries such as the United States, routes for transportation have traditionally been provided in advance of other economic development. For instance, the Ohio Valley was made more livable by the construction of the Cumberland Road in the early 1800s. The Great Lakes region was settled thanks to the 1825 completion of the Erie Canal. In the 19th century, federal land grants to railroad companies aided in the settlement of the West. In Canada, highways and railroads were built farther north in the 1960s and 1970s to encourage settlement and resource extraction. Only if the items can be produced inexpensively enough in the first location to balance the expense of transportation to the second can the movement of goods be justified over the long term (BRITANNICA KIDS).

### **1.1.2. Importance of Transportation**

To move people, things, or animals from one location to another is defined as transportation. It has existed ever since the earliest times when only wooden carts and animals like horses, donkeys, and bulls were used. As time progressed, we observed innumerable inventions, which led to the development of vehicles like cars, buses, trucks, spacecraft, helicopters, ships, planes, etc. that superseded earlier ways of transportation.

Transportation plays a crucial role in modern society, as it enables people to access jobs, education, healthcare, and other essential services (Alizadeh & Ph, 2022). It

also allows for the movement of goods and services, facilitating economic activity and growth.

However, the traditional transportation system based on personal cars and fossil fuels has contributed to a range of negative impacts, such as air pollution, climate change, and congestion. This has led to a growing need for sustainable transportation options that can meet the mobility needs of society while minimizing negative environmental and social impacts.

Transportation is also important for the social and economic development of a country (Tucho, 2022). It connects people with economic opportunities, social services and creates accessibility to different places and opportunities. Additionally, transportation is also important for rural areas, as it connects these areas to urban areas and provide access to markets, services, and jobs (Cook et al., 2017).

Furthermore, transportation is also important for the accessibility and mobility of people with disabilities, children, and the elderly population (Sabahat TOPUZ KIREMITÇİ, 2017). It helps them to participate in society and access to essential services.

Therefore, transportation is a critical aspect of modern society, and it is important to prioritize sustainable transportation options that can meet the mobility needs of society while minimizing negative environmental and social impacts.

It is difficult to imagine rapid industrialization, mass production and distribution without well-constructed infrastructure and transportation. The development of a nation's transportation infrastructure has also had a big impact on how its political, social, economic, and cultural life has changed.

- Transportation helps in price stability and mass production.
- Transportation helps in the development of economy.
- Transportation offers various opportunities.
- Transportation helps in social development.
- Transportation helps in agricultural & industrial development.
- Transportation helps in political development.
- Transportation helps in business growth and organizations.

## **1.2. Sustainable Urban Transportation in Pakistan**

Sustainable urban transportation is at the core of sustainable urban living which allows for social interactions and easy movement while minimizing negative effects on the environment and public health for both the present and future generations. There are formal and informal ways of urban transportation. Informal modes are those that are operated by the private sector, such as "paratransit," "low-cost transport," "third world transport," and vehicles like vans, two- or three-wheel rickshaws, and chinchis. Formal modes are typically those that are designed, planned, and provided by the city government, such as sidewalks, taxis, buses, trucks, and rail. Due to the unsatisfactory

mobility demands of passengers, formal urban transport is less popular in Sub-Saharan Africa than it is in Eastern Europe and East Asia, where it accounts for barely 5% of total trips (Pojani & Stead, 2015). Therefore, in certain locations, informal forms of transportation act as "gap fillers" (Mohareb & Felix, 2017). As a result, even in developing nations, many commuters use their private vehicles and become dependent on them (Shafiullah et al., 2016) the number of registered vehicles increased from 982 million in 2005 to 1776 million in 2015 and is projected to reach a maximum of 2.6 billion vehicles by the year 2050 (L. Wright, 2003). Traffic jams, travel uncertainty and delays, traffic accidents, increased energy (oil/gas) consumption, increased vehicle costs, urban air pollution, and economic losses due to health issues and resulting lost wages are just a few of the issues that have been brought on by the rapid growth in motorization and vehicle dependence (Batoool et al., 2020). According to (Haghshenas et al., 2013), sustainable transportation choices are sought after in developing nations, particularly in Asia and Africa. According to (Litman, 2010), public transit systems have the potential to address a variety of traffic issues, including congestion in the road and parking lots, accidents, costs associated with maintaining the road and parking facilities, consumer costs associated with owning a car, insufficient mobility for non-drivers, excessive energy use, and pollution emissions. (Pojani & Stead, 2015) have critically analyzed the nine options frequently considered for sustainable urban transport in cities, particularly those in developing countries, and find that the Bus Rapid Transit (BRT) system is a viable option for large cities as it can serve about 45,000 passengers per hour in each direction. According to Currie (Delbosc, 2017), (Hensher & Golob, 2008), (L. Wright, 2003), (Yazici et al., 2013) and others, BRT works on a divided right-of-way infrastructure that enables frequent, quick operations in congested economies.

According to (May, 2013), BRT systems offer services that align with the three pillars of sustainability—social, economic, and environmental. In the end, BRT systems assist lower vehicle expenses and environmental pollution by replacing larger numbers of single-occupancy vehicles (such as private cars and motorbikes) with a smaller number of higher-occupancy vehicles like buses and vans (Baghini et al., 2014). BRTs improve urban quality of life in four ways: 1) they reduce travel durations, 2) they reduce air pollution and greenhouse gas (GHG) emissions, 3) they increase traffic safety, and 4) they promote physical activity (Hidalgo et al., 2013). Additional advantages of using the BRT system include increased safety and physical exercise from walking (Carrigan et al., 2013). According to one study, BRT systems are ten times safer per kilometer than driving a car (Litman, 2011). Additionally, when compared to old transportation systems, BRT systems offer special features including Intelligent Transportation System (ITS) technologies that have improved operational effectiveness and service quality. Despite being more affordable than rail transit systems, BRT systems also require significant capital and construction investments in BRT infrastructure.

### **1.2.1. Problems of the Sustainable Transportation System in Pakistan**

Sustainable transportation is a major issue in Pakistan, as the country faces a range of challenges in developing and implementing sustainable transportation options. There are many problems facing Pakistan's urban transportation industry because of the fast modernization and growth of urban economies and the resulting strain on urban transportation. The structural capacity of the current road system cannot support the increasing volume of vehicles. In metropolitan locations, the lack of homogeneity in

transportation systems has exacerbated travel uncertainty and delays. Additionally, the use of fossil fuels has increased air pollution and environmental degradation in the surrounding. Some of the main problems include.

### **Lack of Investment**

Despite a growing need for sustainable transportation options in Pakistan, investment in these options remains limited. This lack of investment is due to a range of factors, including a lack of government support, a lack of public awareness, and a lack of economic incentives for private investment (A. Raza et al., 2022).

### **Insufficient Public Transportation**

The public transportation system in Pakistan is inadequate and inefficient, making it difficult for people to access jobs, education, healthcare, and other essential services. This is due to a lack of investment in public transportation infrastructure and a lack of government support for public transportation options (Imran, n.d., 2009).

### **Poor Road Infrastructure**

The road infrastructure in Pakistan is in poor condition, which makes it difficult for people to access essential services and for sustainable transportation options to be implemented. This is due to a lack of investment in road infrastructure, poor maintenance, and a lack of government support for sustainable transportation options (Ahmed et al., 2021).

### **Dependence on Fossil Fuels**

Pakistan's transportation sector is heavily dependent on fossil fuels, which contributes to air pollution and climate change. This dependence is due to a lack of investment in alternative transportation options and a lack of government support for sustainable transportation options (Lin & Raza, 2020).

### **Limited Awareness**

There is limited awareness and education about sustainable transportation in Pakistan. This lack of awareness is due to a lack of government support for sustainable transportation education and a lack of public awareness campaigns (Report et al., 2021).

Overall, sustainable transportation is a major issue in Pakistan due to a lack of investment, poor infrastructure, dependence on fossil fuels and limited awareness and education about sustainable transportation options.

## **1.3. Parking System**

Car parking systems and related technology have evolved and grown throughout time. Car parking systems have been around almost since the beginning of the motor. In any area with a lot of traffic, there are car parking facilities in place. At the beginning of

the 20th century, parking facilities were built in response to the need for automobile storage.

Automated parking systems had their beginnings in the 1920s in American cities like Cincinnati, Los Angeles, Chicago, and New York City. These multi-story buildings are still standing and have been modified for new purposes in some cases. An Art Deco icon in New York, one of the Kent Automatic Garages, was transformed into offices and opulent condominiums in 1983 and is now known as the Sofia Apartments. The Westinghouse Corporation invented the "Ferris-wheel," or paternoster system, in 1923, and it was subsequently constructed on Chicago's Monroe Street in 1932. This system is currently present across Japan. The first glass-enclosed version of this system was developed by the Nash Motor Company in 1933 for the Chicago Century of Progress Exhibition and served as the model for a more modern design, the Smart Car Towers in Europe.

A device that increases the number of parking spaces in a lot is a car parking system. Parking systems move automobiles into a storage position and are typically driven by electric motors or hydraulic pumps.

Systems for parking cars might be manual or automatic. Since they often require less ground space and building volume than a conventional facility with the same capacity, automatic multi-story automated car park systems are less expensive per parking space. Automated car parking systems are projected to be less expensive in the long run than conventional parking garages. Systems for parking cars reduce exhaust gas because they eliminate the need for drivers to look for parking on the street.

### **1.3.1. Sustainable Parking System**

The transition to multimodal planning is probably necessary. Congestion is a good indicator of economic activity when seen from a socioeconomic perspective. Cities today resemble parking lots more than anything else. Mobility as a service is the direction that transportation will go in the future. Vehicles do not always move along roadways. Typically, a car occupies two spaces: one at the commuter's residence and the other at their workplace.

One of the most effective ways to reduce the demand for parking is to implement a pricing system, where the cost of parking increases, encouraging people to use alternative modes of transportation. This can help to reduce congestion and air pollution, and also generate revenue for municipalities. For example, a study (Shoup, 2005) shows that demand-based pricing in downtown areas can reduce cruising for parking by up to 50%.

Shared parking, which allows different land uses to share the same parking facility, can also be implemented to reduce the need for parking spaces and urban sprawl. For example, (Levinson, D., & Kumar, 2005) show that shared parking can reduce the number of parking spaces required by 30-50%.

Sustainable design features, such as green roofs, rainwater harvesting systems, and electric vehicle charging stations, can also be incorporated into parking facilities to

reduce the environmental impact of parking. For example, (Brown, T., & Dannenberg, 2009) show that green roofs can reduce the heat island effect and improve air quality. “Parking is the most important consideration for all cities” (Sustainable Urban Transport (SUT)).

The effectiveness of road space is increased by well-designed and balanced parking controls, which also enable customers to visit retail establishments, customers to visit businesses, and residents and business establishment owners to move around more easily while engaging in economic and social activities. To meet the demand of both visitors and those involved in the operations of the CBD, it is crucial to promote commercial and retail activities in central business districts. Due to the significant increase in privately owned vehicles, it is essential to implement parking control to reduce the amount of public space designated for parking and promote public transportation.

A policy should guide the design of the parking system. On-Street, Off-Street, and Peripheral Parking should be constructed by the policy. The parking should blend in with the surrounding environment and the land use pattern.

In addition to space on the road for movement, vehicles also need a place to load and unload passengers and park temporarily. According to (Malik & Malik, 2017) estimate, a car only runs for 400 hours (4.6% of the time) on average per year out of 8,760 hours, leaving 8360 hours during which it must be parked. Both on- and off-street parking is possible. On-street parking has the negative effects of limiting street space and causing traffic congestion, which reduces the capacity of the road, causes unnecessary delays, and slows down travel time.

### **1.3.2. Sustainable Parking System in Pakistan**

One Asian nation, Pakistan, has a variety of vehicles that are uncommon in other nations, including the calligraphic truck, Qing Qi, rickshaw, local bus, and motorcycles. But it represents the diversity and culture of our country. People also encounter traffic and parking challenges because of the excessive number of automobiles on the road and the poor upkeep of parking lots. Do you believe that Pakistan's Smart Parking Solution may assist us in preventing parking problems? Are you prepared to walk through the door of technology?

The answer is true! Smart Parking Solutions not only make parking easier, but they also reduce the need for gas, time, and effort spent looking for parking spaces.

Since there are several vehicles on the road, some solutions have been implemented. With the help of electric car parking lots, which show whether parking spaces are available, you may park your car in a sophisticated manner. Below are a few efficient parking solutions.

- Car Parking Lifts & Systems.
- Automated Vertical Car Parking System.
- Elevators Car Parking System.

## Cars Parking Lifts & Systems

A car parking lift system is a mechanical device that is used to stack cars in a vertical or multi-level configuration to save space and maximize the number of vehicles that can be parked in a given area (Rahman et al., 2020). These systems typically consist of a platform that is raised and lowered by hydraulic or electric motors, and can be operated manually or with an automated control system. Figure 1.2 depicts a multi-story car parking system that uses a hydraulic system to raise and lower the car platform.

Hydraulic car parking lift systems are commonly used in multi-level car parking facilities and rely on hydraulic cylinders to lift the platform to the desired height. These systems typically use an electric motor to power the hydraulic pump, which pressurizes the hydraulic fluid and transfers it to the cylinders, allowing the platform to be raised or lowered. In multi-story car parking systems, hydraulic lift systems can be an effective way to maximize the use of available space, as they allow multiple cars to be stacked vertically. Additionally, these systems can be designed to be fully automated, which can further optimize parking efficiency and reduce the need for human intervention. Overall, hydraulic-based car parking lift systems offer a practical solution for maximizing parking capacity in a limited space.

Some common types of car parking lift systems include single-post lifts, two-post lifts, four-post lifts, and scissor lifts (Parking, 2020). The first city to implement a car-raising system in Pakistan is Lahore. However, it makes it possible to envision quick, simple, and effective parking inside businesses, workplaces, and organizations. However, maintaining and administering the elevator car parking system does require skilled personnel; when the automobile is lifted in the parking system, the operator needs to be cautious and experienced enough.



**Figure 1.2.** Less space taken through car lifts systems

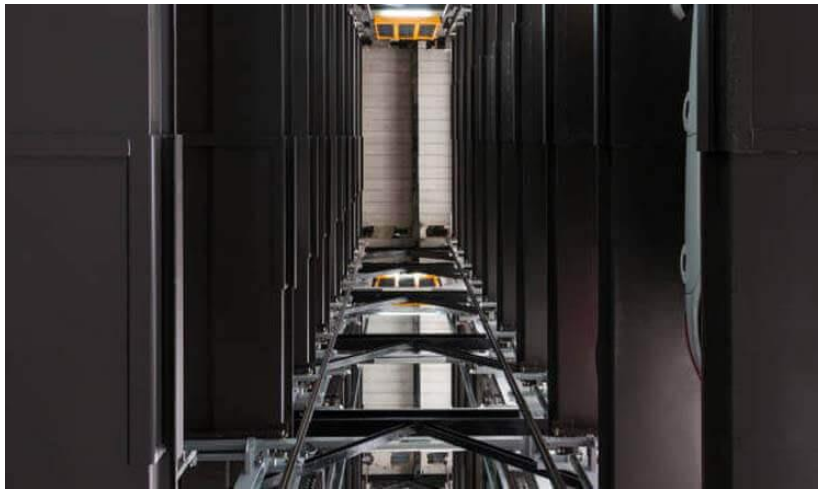
**Source:** (Chris D’Alessandro, April 2022)

## Elevators Car Parking System

Parking is increasingly becoming a problem in many locations. People frequently experience traffic jams due to a scarcity of parking spaces, especially in large cities like Karachi, Islamabad, and Lahore. On the other hand, a clever parking solution will allay your parking phobia.

An elevator car parking system is a type of automated mechanical parking system that uses elevators to lift cars to a storage level, where they are parked in designated spaces (Asif et al., 2019). Figure 1.3 shows an elevator car parking system, which is a type of mechanical parking system that uses elevators to transport cars to a storage level for parking. The system depicted in Figure 1.3 consists of multiple levels of parking, with cars being transported by elevators between the various levels. The elevators themselves are shown as rectangular boxes with doors that open to allow cars to enter and exit.

These systems are often used in urban areas where land is scarce and parking space is limited. The cars are retrieved and delivered to the user by elevator (Liew et al., 2015). Elevator systems can be changed to fit the style and architecture of the building. The pavement of the courtyard or garden will be level with the roof of the elevator. It is set up inside the structure.



**Figure 1.3.** Elevating Vehicles

**Source:** (istockphoto.com)

## Automated Vertical Car Parking System

An automated vertical car parking system is a type of mechanical parking system that uses computer-controlled technology to stack cars in a vertical configuration, typically in multi-level structures (Azshwanth et al., 2019). These systems can be designed to accommodate a variety of vehicle types and sizes, and typically use a combination of lifts, conveyors, and turntables to move cars between

levels (Bhagdev & Agarwal, 2017). They are designed to maximize the number of cars that can be parked in a given area and are often used in urban areas where land is scarce and parking space is limited.

Additionally, this system includes high levels of automation, intelligent parking sensors, and a card reader that can recognize just one vehicle and one card. Figure 1.4 represents an Automated Vertical Car Parking System, which is a type of mechanical parking system that utilizes computer-controlled technology to stack cars in a vertical configuration. Additionally, it was created for large-scale organizations like shopping centers, parking garages, markets, and hospitals. The figure 1.4 shows a vertical stack of cars that are parked on pallets or platforms, which are then lifted or lowered using computer-controlled lifts and conveyors. The system also includes a turntable that allows cars to be moved between different levels of the parking structure. Overall, Figure 1.4 provides a visual representation of an Automated Vertical Car Parking System, showing how cars are stacked and moved between levels using computer-controlled lifts, conveyors, and turntables.



**Figure 1.4.** Vehicle card identification system

**Source:** (taab.pl)

### **1.3.3. Barriers to Sustainable Parking System in Pakistan**

Since the invention of cars, parking problems have arisen. However, it got worse more quickly as urbanization increased. The main element of the transportation plan is parking. Transport performance has dramatically improved because of liberalization, and city static traffic has increased as a result. Due to capacity or equipment limitations, parking spaces for large freight vehicles pose challenges, particularly in metropolitan areas.

There is a lack of clear policies and regulations for parking management in Pakistan, which makes it difficult to effectively plan and implement sustainable parking systems (Ernesto S. et al., 2013). The limited availability of public transportation options in Pakistan means that many people rely on personal vehicles, which puts pressure on parking infrastructure (Barter, paul, 2011).

The implementation of sustainable parking systems can be costly, and many cities in Pakistan may not have the necessary funding to invest in such infrastructure (Rietveld, P., & Stough, 2004). There may be resistance to change among the population, particularly about adopting new technologies or methods of parking management (PIDE, 2015). The implementation of sustainable parking systems may be hindered by political and bureaucratic obstacles, such as a lack of coordination among government agencies, delays in decision-making, and a lack of accountability (Aslam, M., & Hussain, 2015).

Parking is becoming a subject of controversy and concern for a lot of people due to Pakistan's rising automobile ownership rate and lack of advanced public transportation. Parking problems can arise anywhere, including airports, bus stations, and shopping centers. The quality of life for residents may suffer and local businesses may suffer from inadequate parking. Cities constantly review and evaluate their parking plans and performance since parking is so important.

The most typical problems that affect communities are mentioned in the list below.

- Road users lack knowledge.
- Parking space is not being utilized effectively.
- Excessive use of automobiles.
- Effects of parking lots on the economy, environment, and aesthetics.
- Accessible parking spaces.
- Increased parking spaces have an impact.
- Issues with severe spillover are now present.
- Difficult Parking.
- Parking meters that are not sufficient.
- There is not enough parking at the event location.

On the other hand, society has not yet fully embraced smart parking options. Using a web application to find parking lots or leaving their cars in the hands of automated parking systems has put consumers at a disadvantage. However, they continue to park conventionally (Muhammad, R., & Ahmed, 2019). However, parking cars on service roads and major thoroughfares is a typical occurrence. Even though the fine for making incorrect parking charges might reach 1000 Pakistani rupees. (Ahmed, S. & Muhammad, 2018) Emerging nations everywhere require smart parking solutions, so internet users must be aware of this technology.

#### **1.4. Problem Statement**

There are a growing number of automobiles today. Large urban parking lots becoming inefficient, it is harder to find open spaces in congested parking lots, and the necessity to dedicate greater land areas for more parking places are all difficulties that are being caused by this.

In the city of Islamabad, where there are an increasing number of cars, drivers are encountering issues like traffic congestion and a lack of parking. Islamabad, Rawalpindi, and other public locations of the main cities have been noted to have parking issues.

Visitors at markets are required to park their cars along the main road, which usually causes accidents in moreover to traffic delays.

The main aim of this research is to figure out barriers in the parking systems that led to disasters and make the system unsustainable. In other words, sustainability in the parking, system is considered in this research specifically based on the cities of Pakistan.

### **1.5. Study Area**

For this research on barriers to the sustainable parking system, Pakistan is chosen as a research area. Pakistan is a South Asian country that is the fifth most populous country with a population of almost 242 million people. Pakistan is one of the most crowded nations in the world, and most people prefer to travel by their automobile. Since there are so many diverse types of vehicles on roads, parking issues for cars and other forms of transportation are a common thing. The nation currently faces a serious problem with parking.

Figure 1.5 provides a visual representation of the location of the research area, allowing the viewer to get a better understanding of the geographical context in which the research was conducted. Islamabad is the capital of Pakistan and the fourth largest city of Pakistan having an area of 1165.5 km<sup>2</sup>. For residents of the capital city, parking has become a significant problem due to excessive population development, the expansion of residential and commercial sectors, and an increase in the number of vehicles.

The authorities involved are either in deep sleep or a denial state when one looks at the increasingly constricting space that frequently makes mobility a yeoman's job. Due to the issue's delayed attention, people now frequently struggle to find parking for their cars, which is a difficult and stressful task. According to research, approximately 400,000 vehicles enter and exit the city every day, however, the average number of cars and other vehicles owned by city residents is almost equal.



**Figure 1.5.** Study area (Islamabad)

**Source:** (Google maps)

### 1.5.1. Current Parking Systems in Islamabad

Parking is important in ensuring that residents in Islamabad can obtain the goods and services they need. To manage parking in the city, the Capital Development Authority (CDA) must play a significant role. Capital Development Authority needs to pay close attention to the need for parking in Islamabad. Figure 1.6 shows some snapshots of parking areas and parking systems in Pakistan, specifically in Islamabad. The figure 1.6 shows various parking areas in Islamabad, including street parking, and other types of parking facilities.



**Figure 1.6.** Current parking system of Islamabad

**Source:** (istockphoto.com)

### **1.6. Reading Guide**

This thesis is structured into 6 chapters. In the first chapter, the introduction, problem statement, study area, sustainable transportation, its importance, parking system, and its barriers are introduced. In the second chapter the literature study is described, Literature Review. Work-related to the parking system, its sustainability, obstacles, parking system, and its barriers are discussed. Research Methodology is discussed in the third chapter. A qualitative research approach is used in this research. Interviews and questionnaire surveys are discussed in this section. Chapter four includes analyses and chapter five includes findings. Chapter six includes conclusions and suggestions based on this research. Moreover, references were collected from different articles, journals, books, and webpages that had been used during research, and at the end, the appendixes are included. Appendix A contains the questionnaire that was used to collect data from the decision-makers. It includes the questions that were asked, the response options, and the data that was collected. Appendix B contains the responses of the decision-makers regarding the strategies used to minimize the barriers to the implementation of a sustainable parking system. It provides a detailed analysis of the data and discusses the key trends and patterns that emerged.

## 2. LITERATURE REVIEW

### 2.1. Sustainable Transportation

Achieving sustainability in the transportation sector is a still greater challenge to transportation professionals, decision-makers, and experts, as well as urban planners and environmentalists (Hassan & Lee, 2015). All three sustainable pillars which are Environment, Economy & Society had a direct and indirect effect due on the performance of the transportation system. We can say almost every aspect of our society is affected by the transportation systems network. Unfortunately, it is widely acknowledged that current trends in transportation systems around the world are unsustainable (Mosaberpanah & Darban Khales, 2013). The consequences of population growth on transportation are exacerbated by an increase in car ownership (May, 2013).

To help the transportation system become more environmentally tolerable, economically feasible socially equitable, and so tenable in all aspects, it is very essential to evaluate the sustainability of the transportation system. Sustainable transportation (ST) goals would not be attained with any real progress unless and until the issues with transportation systems are quantified (Greene, 2015). The transportation industry requires a holistic and integrated approach to move toward sustainability because it is an interdisciplinary subject. As a result, it is essential to take into consideration and respect the opinions of all stakeholders involved in the transportation systems when quantifying, reporting, assessing, and evaluating them (Moavenzadeh et al., 2012).

Policymakers, Non-Governmental Organizations (NGOs), business partners, researchers and academics, financial institutions, suppliers, energy and service providers, and end users are examples of stakeholders. Sustainability indices sometimes referred to as composite indicators, have a significant and helpful role to play in this area. Indices are recognized as an essential reference and communication tools for all stakeholders since they simplify potentially complex information (in the form of indicators) into simple and understandable formats (Freudenberg, 2003).

Indicators are gathered in their typical form as indices. ST indicators help assess the effects of various factors on the three sustainability pillars by providing measurable measures of a transportation system (Verma et al., 2015). By reducing the negative effects on the environment and society while maximizing financial gains, the transportation system can be made more sustainable (Zegras, 2006). According to (Mahdinia et al., 2018), A group of pertinent ST indicators is used to clarify and illustrate each of the sustainability pillars. A negative ST indicator, such as "Motor fuel utilized by transportation per total vehicle kilometers driven" means that when its value rises, ST will decline. Alternatively, the "percentage of yearly work trips by public transportation per total annual work trips" is an example of a positive ST indicator, denoting that its rising value will have a rising effect on ST.

The development of ST indices is still not fully addressed in the literature, even though indices for sustainable development like the human development index, wellbeing index, ecological footprint and living planet index are adequately explained there

(Böhringer & Jochem, 2007). To close this gap, a thorough evaluation of the literature has been conducted with the main goal of presenting several ST index development approaches that have been used in various parts of the world (at varying scales).

A system's three main dimensions—environmental, social, and economic—are subdivided into subdivisions with a range of goals. It might be possible to track each subdivision's progress toward its goals by classifying indicators depending on subdivisions. Table 2.1 shows a categorization of the environmental, social, and economic aspects of a transportation system, with various subdivisions and corresponding objectives listed.

The table 2.1 organized into three main categories: environmental, social, and economic, with each category subdivided into more specific aspects of the transportation system. The specific subdivisions listed in the table include energy use, vehicle environmental efficiency, land use, safety, accessibility, and others. For each subdivision, the table lists a range of objectives that relate to that particular aspect of the transportation system. These objectives include minimizing greenhouse gas emissions and air pollution, reducing dependence on petroleum and switching to renewable energy sources, increasing safety, improving accessibility, increasing customer benefits, and minimizing expenses for local governments and transportation system operators. Overall, Table 2.1 provides a useful framework for understanding the various dimensions and goals of a transportation system, and can help policymakers and other stakeholders develop strategies and indicators for measuring progress toward these goals. By breaking down the transportation system into specific aspects and objectives, it can be easier to identify areas where improvements are needed and track progress over time.

**Table 2.1.** Sustainable Transportation Goals & Indicators

<b>Components</b>	<b>Subdivisions</b>	<b>Objectives</b>
<b>Environmental</b>	Emissions of greenhouse gases and air pollution	Minimize greenhouse gas emissions and air pollution.
	Energy	Reduce its dependence on petroleum; switch to renewable energy sources and energy with lower emissions of air pollutants and greenhouse gases.
	Land used	Lower the amount of land that is used for transportation.
	Vehicle environmental efficiency	Vehicle's environmental efficiency is increased.
<b>Social</b>	Safety	Increase safety and reduce the risk of an accident.
	Accessibility	Improve the accessibility of transportation infrastructure.
	Diversity	Increase the variety of available transportation options.
<b>Economical</b>	Transportation system customers' expenditures and benefits	Increase customer benefits & decrease expenditures of a transportation system.
	Transportation system operators' expenditures and revenues	Increase revenue and minimize expenses for local governments and transportation system operators.

**Source:** (Litman & Burwell, 2006)

Sustainable transportation goals and indicators are used to measure progress toward a more environmentally friendly, accessible, and efficient transportation system. One of the key goals of sustainable transportation is to reduce emissions of greenhouse

gases and air pollution, which contribute to climate change and have negative impacts on public health. Another goal is to ensure the efficient use of energy in the transportation sector, which can be achieved through the promotion of low-carbon transportation modes, the adoption of electric vehicles, and the use of alternative fuels. Additionally, sustainable transportation aims to minimize the amount of land used for transportation infrastructure, such as roads and parking facilities, and to increase the environmental efficiency of vehicles. Indicators such as emissions per capita, mode share of low-carbon transportation modes, energy consumption per kilometer traveled, and emissions per kilometer traveled can be used to track progress toward these goals. Ensuring the safety of all road users, promoting accessibility and diversity in transportation options, and providing equitable access to transportation services are also critical components of a sustainable transportation system. Safety objectives focus on reducing the number of road accidents and fatalities, particularly for vulnerable road users such as pedestrians and cyclists. Accessibility goals aim to ensure that all individuals, regardless of their socio-economic status or physical ability, have access to transportation services that meet their needs. Diversity objectives seek to promote a wide range of transportation options, including non-motorized modes of transportation and public transit, to provide individuals with choices and reduce reliance on single-occupancy vehicles.

Sustainable transportation goals also include considering the financial aspects of the transportation system, both for the customers and the operators. For transportation customers, sustainable transportation goals aim to minimize expenditures, improve benefits, and provide affordable and accessible transportation options. For transportation operators, sustainable transportation goals aim to optimize expenditures, maximize revenues, and ensure financial viability.

## **2.2. Smart Parking**

The availability of parking spaces is a key factor in smart cities. Traffic computing becomes incredibly great and effective when parking spots in modern cities have high-tech infrastructure connected to cloud computing (Lin et al., 2017). Before arriving at their location, drivers can control their automobiles using the smart parking system. This service effectively calculates the occupancy rate for parking spaces and gives users the option to reserve parking spaces in advance.

Some methods for predicting parking spots end up with a toxic distribution. The Markov Chain makes it simple to anticipate the capacity of various vehicles (Pullola et al., 2007). Due to the high demand for parking spaces, these methods' accuracy varies to some extent and depends on several variables, including the time of day, the weather, how often it rains, etc.

Smart City projects are advancing knowledge and understanding of car parking in various urban settings. As a result, academics and practitioners now have access to the related car parking data collection. The parking data analysis of car parking occupancy is divided into several categories (Caicedo, 2010). When combined with the Internet of Things (IoT) systems, these types of techniques are significantly improved since they can constantly increase the accuracy of occupancy estimates using backpropagation.

Many researchers have examined the evolution of parking systems using various technologies, analyzed unresolved research issues, and put forth prospective ideas, plans, and architectural solutions to these issues. These investigations offer both advantages and disadvantages. (Al-turjman & Malekloo, 2019) divided the smart parking system into two categories: soft and hard design. Additionally, they talked about issues with data interoperability, security, and privacy as well as other difficulties with system architecture.

A system proposed by a researcher (Asif et al., 2019) in which they show the counter for the car entering the parking area and tell the parking gate to stop opening when the maximum number of automobiles are there. An identical counter is created for the departure gate, where the number of vehicles leaving the park is recorded back. Pushing a little button controls the parking, which is controlled by a piezoelectric sensor that measures vehicle weight. When the button is pressed, the counter adds and subtracts 1 from the counter number. The smart parking system is seen as advantageous for car park managers, car park customers, and environmental preservation. The information acquired using the Smart Parking System can be used by car park operators to forecast upcoming parking patterns. To boost the company's profit, pricing tactics can also be changed in accordance with the information gathered. In terms of protecting the environment, reducing air pollution (vehicle emissions) in the atmosphere can lower pollution levels. The decrease in car travel is responsible for this. Fuel consumption will decrease as well because it is directly related to the number of miles a vehicle travels.

Another researcher (Azshwanth et al., 2019). the report suggests a system where vehicles check in and out to keep track of the time. Each type of vehicle has a different pricing structure, including two and four-wheelers. Two standby PCs will be used by the system to keep track of the entry and exit of cars. The identification of license plates allows for time management and vehicle control. The technology will monitor the arrival and departure of vehicles to determine whether the parking lot is full. The price of automobiles will depend on how much time they take.

The main goals of the parking management system are outlined below.

- Parking structure that is organized and well runs.
- Using an IT-based Parking Management System, collect parking fees openly (PMS).
- Free parking theft.
- A strict one-way street (i.e., separate entry-exit points for trucks).
- Wherever necessary, loading and unloading bays are created.
- Every traveler has access to a Clean & Clear parking space.
- There is not a backlog of traffic on internal and main roads.

A crowdsourcing approach is recommended by (H. Dargahwala, et al., 2013) in his research. This strategy identifies parking spots on streets and curbs where there is a low chance that cars will be impounded. The user will mark the slots and spots that distinguish between real and fake ones. The technology will also draw attention to nearby open spaces and locations that can be used instead of those that cost money. It will be a GPS-based parking system that uses Google API to find nearby, unreserved parking

spaces. The user data will enable us to identify the intriguing trends in the most popular parking spaces and places.

There are several apps available for Android and iOS devices that assist in finding and reserving parking spaces in parking lots. These apps allow you to find parking spaces close to you, close to certain designated regions, or merely by entering an address or building name. They may all show you the current availability status in real-time. The following are the most typical characteristics seen in these apps.

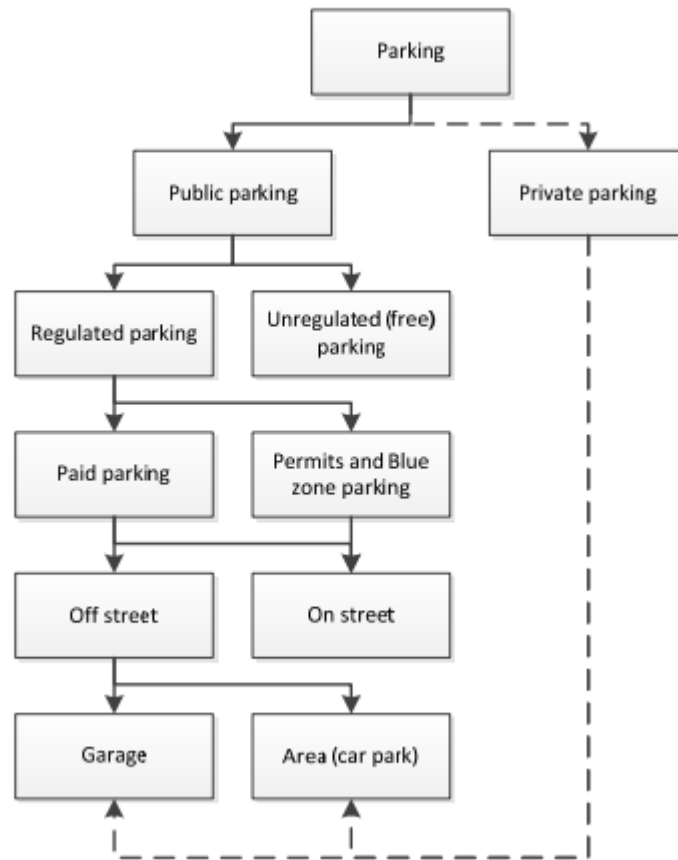
- Before the parking session expires, receive a reminder.
- Parking session extension from any place.
- Simple payment options.
- Several mobile phone numbers on one account.
- Several vehicles on one account.

### **2.2.1. Parking Accommodations**

The parking system is made up of several facilities that can accommodate drivers to accomplish the goals for parking. According to (Litman, 2022), the primary types of parking facilities are.

- Surface parking is a facility that is located directly on the ground (paved or unpaved).
- Structured or underground parking is a multi-story parking structure that includes parking facilities inside or under a building.
- On-street (curb) parking is the term for designated parking spaces that are situated within a road, typically in the curb lane (parking, garage, ramp).

The Netherlands' parking regulation led to a separation of parking activities and types (Final et al., 2013). Figure 2.1 shows the breakdown of parking activities and types in the Netherlands. It demonstrates how the adoption of parking regulations led to a separation of parking activities into two general categories: public parking and private parking. Public parking is further divided into regulated parking and unregulated parking. Regulated parking includes paid parking, permits, and blue zones, which help to utilize parking spaces more effectively. Paid parking on- and off-street is used to control and regulate drivers' parking behavior. Private parking complements the private environment and is not open to the public. Overall, the figure highlights the importance of parking regulations in managing parking activities and promoting efficient use of parking spaces.



**Figure 2.1.** Parking differentiation

**Source:** (Bouwfonds REIM, 2012)

The term "Private parking" refers to parking options that complement the private environment as opposed to public parking. For instance, parking spaces on private land that support homes and businesses. Since environmental target groups are the primary focus of private parking, it is not open to the public and is privately run.

Public parking is now divided into "Regulated parking" and "Unregulated parking" because of the adoption of parking regulations. In addition to paid parking, there are two significant regulatory options: permits and blue zones. Parking spaces are used more effectively when there are permits and blue zones. By introducing parking permits, certain target groups (such as residents of neighborhoods) are given preference over other drivers. "Blue zone parking" imposes time limits and shortens the time that individual drivers must park.

Paid parking limits the utilization of available parking spaces by pricing differential in addition to the two parking laws already mentioned. The purpose of parking space pricing is to make parking places less alluring. It is believed that a price mechanism could control and regulate drivers' parking behavior (Final et al., 2013). On- and off-street parking options both offer paid parking. Off-street activities are comparable to public

parking on private property, in garages, or in specially defined spaces. On-street parking, on the other hand, is available in the public area along the roadway.

### **2.2.2. Parking Rules**

Traffic planners in central governments, municipalities, and consulting firms create parking policies to enhance the built environment and address issues brought on by the increase in car use and related parking (Final et al., 2013). Legislation, regulations, and management techniques for managing urban mobility make up parking policy.

Seven stages can be used to explain the evolution of parking policy in Europe (Dijk & Montalvo, 2011).

- No parking restrictions. Up until the number of parked cars has a detrimental effect on the area's quality and appeal, this phase is acceptable.
- Control and regulation of parking. This implies that parking will eventually be prohibited on some streets.
- Time constraints (free of charge). Due to the increasing turnover of cars, space is used more effectively as a result.
- Parking fees. The use of parking spots is managed using parking charges.
- Parking policies for residents. There will be a need for resident parking plans if parking spaces are overflowed to nearby regions (typically residential areas).
- Facilities of P and R. These are created as an alternative to or supplement to the available parking in the city center.
- Mobility management. It entails several activities to fine-tune the use of both private and public transportation to give travelers a suitable mobility chain.

The list above illustrates how parking policy has evolved. It describes the implementation of restricted policy and charged parking and demonstrates a rise in the regulation of parking-related activities. Until issues occur, simple policies like "no parking measures" are sufficient. Parking-related negative effects that hurt the environment call for increasingly sophisticated policies.

### **2.3. Shared Parking**

In recent years, shared parking has gained popularity as an efficient method of controlling parking in cities. Understanding the elements that influence people's intentions to use shared parking is essential for the implementation of shared parking to be successful.

Infrastructure for parking is an expensive resource that needs to be allocated efficiently. Cooperative parking, often known as shared parking, has been used for many years. The rise of the so-called sharing economy has reignited interest in this strategy, which is viewed as a critical component in efforts to change habits away from the free parking model toward a market-based structure (Shoup, 1997). On behalf of owners, several commercial operators market parking spots (Shao et al., 2016). The first reservation and allocation system for shared parking spaces were created by (Shao et al., 2016).

Various possible advantages of shared parking exist. It can be applied to lower the number of parking places needed for a particular population (Wells et al., n.d.). Shared parking, according to a (Litman, 2006) estimate, could cut the demand for new spots by 10% to 30%. It can also be utilized to deal with spillover parking brought on by inadequately stocked stores and malls (Inan et al., 2019). For both public and residential buildings, shared parking is considered a possible source of income, and several strategies to improve reservation and allocation systems have been put forth (Cai et al., 2019).

All stakeholders involved must cooperate for shared parking (i.e., suppliers as well as demanders). Some researchers have examined people's desire to participate in these systems (Zhang et al., 2018), whereas others have looked for ways to stop people from rejecting the system (Xiao & Xu, 2018). To forecast participants' desire to participate in parking-sharing schemes (Zhang et al., 2018), considered the physical attributes of parking spots and their actual parking behavior. To the best of our knowledge, no prior study has, however, explored the psychological elements that go into deciding whether to join in a shared parking arrangement.

### **2.3.1. Social and Economic Impacts of Shared Parking**

The collaborative economy has exploded since the start of the economic crisis, which has led to a steady increase in the number of people using these services. The collaborative economy is a framework for economic exchange based on three key principles. Peer connection fostered by various technologies (particularly digital), engagement between producers and consumers who maintain an ongoing discourse, and collaboration. Shared parking is a common issue in the transportation sector of the collaborative economy, and parking issues impede sustainable development. To address the problem of parking demand, shared parking has been implemented, and it has grown to be a major research topic in the parking sector and academics.

The impact of the advantages and disadvantages on residential parking suppliers' and managers' intent to adopt a shared parking scheme in a residential area was covered by (Xie et al., 2020) in their discussion of shared parking intention. The findings revealed that management pressure has little bearing on parking suppliers' intentions to embrace shared parking, but risks and benefits do. A parking manager's decision to administer a shared parking program in a residential area is also greatly influenced by the advantages, dangers, and management pressure. While this was going on, (Liang et al., 2019) showed that perceived control and self-efficacy were the key elements influencing parking demanders' adoption of shared parking.

To maximize resource allocation, (Hao et al., 2018) built a dynamic allocation model for the sharing of university parking garages in central urban areas, and through a test case, he was able to determine the precise time during which spaces would be available in universities and residential areas. To determine whether the guiding service can achieve the balanced utilization of regional parking resources and if shared parking is practical, (Zhang et al., 2018) designed a two-level programming induction model based on shared parking in residential zones.

The best model for allocating shared space resources in residential areas was developed by (Ye et al., 2020). (Alexander et al., 2021) investigated how parking lots on

various types of land differed in their peak hours. The findings indicated that parking garages at banks, schools, hospitals, etc., experienced their busiest times throughout the week, while those in entertainment venues, such as movie theatres, experienced their busiest times at night on weekends.

#### **2.4. Barriers to the Sustainable Parking System**

Some barriers prevent policymakers and local administrations from fully implementing parking management in their cities through a strategic and integrated approach, a critical component of their SUMP. According to (Patrick Auwerx et al., 2019) some of these barriers are.

- Lack of knowledge about parking management and its advantages in general.
- Inability to comprehend the idea of parking management, its procedure, or how it fits within a SUMP.
- A lack of institutional support (either financial or at a higher institutional level).
- A lack of institutional coordination (horizontal and vertical).
- A lack of political commitment and politicians' concern that their constituents could reject.
- Limits brought on by other laws and policies, inconsistencies that prevent a comprehensive approach to parking management, etc.
- Lack of public involvement in the creation of parking regulations.

Reducing parking demand to better match parking supply and other spatial aspects of the city is a modern solution to parking issues. A balance between all traffic modes should be reached, giving preference to non-car modes (public transportation, walking, and cycling) as the development of sustainable urban mobility is fostered (EC, 2001). The implementation of parking fees in Central Business Districts (CBDs) and other areas of high appeal is one of the approaches for attaining the most favorable modal split feasible, along with the improvement of the quality of public transportation service. By adopting this strategy, the price of driving a car rises, decreasing its appeal (TBRP 2005, n.d.).

#### **2.5. Sustainable Parking Using the AHP Method**

To choose appropriate parking locations, the AHP approach, one of the MCDM methods, was utilized. Myers and Alpert first suggested the AHP approach in 1968, and it was created by (Saaty, 1987). The AHP approach is a mathematical technique that considers both qualitative and quantitative criteria simultaneously when solving problems involving decision-making.

Several problems exist in cities due to population growth and migration from rural to urban areas. The parking issue is one of these issues. The transportation network is impacted by the parking issue since it alters traffic flow and density (GörkemGülhan, 2010). The fact that local governments' strategies for spatial planning only provide one answer does not suffice to address this issue (Emine Pirinc Bayraktar et al., 2022). As a result, local administrations should be in charge of setting parking regulations (AhmetAtalay, 2020).

The field of transportation is expanding quickly and has a significant role in daily life. Urban transportation issues have gotten worse due to accelerated urbanization and population rise. Easy access to parking facilities is one of the most crucial elements in the success and efficiency of urban land use (Alinia et al., 2015). The importance of choosing appropriate parking spaces has increased as a result. Several factors need to be taken into account when choosing a site (Puspitarini, 1967).

The AHP technique, one of the MCDM methods, is useful for resolving site selection issues since it considers a variety of qualitative and quantitative variables simultaneously. The GIS technology used to choose parking lots can also analyze a variety of factors (Ozturk & Kilic-Gul, 2020).

The steps taken by Saaty for the AHP method are.

- Developing the Hierarchical Framework.
- Pairwise Comparison Matrix Construction.
- Criteria weights estimation.
- Consistency Ratio Calculation.

The hierarchal structure for determining parking areas of land use considers proximity to various amenities and facilities as one of the criteria. Table 2.2 presents a hierarchical structure for determining parking areas of land use based on different criteria. The objective of this structure is to optimize land use for parking while balancing the needs of the community with available land resources. The hierarchical structure is broken down into three levels, with each level comprising sub-criteria.

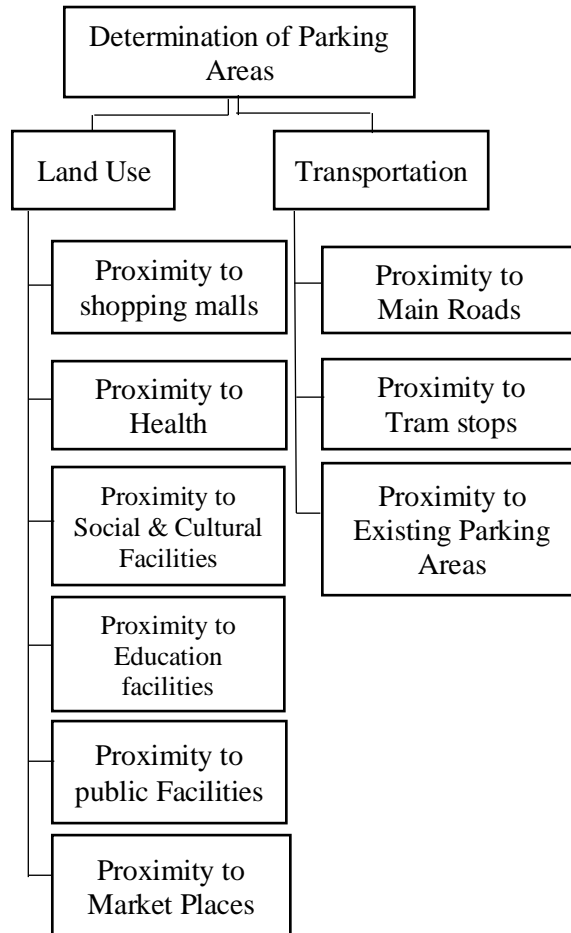
At the first level, the primary criterion is optimizing land use for parking, which is further broken down into three sub-criteria: site availability, zoning and land use regulations, and community impact. The site availability sub-criterion considers the availability of land for parking, while the zoning and land use regulations sub-criterion considers the regulatory framework for land use in the area. The community impact sub-criterion considers the impact of parking on the community, such as the effect on local businesses or residential areas.

At the second level, the community impact sub-criterion is further broken down into six sub-criteria: proximity to shopping malls, health centers, social and cultural facilities, education facilities, public facilities, and market places. This sub-criterion emphasizes the importance of considering the proximity of parking areas to these amenities and facilities to better balance the needs of the community with available land resources.

At the third level, each of the six sub-criteria of the community impact sub-criterion is further elaborated with a set of considerations. For instance, under the proximity to shopping malls sub-criterion, the considerations include the distance from the parking area to the mall entrance, availability of parking spaces at peak times, and other relevant factors.

In summary, Table 2.2 provides a hierarchical structure for determining parking areas based on multiple criteria, with the aim of optimizing land use for parking while balancing the needs of the community with available land resources.

**Table 2.2.** Hierarchical structure of criteria



**Source:** (Saaty, 1990)

The objective of optimizing land use is broken down into sub-criteria of site availability, zoning and land use regulations, and community impact. Proximity to shopping malls, health centers, social and cultural facilities, education facilities, public facilities, and market places is considered under the sub-criteria of community impact. By considering the proximity of parking areas to these amenities and facilities, the decision-making process can better balance the needs of the community with the available land resources.

The hierarchal structure for determining parking areas for transportation considers proximity to transportation infrastructure as one of the criteria. Proximity to main roads, tram stops, and existing parking areas is considered under the sub-criteria of traffic congestion. if a parking area is located close to main roads or tram stops, it can reduce congestion and provide a convenient option for people to park while they use these modes

of transportation. On the other hand, if the parking area is located too far from these transportation nodes, it may reduce the accessibility of the parking area and discourage its use.

### 3. METHODOLOGY

This chapter discusses the methodology used in this research. A qualitative research approach method is used in this research. A qualitative approach deals with the evaluation of theories drawn from the proposed issues of parking. Examining data through interviews, and questionnaires a qualitative approach is suitable for studying and interpreting complex phenomena. To fully understand complicated phenomena researchers must gather information from actual locations and conditions.

In general, qualitative research refers to a variety of methods and approaches, such as ground theory, surveys, and interviews. Also, the research provides conclusions not obtained using statistical methods or other forms of measurement.

#### 3.1. Qualitative Research Approach

This research has one of its purposes is to investigate the difficulties faced by drivers during parking by acquiring information from the real-world environment. In this case, a qualitative research methodology was applied to the research work through the conduct of interviews. And a questionnaire survey is conducted to find a participant for implementing a system on a smart parking system. For the analysis of data collected through interviews, the researcher has used the Analytic Hierarchy Process (AHP).

##### 3.1.1. Quantitative & Qualitative research

Quantitative research involves the collection and analysis of numerical data and seeks to establish relationships and make predictions through statistical analysis. Qualitative research, on the other hand focuses on understanding human experiences and perspectives through the collection and analysis of non-numerical data, such as text, images, and audio. The primary goal of qualitative research is to gain an in-depth understanding of a particular phenomenon, while the goal of quantitative research is to test hypotheses and make generalizations about a population.

##### Quantitative Research

- Emphasizes numerical data collection through methods such as surveys, experiments, and standardized tests.
- Typically uses large sample sizes and statistical analysis to identify patterns and make generalizations about a population.
- Focuses on testing hypotheses and making predictions.
- Aimed at producing objective, verifiable results.

##### Qualitative Research

- Emphasizes the collection of non-numerical data, such as interviews, observations, and open-ended surveys.
- Typically uses small sample sizes and focuses on understanding the experiences, perspectives, and attitudes of individuals.

- Focuses on gaining an in-depth understanding of a particular phenomenon.
- Aimed at producing rich, detailed descriptions and insights into human experiences and behaviors.

### 3.1.2. Interviews

The interviews aimed to address two distinct research questions related to parking in Islamabad. Table 3.1 outlines the two research questions that the interviews aimed to address regarding parking in Islamabad. The first research question aimed to identify the main barriers and challenges associated with parking in the city, while the second question focused on exploring the benefits of a smart parking system.

The first research question aimed to understand the difficulties that people face in parking in Islamabad. The results of the interviews revealed that the main barriers and challenges associated with parking in the city were the limited availability of parking space, illegal parking, lack of proper parking management, and inadequate public transportation. The limited availability of parking space is a common issue in many cities, and the interviews highlighted the severity of the problem in Islamabad. The illegal parking was found to be another significant challenge as it can cause traffic congestion and accidents. Additionally, lack of proper parking management and inadequate public transportation were also identified as significant barriers to parking in the city.

The second research question aimed to explore the benefits of a smart parking system. The results showed that a smart parking system could improve parking efficiency, reduce congestion, enhance safety, increase revenue, and improve the user experience. By adopting innovative solutions such as a smart parking system, the interviews suggested that the city could address many of the challenges associated with parking and improve the overall parking experience for residents and visitors.

In summary, Table 3.1 highlights the two research questions addressed by the interviews, providing valuable insights into the current state of parking in Islamabad and the potential benefits of adopting innovative solutions to address the challenges associated with parking in the city.

**Table 3.1.** Questions asked by the interviewer

Q1: What are the most significant challenges and barriers associated with parking in Islamabad, and how can they be addressed effectively?

Q2: How can a smart parking system improve parking efficiency, reduce congestion, enhance safety, increase revenue, and improve the user experience in Islamabad?

The target group's attributes were used to guide the recruitment of participants. They received invitations and a request to participate, and depending on their responses, interviews were scheduled. For those whose schedules altered unexpectedly, phone interviews were conducted. Two in-person and three phone interviews took place. Participants' backgrounds and interviews are shown in table 3.2. Table 3.2 provides information on the background of the five participants who were interviewed for the study. The table includes information on each participant's age, gender, occupation, and traveling schedule.

The table 3.2 provides a brief overview of the characteristics of the participants and their car ownership status. These details are important to consider when analyzing the participants' responses and insights into parking in Islamabad.

**Table 3.2.** Details of Participants

<b>Participant</b>	<b>Details</b>
Participant 1	Gender: Male Age: 30 Resident: Islamabad Occupation: Assistant Director Town planner Driving time in Twin cities: 2-3 times a week
Participant 2	Gender: Male Age: 35 Resident: Islamabad Occupation: Deputy Director Planning Driving time in Twin cities: Regularly
Participant 3	Gender: Male Age: 34 Resident: Islamabad Occupation: Town Planner Driving time in Twin cities: 5 days a week
Participant 4	Gender: Male Age: 45 Resident: Islamabad Occupation: Director of General planning Driving time in Twin cities: 2 days a week
Participant 5	Gender: Male Age: 42 Resident: Islamabad Occupation: Director of Planning Driving time in Twin cities: 2-3 days a week

### 3.1.3. Data Collection

One of the interviews was conducted at a venue the interviewer had picked. Here, the interviewee was given a room invitation. The participant invited the interviewer to a location of his choosing for the second interview. A 10 to 15-minute interview was conducted. The interview's purpose was explained at the beginning, and participants were made aware of the aims. The purpose was to understand the difficulties with parking in Islamabad City, not to examine them. Additionally, they were told that there was no correct or incorrect response. Table 3.2 in the first column lists the interviewees' code names in sequence from the first to the last one conducted. The second column displays the relevant information regarding the interviewee.

By conducting structured interviews, data was gathered. The target population for this study consisted of vehicles in the Islamabad region. Both locals and outsiders were included in that. Participants who drive to the city region were questioned to explore parking difficulties from the perspective of tourists. Face-to-face and phone interviews were the two types of interviews that were conducted. Every interview was conducted in a pair, with one person conducting the interview and the other taking notes. Each interview ended with a discussion between the interviewer and the person taking notes to interpret the information gathered. This was done while they were still fresh, and the results were documented.

Subgroups were created from the stratified sample that served as the target group. The goal was to have as many volunteers as possible representing the various traits of the target group. Five male interviewees made up the total number of participants. Two of the interviews were between the ages of 40-45, while three were between 30-35. In addition, only two of the interviewees were inexperienced, while the other three had experience driving.

The following are the barriers discussed with the participants.

- Environmental pollution
- Excessive Automobile use
- Inadequate information for motorists
- Inefficient use of existing parking capacities
- Inconvenient parking spaces
- Town planning & parking
- Driver behavior
- Parking policies
- Parking prices
- Narrow streets
- Violation of buildings & highway codes
- Off-street parking
- Parallel parking
- Poor infrastructure
- Lack of Technology

## 3.2. Strategies

To overcome the parking barriers here are some strategies discussed in this section.

### 3.2.1. On-street & Off-street Parking

On-street parking refers to parking spaces that are located on public roads, such as along the side of a street or in a designated parking lane. These spaces are often managed by municipalities and are subject to regulations such as time limits, parking fees, and restrictions on certain types of vehicles (Dictionary, n.d.). On-street parking can have a significant impact on the functioning of a city, affecting issues such as traffic flow, pedestrian safety, and the availability of parking for residents and visitors (A. B. S. and D. Banister, 2008). The image on the right of Figure 3.1 shows an example of off-street parking, where cars are parked in a designated parking lot or garage. The parking area appears to be privately owned and managed by a business, as indicated by the sign in the background. This type of parking can provide a dedicated and convenient parking space for drivers, as well as potentially generating revenue for the parking lot owner. However, it may also contribute to urban sprawl, as large parking lots can take up significant amounts of space and reduce the density of urban areas. The image on the left of Figure 3.1 shows an example of on-street parking, where cars are parked along the side of a public street. The parked cars are situated in a designated parking lane, which is separated from the other lanes of traffic by a dashed line. On-street parking can provide a convenient parking option for drivers, as it is often located near destinations such as shops or restaurants. However, it may also contribute to congestion and reduce the capacity of the road for other forms of transportation, such as bicycles or public transit.



**Figure 3.1.** On-street & off-street parking

**Source:** (fastcompany.com)

Off-street parking, on the other hand, refers to parking spaces that are located on private property, such as in a parking lot or a garage. These spaces are typically managed by private businesses or property owners and may be subject to different regulations than on-street parking (Wikipedia, n.d.). Off-street parking can also have an impact on the functioning of a city, affecting issues such as land use, development, and the availability of parking for residents and visitors (Ewing, 2002).

It is important to note that both on-street and off-street parking have their advantages and disadvantages, and the appropriate type of parking will depend on the specific context and goals of a city or community.

### 3.2.2. Remote Parking

Remote parking refers to parking facilities that are located away from the destination or activity for which the parking is intended (A. B. Schwanen, 2008). Remote parking is often provided in the form of park-and-ride facilities, which allow drivers to park their cars at a location outside of the city center or other congested area and then take public transportation, carpool, or bike-share to their final destination (Roegling, 2009). Remote parking can also include park-and-walk facilities, which allow drivers to park at a location near a destination and then walk to it. Figure 3.2 illustrates the concept of remote parking through a diagram of a typical park-and-ride facility. The image shows a parking lot located on the outskirts of a city, with arrows indicating the direction of traffic flow. The parking lot is connected to a transit station by a dedicated shuttle or bus, which provides a convenient link to the city center or other popular destinations. The diagram also highlights the key features of a park-and-ride facility, such as the availability of parking spaces, the location of the transit station, and the frequency of shuttle or bus services. The figure 3.2 provides a visual representation of how remote parking can help to reduce traffic congestion, improve air quality, and provide more efficient and sustainable transportation options for commuters and visitors.



**Figure 3.2.** Remote parking

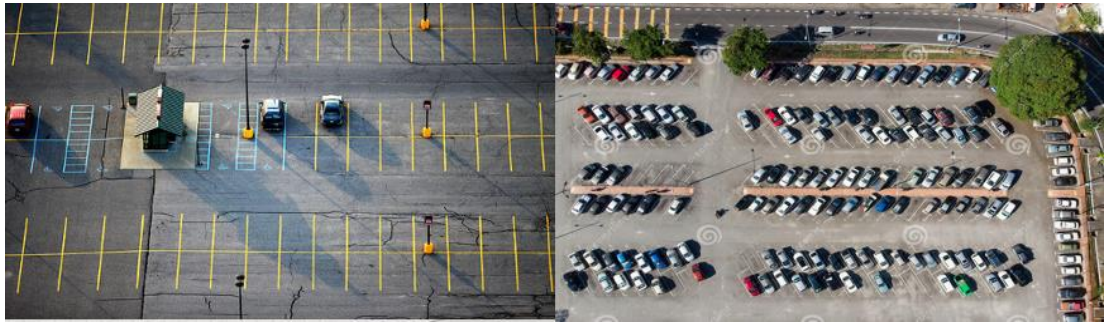
**Source:** (depositphotos.com)

### 3.2.3. Open Space Parking

Open space parking refers to parking facilities that are located on open land or undeveloped areas and are often found in suburban or rural areas. This type of parking can include surface lots, gravel or grass lots, or unpaved areas (S. S. H. Raza, 2011). Open space parking is often used for events, recreational activities, or temporary parking needs (Lockwood, 2006). It can also be used as a temporary parking solution for a construction site or a special event.

However, open space parking can have negative environmental impacts such as loss of natural habitat, increased stormwater runoff, and air and noise pollution (Kim, 2019). It can also lead to urban sprawl and fragmentation of natural areas. Figure 3.3

shows an image of an open space parking system, which is located in an open field with line marking for efficient parking.



**Figure 3.3.** Open space parking

**Source:** (Eric Betz, Science news service, 2010)

### 3.2.4. Use of Technology in Existing Parking Spaces

The use of technology in existing parking spaces can include a range of solutions such as smart parking systems, which use sensors and cameras to detect the presence of vehicles in parking spaces and provide real-time information on the availability of parking to drivers (Arem, 2010). This can improve parking efficiency and reduce traffic congestion. Dynamic pricing systems, which adjust the price of parking based on demand, can encourage drivers to use parking spaces during off-peak hours and reduce the number of cars circling in search of a parking spot (Bell, 2011). Mobile parking payment systems, which allow drivers to pay for parking using their smartphones can reduce the need for physical parking meters and make it more convenient for drivers to pay for parking (M. R. B. and A. B. Schwanen, 2012). Figure 3.4 shows a mobile phone screen displaying a mobile parking payment system. The image includes a parking zone code and a time limit, as well as options for payment through a mobile app or by phone call. The app also provides information on the user's current balance and the parking duration. The image illustrates how technology can make the parking experience more convenient and user-friendly by allowing drivers to pay for parking using their mobile devices. It also highlights the potential for technology to reduce the need for physical parking meters and streamline the payment process.



**Figure 3.4.** Use of technology in parking

**Source:** (happiestminds.com)

## Data Analysis

The handwritten interview notes were transcribed into a word document immediately after each interview to ensure the quality of the analysis. To enable access by both researchers, the raw data, including interview notes, was kept in a folder. To respond to research question one, the remarks made by respondents regarding difficulties with parking in urban areas were taken from the interview notes and divided into groups.

- Finding a parking spot
- paying parking costs
- Cost of time spent parking

The interviewees' replies served as the inspiration for the category names. For example, the category of paying parking charges was picked for research question one because some interviewees reported that they had difficulty paying parking fees. To respond to research question number two, the advantages of smart parking in the neighborhood were summarized from the interview notes and categories.

- Time-Saving
- Convenience in locating and paying for parking
- Favorable pricing of the time spent parked

The names of the categories were taken from the answers of the interviewees.

### 3.3. Analytic Hierarchy Process (AHP)

An organized method for organizing and evaluating complicated decisions is the Analytic Hierarchy Process (AHP). Based on arithmetic and psychology, Thomas L. Saaty created it in the 1970s. The technique has been widely employed in group decision-making in a variety of contexts, in industries like government, business, healthcare, and educational (Vaidya & Kumar, 2006) (Sipahi & Timor, 2010). One of the most popular tools for multi-criteria decision-making is it.

The foundation of AHP is the notion that people's experience and knowledge are taken into account together with actual data when making judgments (Sipahi & Timor, 2010). The approach is built on six crucial processes and can handle both quantitative and qualitative decision criteria (Han & Vries, 2007) (Saaty, 1980).

- Identify the problem decision.
- Breaking down the decision-making process and related criteria into a hierarchy structure.
- Making a comparative judgment, creating matrices for paired comparisons and determining the relative importance of the criteria.
- Synthesizing once the alternatives' resulting priority has been determined.
- Verify the consistency of judgment.
- The conclusion.

The AHP offers a way to divide the issue into a hierarchy of smaller issues that are simpler to understand and evaluate from a variety of perspectives. Each alternative is ranked on a number scale using subjective judgments that have been transformed into numerical values (Saaty, 1977). The following steps can be used to explain the AHP methodology:

The issue is broken down into a hierarchy of objectives, standards, substandard, and solutions. The most innovative and significant phase of decision-making is this. The foundation of the AHP approach is the hierarchical structuring of the decision issue (Saaty, 1980). A hierarchy shows a connection between items on one level and those on the level below it.

Every element in the hierarchy is connected to every other element, at the very least indirectly, thanks to this interaction that percolates down to the lowest levels of the hierarchy (Koczkodaj, 1992). A network can be more structured as a hierarchy. A hierarchy and an inverted tree structure are comparable.

In the pairwise comparison of alternatives on a qualitative scale as detailed below, data are gathered from experts or decision-makers corresponding to the hierarchic structure. The contrast can be rated by experts as being equally important, weakly important, fairly, strongly, and absolutely strongly important. A format that has been specifically designed can be used to collect the opinion. Table 3.3 represents the decision-making tool designed to collect opinions from experts or decision-makers about the relative importance of different criteria or alternatives in a hierarchic structure. Table 3.3 consists of a series of rows and columns, with the rows representing the criteria or alternatives being compared, and the columns representing the different levels of importance.

Each cell in the table contains a linguistic variable, which is used to represent the degree of importance that an expert assigns to a particular criterion or alternative. The linguistic variables used in the table are "Equally important," "Weakly important," "Fairly important," "Strongly important," and "Absolutely important." These variables represent different levels of importance and can be interpreted as fuzzy numbers.

To use table 3.3, an expert is asked to compare two criteria or alternatives and assign a linguistic variable that represents the degree of importance of one over the other. The expert continues to compare each pair of criteria or alternatives until all pairwise comparisons have been made. The result is a matrix of linguistic variables that can be used to calculate the weights of the criteria or alternatives using a fuzzy logic approach.

Overall, Table 3.3 provides a structured way to collect and organize expert opinions about the relative importance of different criteria or alternatives in a hierarchic structure. By using linguistic variables to represent the degree of importance, the table allows for uncertainty and imprecision in the decision-making process.

**Table 3.3.** Fuzzy Triangular Scale

Fuzzy Triangular scale
1 Equally important (1,1,1)
3 Weakly important (2,3,4)
5 Fairly important (4,5,6)
7 Strongly important (6,7,8)
9 Absolutely important (9,9,9)

**Source:** (Right, Saaty, 1990)

Table 3.3 represent a 9-point scale presented by Saaty in 1990, where each number represents a specific level of importance. The numbers 1 to 9 are assigned to the linguistic variables in a way that reflects their relative importance and the degree of certainty. For example, a value of 1 indicates a very low degree of importance, while a value of 9 indicates a very high degree of importance. The Saaty scale provides a structured and systematic way to incorporate expert knowledge and subjective judgment into the decision-making process.

It allows for the quantification of uncertain and imprecise data, making it a useful tool for applications such as multi-criteria decision analysis and decision-making under uncertainty.

A square matrix is created using the pairwise comparisons of the various criteria generated in step 2. The matrix's diagonal members are 1 in number. The comparison matrix's major value and the related normalized right eigenvector indicate the relative weights assigned to the various criteria. Concerning the criteria or sub-criteria, the components of the normalized eigenvector are referred to as weights, and the alternatives, as ratings.

The order “n” matrix's consistency is evaluated. This method uses subjective comparisons, and the level of redundancy allows the AHP to accept inconsistencies. AHP has many advantages over other decision-making methods. It is a flexible and intuitive method that can be used to evaluate and prioritize a wide range of alternative solutions (T. Belton, V., & Gear, 2002). It is also easy to use, even for people with limited mathematical or analytical skills. The use of pairwise comparisons helps to minimize the subjectivity of the decision-making process and provides a clear and transparent method for evaluating alternatives.

However, like any other method, AHP also has its limitations. The method relies on the accuracy and consistency of the pairwise comparisons, which can be affected by personal biases and lack of information (Roy, 2003). Also, AHP is not suitable for problems with a large number of criteria and sub-criteria. Therefore, it is essential to use

AHP in conjunction with other methods such as sensitivity analysis to ensure the robustness and reliability of the final decision.

### **3.3.1. Survey**

In this paragraph, the research questionnaire will be discussed. Firstly, the research questions are presented then the methods and approaches that were implemented are described and finally the anticipated results are presented.

The questionnaire framework consists of three phases shown in fig. in which the research problem and the relevant question are solved. The first phase discusses the environmental factor having air, water, and noise pollution effects on the parking system. It gives background knowledge on the topics of parking and parking sustainability. The literature review is carried out to identify several current sustainable developments in parking, in addition to a description of the subjects and relevant methods.

The infrastructure and accessibility of the parking system are included in the economic factor, in the second phase. The third phase consists of some social factors like cost, equity and community.

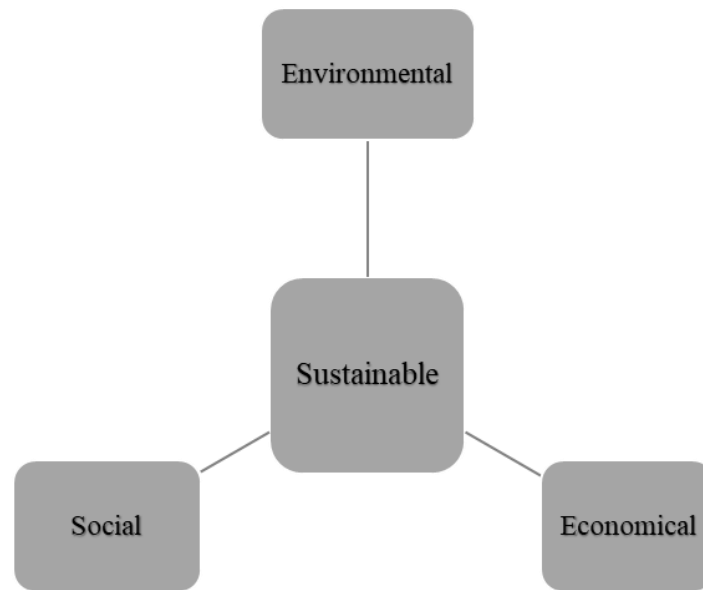
### **3.3.2. Questionnaire Design**

This section describes the selection and design of the questionnaire. In this research data is collected through an internet-based questionnaire. The questionnaire is constructed through google forms which is meant to be a survey tool. The selected participants received a generated link through e-mails and different social media platforms. The unique link guides the respondents' rating criteria and procedure for how to fill out the survey.

At the start of the questionnaire, a brief introduction of the topic is given and then contact information was gathered by the respondents. This questionnaire design consists of three main sustainability factors which are environmental, social, and economic. Different barriers to the parking system are discussed in the questionnaire design based on barriers.

### **3.4. Sustainable Factors**

Sustainability is a complex and multi-faceted concept that encompasses a wide range of factors related to environmental, social, and economic well-being. In the context of parking, sustainable factors refer to the environmental and social impacts of parking facilities and the strategies used to minimize those impacts. Figure 3.5 shows the three pillars of sustainability: environmental, social, and economic. The environmental pillar refers to the impact of parking facilities on the natural environment, such as air and water quality, energy use, and greenhouse gas emissions. The social pillar refers to the impact of parking facilities on communities, including issues such as accessibility, safety, and equity. The economic pillar refers to the cost and financial sustainability of parking facilities, including issues such as revenue generation, operational costs, and return on investment. The three pillars are interconnected and interdependent, and a sustainable parking system must balance the needs and impacts of all three pillars.



**Figure 3.5.** Sustainable factors

Data from governmental and commercial participants in parking are gathered via a questionnaire. Experts representing both parties are invited to complete the questionnaire, which determines the weights of the criteria and evaluates developments.

### **Environmental**

Environmental factors of sustainability refer to the natural and physical components of the planet that play a role in determining the health and well-being of ecosystems and human societies ((UNEP), 2016). These factors include climate change, deforestation, pollution, soil degradation, loss of biodiversity, and over-exploitation of natural resources (European Commission, 2017). Environmental factors of sustainability refer to the various physical, chemical, and biological conditions and influences that affect the well-being of living systems and the planet as a whole (International transport forum, 2016). To achieve sustainability, it is important to understand and address these environmental factors by implementing sustainable practices and policies.

In the context of parking systems, sustainability can be achieved through various environmental factors by providing efficient and convenient parking options, such as carpooling, bike parking, and public transportation can reduce the number of cars on the road and therefore lower carbon emissions (I. P. I. (IPI), n.d.-b). Implementing energy-efficient lighting and ventilation systems in parking facilities can lower energy consumption and costs ((NACTO), n.d.-b). Incorporating green spaces, such as rain gardens, green roofs, and permeable paving, into parking areas can improve air and water quality, and provide a habitat for wildlife ((USGBC), n.d.).

Smart parking systems can improve parking efficiency by dynamically adjusting prices, finding vacant spots and directing vehicles to the nearest available spot. This can

reduce traffic congestion, emissions and parking search time (I. of T. E. (ITE), n.d.). Electric vehicle charging: Providing charging infrastructure for electric vehicles in parking facilities can encourage the use of clean transportation and reduce dependence on fossil fuels (N. R. E. L. (NREL), n.d.). Overall, sustainable parking systems can not only reduce the impact on the environment but also create more livable and efficient communities.

### **Economical**

Economic factors of sustainability refer to the economic systems, practices, and policies that drive the use of resources and impact the environment. This can include the production, consumption, and distribution of goods and services, as well as the use of natural resources, such as water, energy, and minerals (Wackernagel, 2004). To achieve sustainability, it is important to promote economic systems that are environmentally responsible and socially equitable, such as reducing waste and pollution, promoting energy efficiency, and supporting sustainable economic growth (D. Banister et al., 2011). This can also include the development of green technologies, the promotion of sustainable agriculture and forestry practices, and the creation of sustainable jobs and businesses.

The economic factor of sustainability refers to the financial and economic conditions that can influence a business or industry. These factors can include interest rates, inflation, economic growth, and unemployment (T. I. P. I. (IPI), n.d.). In the context of parking systems, economic factors can include the costs of building and maintaining parking facilities, the revenue generated from parking fees, and the economic impact of reduced traffic congestion and increased accessibility (Hepburn, 2007). Economic sustainability can be achieved by implementing strategies that lower the costs of operating and maintaining parking facilities and by maximizing the revenue generated from parking fees (T. N. R. E. L. (NREL), n.d.). For example, a smart parking system may lower operational costs by reducing the need for parking attendants and increasing the efficiency of space utilization (T. I. of T. E. (ITE), n.d.). Additionally, implementing pricing strategies such as dynamic pricing can increase revenue by adjusting prices based on demand.

The numerous economic benefits of automated parking are advantageous to both developers and customers, ensuring profitability while upholding the necessary balance to achieve long-term economic goals in support of sustainable growth (Spreng, 2003). Moreover, by incorporating sustainable infrastructure such as electric vehicle charging stations and bicycle parking, parking facilities can attract new patrons, increase revenue and decrease overall costs ((UITP), n.d.). Overall, sustainable parking systems can not only be cost-effective but also create more livable and efficient communities.

### **Social**

Social factors refer to the cultural, demographic, and societal factors that can influence a business or industry. In the context of parking systems, social factors can include accessibility, safety, community engagement, and the impact on local residents and businesses (Berechree, 2005). Accessibility is an important social factor in parking systems as it relates to the ability of people with disabilities, the elderly, and low-income groups to access parking facilities (I. P. I. (IPI), n.d.-a). The Americans with

disabilities act sets standards for accessibility in parking facilities, but it is also important to consider how the design of parking facilities can promote accessibility for all users (Waschefort, 2006).

Safety is another important social factor in parking systems, as it relates to the ability of users to feel safe and secure while using parking facilities (Council, n.d.). This can include measures such as lighting, surveillance, and emergency response systems (Schmieder-Ramirez, 2008). Community engagement is an important aspect of parking systems, as it can help to ensure that parking facilities are designed and managed in a way that meets the needs and preferences of local residents and businesses ((NACTO), n.d.-a). This can include community meetings, surveys, and feedback mechanisms.

In addition, parking systems can also have an impact on the quality of life of local residents and businesses, by reducing traffic congestion, improving air quality, and providing opportunities for economic development ((NARC), n.d.). Overall, social sustainability in parking systems can be achieved by ensuring accessibility, safety, community engagement and taking care of the impact of parking on society (Flin, 2009).

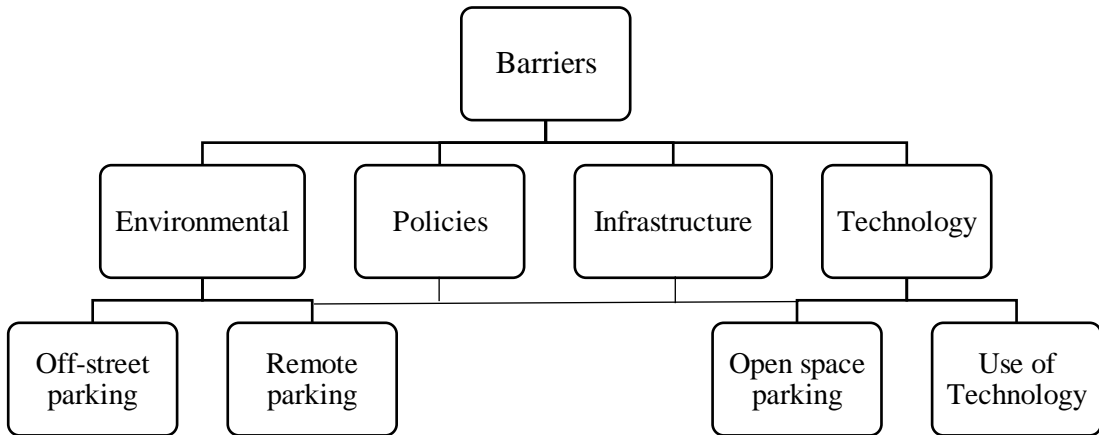
## 4. ANALYSIS

This chapter describes the analysis of the research data, which includes data collection, respondent description, AHP analysis, development evaluation, and dominance judgments by the decision-makers. The expert responses are chosen from a panel of decision-makers from municipalities and parking corporations. A qualitative research approach was used for the research study through the use of interviews. To find possible participants in the deployment of a smart parking system, a questionnaire survey is also conducted. To examine the information gathered through interviews, the researcher used the Analytic hierarchy approach.

### 4.1. AHP Analysis

All computations utilized in the AHP analysis are regarded as being fundamental AHP steps. As a result, an automated Microsoft excel sheet was used to carry out the analysis. Given the fundamental nature of the procedure, the analysis's methodologies and parameters are listed. The quantity of usable datasets is influenced by the consistency ratio. As a result, the consistency of the results is shown first, and then the weights of the other criteria.

Table 4.1 presents the hierarchical structure used in the AHP analysis for evaluating potential solutions to parking barriers. The top level of the hierarchy is the goal, which is defined as "Barrier". The second level includes four types of barriers: Environmental, Policies, Infrastructure, and Technology. The third level presents strategies that aim to address these barriers and improve the parking situation, including Off-street parking, Remote parking, Open space parking, and the use of technology in existing parking spaces. Table 4.1 provides a clear and organized overview of the complex parking problem and how it can be tackled through various strategies. The hierarchical structure helps to break down the problem into manageable components, allowing decision-makers to focus on specific areas that require attention. The use of AHP methodology provides a systematic and objective approach to evaluate the effectiveness of the proposed solutions and determine the optimal course of action. Overall, Table 4.1 is a valuable tool for decision-making in the field of parking management.

**Table 4.1.** Hierarchal structure

Secondly, Determine the relative importance of different attributes or criteria concerning the goal (T. R. Belton, V., & Gear, 2002). Table 4.2 provides a scale of relative importance used in pairwise comparison matrices in AHP analysis. The scale consists of six values representing increasing levels of importance, ranging from 1 for equal importance to 9 for extreme importance. The scale is used to compare different options and determine their relative importance with respect to a specific attribute or criteria. In addition to the six values, Table 4.2 also includes four intermediate values, 2, 4, 6, and 8, which are used when there is not a clear difference in importance between two options. These intermediate values help to provide a more refined evaluation of the options. Furthermore, Table 4.2 includes values for inversed comparison, which are  $1/3$ ,  $1/5$ ,  $1/7$ , and  $1/9$ . These values are used when one option is less important than the other, and they help to provide a more accurate and comprehensive evaluation of the options. Overall, Table 4.2 provides a scale of relative importance that helps decision-makers evaluate and compare different options based on their level of importance with respect to a particular attribute or criteria in AHP analysis. The scale includes different values to handle different scenarios and ensure a more comprehensive evaluation of the options.

**Table 4.2.** Scale of relative importance

1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values
1/3,1/5,1/7,1/9	Values for inversed comparison

**Source:** (Saaty, 1980)

The length of a pairwise matrix is equivalent to the number of criteria used in the decision-making process (Yu, D., & Hwang, 1999). The pairwise comparison matrix values depend on decision-makers. The questions asked the decision-makers about the importance of one factor over the other factors. Criteria weights are obtained by the normalized pairwise matrix. The weights are calculated by averaging all the elements in the rows of a normalized matrix (Wong, 2011).

The next step is calculating the consistency which is to check whether the calculated values are correct or not (Wang, 2017). For this, the pairwise comparison matrix is taken and all the values are multiplied by the criteria weight. By taking the sum of each value in rows it will give a weighted sum value. Then calculated the ratio of weighted sum value and criteria weight for each row. Then  $\lambda_{max}$  will be calculated by averaging all values.

$$\lambda_{max} = 4.446792$$

Next, the Consistency index will be calculated which is given by the formula (Saaty, 1977).

$$\text{Consistency index (C.I)} = \frac{\lambda_{max} - n}{n - 1} \quad (4.1)$$

The Random Consistency Index is used to determine the Consistency Ratio (CR) (Saaty, 1980). The random index is the consistency index of a randomly generated pairwise matrix. The random consistency index for criteria is shown in Table 4.3.

Table 4.3 provides the Random Consistency Index (RCI) values for different matrix sizes. The RCI values are calculated based on a randomly generated pairwise matrix and are used to evaluate the consistency of judgments made in the decision-making process. The table shows RCI values for matrix sizes ranging from 1 to 15. For example, for a matrix size of 4, the RCI value is 0.9. This means that if the calculated Consistency Ratio (CR) for a pairwise comparison matrix with a size of 4 is greater than 0.9, then the judgments made by the decision-makers are considered inconsistent, and the pairwise comparison matrix needs to be revised.

The RCI values in Table 4.3 are used to determine the acceptable threshold for the CR. The CR is calculated by dividing the difference between the maximum eigenvalue and the number of criteria by the number of criteria minus one. The CR value is then compared to the acceptable threshold value, which is determined based on the matrix size and the corresponding RCI value. If the CR value is less than or equal to the acceptable threshold, the judgments made in the pairwise comparison matrix are considered consistent. Otherwise, the pairwise comparison matrix needs to be revised. Table 4.3 serves as a reference for selecting an acceptable threshold for the CR based on the matrix size.

**Table 4.3.** Random Consistency index

Number of criteria	Random index
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

**Source:** (Satty, 1980)

The results of the pairwise comparisons in the questionnaire are used to determine the criteria weights. (Saaty 1980) introduces the Random Consistency Index (RI). As a result of the unpredictability brought on by growing complexity, it is used to split the Consistency Index and is dependent on the number of criteria utilized in the analysis. The RI values are shown in Table 4.3. In this study, group-level and criterion-sublevel criteria are taken into consideration. The RI for the four criteria groups at the group level is 0.90. So, the consistency ratio will be calculated as:

$$\text{Consistency ratio} = \frac{C.I}{R.I}$$

Since the value of the consistency ratio C.R is 0.16 which is not less than the 0.10 standard value it assumes that the matrix is not reasonably consistent. The individual Consistency Ratios (CR) on a group level, as well as for Financial and Sustainability aspects, have been computed for each respondent. Saaty (1980, 1990) recommends a Consistency Ratio of no more than 0.10. Saaty concluded that the result is reliable when the boundary of 10% inconsistency is used. According to the research, the Consistency Ratio in AHP analysis frequently leads to issues. Saaty proposes challenging respondents with their consistency to include consistency checks during the data gathering. Along with reassessing pairwise comparisons, it might be beneficial to take another look at the decision issue and the employed hierarchy model. According to (Karlström et al. (2002), a larger consistency ratio should be used.

So, the decision-making process can be continued using AHP. Based on the requirements, the criteria weights can be used by the decision-makers for further calculations. Table 4.4 displays the criteria weights assigned to different strategies in the AHP analysis. These weights indicate the relative importance of each criterion in achieving the desired outcomes. The table shows four strategies - Environmental aspects, Policies, Infrastructure, and Technology, and their corresponding criteria weights.

**Table 4.4.** Criteria weights of strategies

<b>Strategies</b>	<b>Criteria weights</b>
Environmental aspects	0.549
Policies	0.305
Infrastructure	0.104
Technology	0.040

The highest weight of 54% has been assigned to Environmental aspects, which suggests that they are the most crucial factor in determining the success of the strategies. This indicates that the decision-makers need to focus on developing strategies that minimize the environmental impact of parking facilities. The second-highest weight of 30% has been assigned to Policies, indicating that they play a significant role in achieving the desired outcomes. The policymakers need to ensure that the policies are designed in such a way that they support the development and implementation of sustainable parking strategies.

Infrastructure has been assigned a weight of 10%, suggesting that it is a relatively less critical factor in the success of the strategies. This means that the decision-makers need to focus less on infrastructure and more on other factors to achieve the desired outcomes. Finally, Technology has been assigned the lowest weight of 4%, indicating that it is the least important factor in achieving the desired outcomes. This implies that the decision-makers can give less emphasis to technology while developing and implementing sustainable parking strategies.

Overall, the criteria weights in Table 4.4 provide guidance to decision-makers on how much emphasis should be given to each factor in developing and implementing sustainable parking strategies. The assigned weights help to prioritize the factors and ensure that the decision-making process is objective and consistent.

## 5. FINDINGS

Environmental impact can be seen in the increased amount of open space and biodiversity as a result of parking lot development, as well as the emissions of greenhouse gases and other air pollutants that occur when vehicles cruise for parking. Traveling by private car has become much more convenient. However, increased automobile use has resulted in several significant environmental issues that have a negative impact on our health and standard of living.

The pairwise comparison of several strategies for the environment, policy, infrastructure, and technology will now be normalized in a square matrix. Following the acquisition of the normalized matrices of various factor-related strategies, the strategies will be arranged in a hierarchy. Strategies are ranked according to their weightage. The highest value is ranked first, and the lowest value is ranked last.

### **Fuzzy Weighted Normalized Matrix with respect to Environment**

Now, the pairwise comparison of different strategies will be normalized concerning the environment in a square matrix (Chen, C. L., & Hwang, 1992). By taking the geometric means and average of the pairwise comparison matrix a normalized matrix can be obtained. Table 5.1 is a representation of a Fuzzy Weighted Matrix that compares different strategies based on their environmental impact. The matrix includes four strategies, labeled as S1, S2, S3, and S4. The rows represent the different strategies, and the columns represent the different criteria used to evaluate the strategies. The first column, labeled as "Average (Mi)," represents the average of each strategy with respect to the environment. This value is calculated by taking the geometric means of the pairwise comparison matrix, as described in the previous step. The higher the average value, the more significant the environmental impact of the strategy. The second column, labeled as "Normalized weights," represents the relative importance of each strategy with respect to the environment. The normalized weight is calculated by dividing the average of each strategy by the sum of the averages for all the strategies. The sum of all the normalized weights is equal to 1, indicating that the weights have been scaled to reflect the relative importance of each strategy in terms of environmental impact. The normalized weights help decision-makers to identify the most environmentally friendly strategy based on the relative importance of the environment in the decision-making process. In this case, strategy S1 has the highest normalized weight of 0.337, indicating that it is the most important strategy in terms of its environmental impact. On the other hand, strategy S3 has the lowest normalized weight of 0.155, suggesting that it has the least impact on the environment.

Overall, Table 5.1 provides a useful tool for decision-makers to analyze and compare the environmental impact of different strategies and to identify the most environmentally friendly strategy based on the relative importance of the environment in the decision-making process.

**Table 5.1.** Fuzzy weighted matrix with respect to environment

				<b>Average (Mi)</b>	<b>Normalized weights</b>
<b>S1</b>	0.255	0.331	0.424	0.337	0.331
<b>S2</b>	0.163	0.230	0.313	0.235	0.231
<b>S3</b>	0.127	0.156	0.191	0.158	0.155
<b>S4</b>	0.245	0.281	0.332	0.286	0.281
				1.018	1

### **Fuzzy Weighted Normalized Matrix with respect to Policy**

For policy, the pairwise comparison will be normalized in a square matrix by taking the geometric mean and average. The sum of a normalized matrix will be 1 (Jain, A. K., & Zadeh, 1978). Table 5.2 is a Fuzzy Weighted Matrix that compares different strategies based on their alignment with established policies. The matrix has been normalized by taking the geometric mean and average of the pairwise comparisons, and the sum of the normalized matrix is equal to 1. The table includes four strategies (S1, S2, S3, and S4) and two columns that provide information on the mean scores and normalized weights of each strategy. The mean scores represent the degree to which each strategy aligns with established policies, while the normalized weights indicate the relative importance of policy compliance for each strategy. We can see that S1 has the highest mean score of 0.485, which suggests that it aligns most closely with established policies. On the other hand, S4 has the lowest mean score of 0.054, indicating that it is the least aligned with established policies. When considering the normalized weights, we see that S1 has the highest weight of 0.604, which implies that policy compliance is the most critical factor in determining the success of this strategy. S2, S3, and S4 have normalized weights of 0.222, 0.123, and 0.050, respectively, indicating that policy compliance is less important for these strategies.

Overall, Table 5.2 serves as a tool to compare the policy compatibility of different strategies and to identify the most policy-compliant strategy based on the relative importance of policy compliance in the decision-making process. It provides decision-makers with a clear understanding of the extent to which each strategy aligns with established policies and the relative importance of policy compliance in determining the success of each strategy.

**Table 5.2.** Fuzzy weighted matrix with respect to policy

				<b>Average (Mi)</b>	<b>Normalized weights</b>
<b>S1</b>	0.485	0.604	0.736	0.608	0.603
<b>S2</b>	0.187	0.222	0.261	0.224	0.222
<b>S3</b>	0.125	0.122	0.125	0.124	0.123
<b>S4</b>	0.054	0.049	0.048	0.050	0.050
				1.008	1

### **Fuzzy Weighted Normalized Matrix with respect to Infrastructure**

Again, the pairwise comparison of different strategies will be normalized for the infrastructure in a square matrix. Table 5.3 is a Fuzzy Weighted Matrix that compares different strategies with respect to infrastructure. The table shows the average scores of different strategies in terms of infrastructure impact and their corresponding normalized weights. The average score of each strategy reflects the extent to which the strategy aligns with the existing infrastructure, while the normalized weight shows the relative importance of infrastructure compatibility for each strategy. We can observe from Table 5.3 that S1 has the highest mean score of 0.492, indicating that it aligns most closely with the existing infrastructure. S2 has a mean score of 0.190, S3 has a mean score of 0.073, and S4 has a mean score of 0.095, suggesting that they are less compatible with the existing infrastructure. Looking at the normalized weights, we see that S1 has the highest weight of 0.614, indicating that infrastructure compatibility is the most crucial factor in determining the success of this strategy. S2, S3, and S4 have normalized weights of 0.225, 0.083, and 0.078, respectively, which suggests that infrastructure compatibility is less important for these strategies.

Overall, Table 5.3 provides a tool to compare and analyze the infrastructure compatibility of different strategies and to identify the strategy that best aligns with the existing infrastructure based on its relative importance in the decision-making process.

**Table 5.3.** Fuzzy weighted matrix with respect to infrastructure

				Average (Mi)	Normalized weights
<b>S1</b>	0.492	0.614	0.748	0.618	0.613
<b>S2</b>	0.190	0.226	0.265	0.227	0.225
<b>S3</b>	0.073	0.083	0.094	0.083	0.083
<b>S4</b>	0.095	0.075	0.066	0.079	0.078
				1.008	1

### Fuzzy Weighted Normalized Matrix with respect to Technology

Technology refers to the use of scientific knowledge and innovations to create new products or improve existing ones, ultimately increasing efficiency and productivity. In the context of Table 5.4, technology is a key factor for evaluating and comparing different strategies.

Table 5.4 presents a Fuzzy Weighted Matrix that compares various strategies with respect to their level of technological advancement. The average values of each strategy represent the degree to which they are technologically advanced. The normalized weights of each strategy indicate the relative importance of technology for that strategy. By normalizing the weights, this matrix highlights the significance of technology for each strategy in the decision-making process. Overall, this matrix serves as a useful tool to compare and evaluate different strategies in terms of their technological compatibility.

**Table 5.4.** Fuzzy weighted matrix with respect to technology

				Average (Mi)	Normalized weights
<b>S1</b>	0.525	0.607	0.693	0.608	0.606
<b>S2</b>	0.234	0.247	0.262	0.248	0.247
<b>S3</b>	0.124	0.116	0.111	0.117	0.116
<b>S4</b>	0.027	0.028	0.030	0.028	0.028
				1.002	1

After obtaining the normalized matrices for different strategies with respect to various factors, the next step is to categorize the strategies in order of priority. This is done by calculating the overall priorities for each strategy, which are based on the weights obtained for each factor. The strategy with the highest overall priority is considered the most valuable and is given the highest rank, while the strategy with the lowest priority is given the lowest rank. Table 5.5 shows the ranking of the four strategies, where S1 has the highest priority with a weight of 0.329637, followed by S4 with a weight of 0.280014, S2 with a weight of 0.230354, and S3 with the lowest weight of 0.155219. The ranking reflects the relative importance of each strategy in the decision-making process, and can help stakeholders identify the best course of action for parking management based on the available options. Where S1 is On-street and off-street strategy, S2 is the Remote parking strategy, S3 is the Open-space parking strategy and S4 is the use of technology in the existing parking system. Strategy 1 will be ranked first. It is more valuable. It achieved the highest weight and strategy 3 will be ranked last because it achieved the lowest value. Overall Table 5.5 represent the ranking of all strategies.

**Table 5.5.** Ranking of strategies

<b>S1</b>	0.329637
<b>S4</b>	0.280014
<b>S2</b>	0.230354
<b>S3</b>	0.155219

The results from Table 5.5 show that the On-street and off-street parking strategy (S1) is the best strategy to address the barriers to parking in Pakistan. This strategy scored the highest weightage (0.329637) among all the other strategies, which indicates that it is the most important factor in addressing the parking issue. The recommendation for this strategy is to construct off-street parking for specific buildings or facilities, and to encourage people to use distant parking by providing advice and rewards for long-term parking. This approach is cost-effective and can use land that would otherwise be unsuitable. By shifting parking spaces and traffic, it is possible to increase density and reduce the effects of traffic in key areas, improving productivity and environmental quality. In contrast, the Open-space parking strategy (S3) achieved the lowest weightage (0.155219), making it the least significant factor in addressing the parking issue. The recommendation for this strategy is to limit its implementation and to focus on other strategies that offer more effective solutions to the parking problem in Pakistan.

In summary, the fuzzy AHP analysis indicates that the On-street and off-street parking strategy is the best option to address the barriers to parking in Pakistan. The other strategies can also be implemented, but they are less effective and should be used in combination with the primary strategy.

## 6. CONCLUSIONS

This chapter concludes with the findings of the research. The results are first summarized. The conclusions are then presented and discussed. Based on the qualitative data analysis and AHP method, several barriers to sustainable parking systems in Islamabad were identified, including a lack of proper planning and regulations, inadequate infrastructure and technology, and limited public awareness and participation. However, strategies were also proposed to overcome these barriers, such as improving planning and regulation, implementing new technology, and raising public awareness through education and engagement.

The proposed research framework in this study provides a comprehensive method for decision-making by integrating a literature review with Multi-Criteria Decision Analysis (MCDA). The multi-criteria decision-making process incorporates several approaches, including the Analytic Hierarchy Process (AHP), qualitative evaluation, and performances, making it a comprehensive and versatile decision-making method. The study aims to provide a thorough analysis and evaluation of the proposed framework by considering both the overall framework and each of its components, thereby contributing to the field of decision-making.

According to decision-makers, the research approach has been successful in identifying the most promising developments in sustainable parking. It makes it possible to look up criteria weights and look at many different advances. Because, in contrast to AHP, the evaluation job was not connected with the determination of criteria weights, a large number of developments may be evaluated. The combination of methodologies may have made the analysis more challenging. The expert respondents faced challenging tasks as a result of the data collecting. According to the experts' comments on the questionnaire, several of the experts encountered problems because they lacked knowledge of or expertise with the choice criteria. Other qualitative methods, including interviews, could give data directly from experts in the field of environmentally friendly parking options.

From the literature research, relevant decision-makers, criteria, and sustainable developments were identified. To choose from the large number of criteria identified in the literature, it was necessary to construct selection rules and techniques during the research because there were no standardized criteria. A set of criteria could be delivered more effectively through qualitative research, such as interviewing experts from practice and researchers. To determine if the appropriate criteria or developments are chosen, additional interviews may be used.

To determine criteria weights, the AHP method was adopted. The Saaty (1980) method was entirely used. Similar types of pairwise comparisons could be used to evaluate a set number of advancements. It was more effective to use the current research strategy given the uncertain amount of developments at the beginning of this study. In addition, several modifications were made in this study, including using lower scale levels for paired comparisons to lessen task difficulties and a higher acceptable maximum consistency than is often utilized. The sensitivity of the analysis might be increased by

meticulously implementing Saaty's recommendations. Respondents' task performance may be corrected by an automated consistency check in the questionnaire program. The slight variations in the criteria could be the result of an inadequate list of criteria, an unclear description of the requirements, or ignorance. As already said in this paragraph, qualitative research may provide more information on the standards.

Environmental factors, such as limited space and urban density, play a significant role in creating barriers to sustainable parking systems. The increasing demand for parking in urban areas has led to the development of parking structures that consume valuable land, contribute to air and noise pollution, and generate greenhouse gas emissions. To overcome these environmental barriers, it is essential to promote alternative modes of transportation, such as public transit, biking, and walking, and to invest in innovative technologies that reduce the environmental impact of parking. By considering the environmental impact of parking and promoting sustainable transportation options, we can create a more livable and sustainable future for our communities.

The excessive usage of automobiles is a major barrier to the implementation of sustainable parking systems. The widespread reliance on cars as the primary mode of transportation has led to an increased demand for parking, which has put a strain on limited urban space and contributed to environmental degradation. To address this barrier, it is necessary to promote alternative modes of transportation, such as public transit, biking, and walking, and to encourage car-free lifestyles. By reducing the demand for parking and promoting sustainable transportation practices, we can help to create a more sustainable future for our communities.

Technological limitations present a significant barrier to the implementation of sustainable parking systems. While advances in technology have the potential to revolutionize the way we manage and allocate parking, there are challenges associated with developing and implementing new technologies, particularly for small and medium-sized enterprises. The lack of standardization in the field of sustainable parking technology can also lead to confusion and reduced adoption. To overcome these technological barriers, it is crucial to invest in research and development and to establish clear standards and regulations. By working to promote technological innovation and create a supportive environment for the development of sustainable parking systems, we can ensure a more sustainable future for transportation.

Off-street parking can be an effective strategy to overcome some of the barriers to sustainable parking. Providing parking facilities that are located away from street-level, off-street parking can reduce the impact of parking on urban space, minimize air and noise pollution, and provide a safer and more secure environment for drivers and pedestrians. In addition, off-street parking can help to promote the efficient use of space, increase the availability of parking, and reduce the need for street-level parking. To be most effective, off-street parking strategies should be implemented in combination with other sustainable transportation initiatives, such as the promotion of alternative modes of transportation and the use of innovative technologies. By adopting a comprehensive approach to sustainable parking, we can help to create a more sustainable future for transportation.

## REFERENCES

## Articles

- Abraham, S., Ganesh, K., Kumar, A. S., & Ducqd, Y. (2012). Impact on Climate Change Due to Transportation Sector – Research Prospective. *Procedia Engineering*, 38, 3869–3879. <https://doi.org/https://doi.org/10.1016/j.proeng.2012.06.445>
- Ahmed, S., & Muhammad, R. (2018). *Challenges of parking management in Pakistan: An overview*. *Journal of Transport Economics and Policy*, 52(2), 171-189.
- Ahmed, K., Bhattacharya, M., Qazi, A. Q., & Ghumro, N. A. (2021). Transport infrastructure and industrial output in Pakistan: An empirical investigation. *Research in Transportation Economics*, 90, 101040. <https://doi.org/https://doi.org/10.1016/j.retrec.2021.101040>
- AhmetAtalay, Y. (2020). Kentiçi Otopark Analizi: Elazığ İli Örneği. *Journal*, 32(2), 403–413.
- Alizadeh, H., & Ph, D. (2022). *Importance of Transportation*. 1–20.
- Al-turjman, F., & Malekloo, A. (2019). Smart parking in IoT-enabled cities: A survey. *Sustainable Cities and Society*.
- Alexander Litman, T., & Todd Litman Victoria, by. (2021). *www.vtpi.org Info@vtpi.org 250-508-5150 Parking Management Strategies, Evaluation and Planning*.
- Alinia, K., Yarahmadi, A., Zarin, J. Z., Yarahmadi, H., & Lak, S. (2015). Parking Lot Site Selection: An Opening Gate Towards Sustainable GIS-based Urban Traffic Management. *Journal of the Indian Society of Remote Sensing*, 43, 801–813.
- Arem, A. B. S. and B. van. (2010). *Smart Parking Systems*, *Journal of Transport Economics and Policy*.
- Aslam, M., & Hussain, I. (2015). *Examining the challenges of sustainable parking management in urban areas of Pakistan*. *Journal of Sustainable Development*, 8(5), 113-121.
- Asif, S., Wajiha, S., Hassan, B., Sattar, A., & Fahad, M. (2019). Automated Car Parking System. *International Journal of Computer Applications*, 178, 1–2. <https://doi.org/10.5120/ijca2019919078>
- Azshwanth, D., Koshy, M. T., & Balachander, T. (2019). Automated car parking system. *Journal of Physics: Conference Series*, 1362(1), 1–2. <https://doi.org/10.1088/1742-6596/1362/1/012059>
- Baghini, M. S., Ismail, A., Hafezi, M. H., Seifabad, O. K., & Almansob, R. A. (2014). Bus Rapid Transit (BRT) system impacts to environmental quality. *Research Journal of Applied Sciences, Engineering and Technology*, 7(7), 1158–1164. <https://doi.org/10.19026/rjaset.7.400>
- Badassa, B. B., Sun, B., & Qiao, L. (2020). *Sustainable Transport Infrastructure and Economic Returns: A Bibliometric and Visualization Analysis*. 1–24. <https://doi.org/10.3390/su12052033>
- Bamwesigye, D., & Hlavackova, P. (2019). Analysis of sustainable transport for smart cities. *Sustainability (Switzerland)*, 11(7). <https://doi.org/10.3390/SU11072140>

- Banister, A. B. S. and D. (2008). *The Impact of On-Street Parking on Urban Mobility, Journal of Transport Economics and Policy*, 2008.
- Banister, D. (2007). Sustainable transport: Challenges and opportunities. *Transportmetrica*, 3, 91–106. <https://doi.org/10.1080/18128600708685668>
- Banister, D., Anderton, K., Bonilla, D., Givoni, M., & Schwanen, T. (2011). Transportation and the Environment. *Annual Review of Environment and Resources*, 36(1), 247–270. <https://doi.org/10.1146/annurev-environ-032310-112100>
- Barter, P. 2011. (n.d.). *Parking Policy in Asian Cities*. © Asian Development Bank. <http://hdl.handle.net/11540/123>. License: CC BY 3.0 IGO.
- Batool, I., Irshad, M., & Abid, M. (2020). A Policy Move towards Sustainable Urban Transport in Pakistan: Measuring the Social, Environmental and Economic Impacts of Lahore BRT System. *The Lahore Journal of Economics*, 25(1), 27–57. <https://doi.org/10.35536/lje.2020.v25.i1.a2>
- Bell, M. R. (2011). *Dynamic Pricing of On-Street Parking, Transport Reviews*.
- Belton, V., & Gear, T. (2002). A comparison of some methods for priority setting in multi-criteria decision-making. *European Journal of Operational Research*, 136(3), 441–456.
- Belton, V., & Gear, T. R. (2002). *Multiple criteria decision analysis: an integrated approach*. Springer.
- Berechree, S. G. and F. (2005). *The Social Sustainability of Transport*.
- Bhagdev, M., & Agarwal, N. (2017). *Vertically automated rotary parking system*. <https://doi.org/10.1109/RTEICT.2017.8256571>
- Böhringer, C., & Jochem, P. E. P. (2007). Measuring the immeasurable — A survey of sustainability indices. *Ecological Economics*, 63(1), 1–8. <https://doi.org/https://doi.org/10.1016/j.ecolecon.2007.03.008>
- Brown, T., & Dannenberg, A. (2009). (n.d.). *Greening of the Urban Transportation System. Journal of Urban Planning and Development*, 135(4), 221–232.
- Cai, Y., Chen, J., Zhang, C., & Wang, B. (2019). A parking space allocation method to make a shared parking strategy for appertaining parking lots of public buildings. *Sustainability (Switzerland)*, 11(1). <https://doi.org/10.3390/su11010120>
- Caicedo, F. (2010). Real-time parking information management to reduce search time, vehicle displacement and emissions. *Transportation Research Part D: Transport and Environment*, 15(4), 228–234. <https://doi.org/https://doi.org/10.1016/j.trd.2010.02.008>
- Chen, C. L., & Hwang, C. L. (1992). *Fuzzy multiple attribute decision making: methods and applications*. Springer.
- Commission, E. (2017). *Greening Transport: Reducing Greenhouse Gas Emissions from Transport*.
- Conference, T. V. (1996). The Vancouver Conference. *Towards Sustainable Transportation, March*.
- Cook, J. R., Huizenga, C., Petts, R., Sampson, L. R., Visser, C., & Yiu, A. (2017). *RURAL*

*TRANSPORT RESEARCH IN SUPPORT OF SUSTAINABLE DEVELOPMENT GOALS. 87.*

- Council, N. S. (n.d.). *Designing for Safety*.
- Delbosc, A. (2017). Delay or forgo? A closer look at youth driver licensing trends in the United States and Australia. *Transportation*, 44(5), 919–926. <https://doi.org/10.1007/s11116-016-9685-7>
- Dijk, M., & Montalvo, C. (2011). Policy frames of Park-and-Ride in Europe. *Journal of Transport Geography - J TRANSP GEOGR*, 19, 1106–1119. <https://doi.org/10.1016/j.jtrangeo.2011.05.007>
- Dictionary. (n.d.). (<https://www.dictionary.com/browse/on-street-parking>).
- EC. (2001). WHITE PAPER: European transport policy for 2010: time to decide. *Commission of the European Communities, 2001*, 124.
- Emine Pirinc Bayraktar, Ozgur Isinkaralar, & Kaan Isinkaralar. (2022). Usability of several species for monitoring and reducing the heavy metal pollution threatening the public health in urban environment of Ankara. *World Journal of Advanced Research and Reviews*, 14(3), 276–283. <https://doi.org/10.30574/wjarr.2022.14.3.0553>
- Ernesto Sánchez-Triana, Javaid Afzal, Dan Biller, and S. M. (n.d.). *Greening Growth in Pakistan through Transport Sector Reforms*.
- Ewing, E. J. M. and R. E. (2002). *Off-Street Parking Requirements and the Production of Urban Form*, *Journal of the American Planning Association*, 2002.
- Final, C., Id, S., Drs, W., Ra, J., Tu, G. S., Pink, C. E. O., & Faculty, T. (2013). *Master Thesis Towards sustainable parking: decision making of governmental and commercial stakeholders*.
- Flin, R. J. A. and R. E. (2009). *Social Sustainability in Transport: An Assessment Framework*.
- Freudenberg, M. (2003). Composite indicators of country performance: a critical assessment. *OECD Science, Technology and Industry Working Papers*, 16, 35.
- Garrett, M. (2014). American Public Transportation Association. *Encyclopedia of Transportation: Social Science and Policy*. <https://doi.org/10.4135/9781483346526.n56>
- Geurs, K., Boon, W., & Wee, B. (2009). Social Impacts of Transport: Literature Review and the State of the Practice of Transport Appraisal in the Netherlands and the United Kingdom. *Social Research in Transport (SORT) Clearinghouse*, 29. <https://doi.org/10.1080/01441640802130490>
- GörkemGülhan, H. (2010). PARKING MANAGEMENT BASED APPROACH ON PARKING PROBLEM: EXAMPLE OF IZMIR. *Journal*, 12(1), 63–73.
- Greene, D. L. (2015). *Sustainable Transportation* (J. D. B. T.-I. E. of the S. & B. S. (Second E. Wright (ed.); pp. 845–849). Elsevier. <https://doi.org/https://doi.org/10.1016/B978-0-08-097086-8.91073-0>
- H. Dargahwala, A. Goriawala, Z. Balbale, N. M. (2013). GPS Based Parking System for

- Unplanned Metrocities with Visualization of Request Data. *International Journal of Engineering Research and Technology*, 2(10), 2527–2530.
- Haghshenas, H., Vaziri, M., & Gholamialam, A. (2013). Sustainable Urban Transport Assessment in Asian Cities. *Current World Environment*, 8, 221–230. <https://doi.org/10.12944/CWE.8.2.07>
- Han, Q., & Vries, B. De. (2007). *Governance instruments for energy neutral housing developments. 2000*.
- Hao, J., Chen, J., & Chen, Q. (2018). Floating Charge Method Based on Shared Parking. *Sustainability*, 11, 72. <https://doi.org/10.3390/su11010072>
- Hassan, A. M., & Lee, H. (2015). Toward the sustainable development of urban areas: An overview of global trends in trials and policies. *Land Use Policy*, 48, 199–212. <https://doi.org/https://doi.org/10.1016/j.landusepol.2015.04.029>
- Hensher, D. A., & Golob, T. F. (2008). Bus rapid transit systems: a comparative assessment. *Transportation*, 35(4), 501–518. <https://doi.org/10.1007/s11116-008-9163-y>
- Hepburn, C. (2007). *Sustainable Development: A Review of the Economic Literature*.
- Hidalgo, D., Pai, M., Carrigan, A., & Bhatt, A. (2013). Toward People’s Cities through Land use and Transport Integration: A Review of India’s National Urban Investment Program. *Transportation Research Record*, 2394(1), 10–18. <https://doi.org/10.3141/2394-02>
- Imran, M. (n.d.). *Public Transport in Pakistan : A Critical Overview*. 53–83.
- Inan, M., Inci, E., & Lindsey, R. (2019). Spillover parking. *Transportation Research Part B: Methodological*, 125, 197–228. <https://doi.org/10.1016/j.trb.2019.05.012>
- Indicators, T., Indicators, S. T., & Litman, T. (2008). Sustainable Transportation Indicators. *Transportation*, November.
- Jain, A. K., & Zadeh, L. A. (1978). *Concept of fuzzy sets. In Readings in fuzzy sets for intelligent systems (pp. 1-8)*. Morgan Kaufmann.
- Jeon, C., & Amekudzi-Kennedy, A. (2005). Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics. *Journal of Infrastructure Systems - J INFRASTRUCT SYST*, 11. [https://doi.org/10.1061/\(ASCE\)1076-0342\(2005\)11:1\(31\)](https://doi.org/10.1061/(ASCE)1076-0342(2005)11:1(31))
- Kim, R. C. P. and H. J. (2019). *Open Space Parking Management, Journal of Planning and Transportation Engineering*.
- Koczkodaj, W. W. (1992). *A generalization of the Analytic Hierarchy Process. European Journal of Operational Research*, 59(2), 205-216.
- Levinson, D., & Kumar, A. (2005). (n.d.). *Shared Parking. Washington, DC: National Cooperative Highway Research Program*.
- Liang, J.-K., Eccarius, T., & Lu, C.-C. (2019). Investigating factors that affect the intention to use shared parking: A case study of Taipei City. *Transportation Research Part A: Policy and Practice*, 130, 799–812. <https://doi.org/https://doi.org/10.1016/j.tra.2019.10.006>

- Lin, T., Rivano, H., Mouël, F. Le, Lin, T., Rivano, H., Le, F., Survey, M. A., Solutions, P., Transactions, I., & Lin, T. (2017). A Survey of Smart Parking Solutions To cite this version: HAL Id: hal-01501556. *IEEE Transactions on Intelligent Transportation Systems*, 18(12), 3229–3253.
- Litman, T. (2006). *Parking Management Best Practices*. American Planning Association.
- Litman, T. (2010). Guidance For Incorporating Distributional Impacts by. *Victoria Transport Policy Institute, Victoria, British ...*, 8(2), 50–65.
- Litman, T. (2011). Well Measured. *Transportation Research Record, December*, 10–15.
- Litman, T. (2022). *by*.
- Liew, Y., Lim, C. S., Tan, M., & Tan, C. W. (2015). A Review of Multi-Car Elevator System. *Jurnal Teknologi*, 73. <https://doi.org/10.11113/jt.v73.4410>
- Lin, B., & Raza, M. Y. (2020). Energy substitution effect on transport sector of Pakistan: A trans-log production function approach. *Journal of Cleaner Production*, 251, 119606. <https://doi.org/https://doi.org/10.1016/j.jclepro.2019.119606>
- Lockwood, J. H. S. and C. R. J. (2006). *Open Space Parking and Ecological Sustainability, Landscape and Urban Planning*.
- Mahdinia, I., Habibian, M., Hatamzadeh, Y., & Gudmundsson, H. (2018). An indicator-based algorithm to measure transportation sustainability: A case study of the U.S. states. *Ecological Indicators*, 89. <https://doi.org/10.1016/j.ecolind.2017.12.019>
- Malik, F. A., & Malik, F. A. (2017). *Sustainable Parking. April*, 10–14.
- May, A. D. (2013). Urban Transport and Sustainability: The Key Challenges. *International Journal of Sustainable Transportation*, 7(3), 170–185. <https://doi.org/10.1080/15568318.2013.710136>
- Miller, P., De Barros, A., Kattan, L., & Wirasinghe, S. C. (2016). Public transportation and sustainability: A review. *KSCE Journal of Civil Engineering*, 20, 1076–1083. <https://doi.org/10.1007/s12205-016-0705-0>
- Moavenzadeh, J., Chiesa, T., Ammirati, S., Doherty, S., Lanitis, J., Sayler, P., Bernard, M., & Aase, G. (2012). Sustainable Transportation Ecosystem: Addressing sustainability from an integrated systems perspective. *World Economic Forum, April*, 53.
- Mohareb, N., & Felix, M. (2017). Affordable and Common Modes of Transportation in Developing Cities and Their Effect on the Sustainability of Streets. *Procedia Environmental Sciences*, 37, 319–329. <https://doi.org/10.1016/j.proenv.2017.03.062>
- Mosaberpanah, M., & Darban Khales, S. (2013). The Role of Transportation in Sustainable Development. In *American Society of Civil Engineers*. <https://doi.org/10.1061/9780784412688.053>
- Muhammad, R., & Ahmed, S. (2019). *Analysis of the current state of parking management in Pakistan. Journal of Transport Economics and Policy*, 53(3), 191–214.
- Ozturk, D., & Kilic-Gul, F. (2020). GIS-based multi-criteria decision analysis for parking site selection. *Kuwait Journal of Science*, 47(3), 2–15.

- Patrick Auwerx, Robert Pressl , Ivo Cré (Polis), N. K. & T. R. (2019). *Parking and Sustainable*.
- Parking, A. (2020). *A research on fully automated parking systems and operational planning and control problems Tam otomatik otopark sistemlerinde operasyonel planlama ve kontrol problemleri üzerine bir araştırma A research on fully automated parking systems and operational* . 4, 2239–2254. <https://doi.org/10.17341/gazimmfd.695676>
- PIDE. (2015). *00058561\_Prodoc - Pakistan Sustainable Transport.pdf*.
- Pipitone, E., Caltabellotta, S., & Occhipinti, L. (2021). A life cycle environmental impact comparison between traditional, hybrid, and electric vehicles in the european context. *Sustainability (Switzerland)*, 13(19). <https://doi.org/10.3390/su131910992>
- Pojani, D., & Stead, D. (2015). Sustainable urban transport in the developing world: Beyond megacities. *Sustainability (Switzerland)*, 7(6), 7784–7805. <https://doi.org/10.3390/su7067784>
- Pullola, S., Atrey, P. K., & Saddik, A. El. (2007). Towards an Intelligent GPS-Based Vehicle Navigation System for Finding Street Parking Lots. *2007 IEEE International Conference on Signal Processing and Communications*, 1251–1254.
- Puspitarini. (1967). 濟無No Title No Title No Title. *Angewandte Chemie International Edition*, 6(11), 951–952., 2(6), 65–70.
- Rahman, A., Golam Mostafa, S. M., Shakil, M., Hasan, M., Al, A., & Chowdhury, S. (2020). Multilevel Automated Car Parking System. *Journal of Advanced Research in Dynamical and Control Systems*, 12, 2020.
- Raza, A., Ali, M. U., Ullah, U., Fayaz, M., Alvi, M. J., Kallu, K. D., Zafar, A., & Nengroo, S. H. (2022). *Evaluation of a Sustainable Urban Transportation System in Terms of Traffic Congestion — A Case Study in Taxila , Pakistan*. 1–25.
- Raza, S. S. H. (2011). *Open Space Parking Design and Management, Journal of Transportation Engineering, Part A: Systems*.
- Report, I., Global, S., & Transport, S. (n.d.). *SUSTAINABLE TRANSPORT , SUSTAINABLE DEVELOPMENT Introduction : The importance of sustainable transport for the 2030 Agenda and the Paris Agreement*.
- Rietveld, P., & Stough, R. R. (Eds. ). (2004). *Barriers to Sustainable Transport: Institutions, Regulation and Sustainability (1st ed.)*. Routledge.
- Roegling, R. J. A. and G. P. (2009). *Park-and-Ride in Public Transport, Transportation Research Part A: Policy and Practice*.
- Roman, M. (2022). Sustainable Transport: A State-of-the-Art Literature Review. *Energies*, 15(23). <https://doi.org/10.3390/en15238997>
- Roy, B. (2003). *Multicriteria decision making: an introduction to the analytic hierarchy process*. *Interfaces*, 33(6), 19-43. Saaty, R. W. (1987). The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling*, 9(3), 161–176. [https://doi.org/https://doi.org/10.1016/0270-0255\(87\)90473-8](https://doi.org/https://doi.org/10.1016/0270-0255(87)90473-8)
- Saaty, T. L. (1977). *A scaling method for priorities in hierarchical structures*. *Journal of mathematical psychology*, 15(3), 234-281.

- Saaty, T. L. (1980). *The analytic hierarchy process*. McGraw-Hill.
- Schiavo, F. T., Calili, R. F., de Magalhães, C. F., & Fróes, I. C. G. (2021). The meaning of electric cars in the context of sustainable transition in Brazil. *Sustainability (Switzerland)*, *13*(19), 1–24. <https://doi.org/10.3390/su131911073>
- Schiller, P., & Kenworthy, J. (2017). An introduction to sustainable transportation: Policy, planning and implementation: Second edition. In *An Introduction to Sustainable Transportation: Policy, Planning and Implementation: Second Edition*. <https://doi.org/10.4324/9781315644486>
- Schmieder-Ramirez, L. P. (2008). *Sustainable Transport: A Review of the Social and Behavioral Aspects*. Schwanen, A. B. (2008). *The Impact of Park-and-Ride on Urban Mobility*.
- Schwanen, M. R. B. and A. B. (2012). *Mobile Payment for On-Street Parking*, *Journal of Transport Economics and Policy*.
- Schwedes, O., & Hoor, M. (2019). Integrated Transport Planning: From Supply- to Demand-Oriented Planning. Considering the Benefits. *Sustainability*, *11*, 5900. <https://doi.org/10.3390/su11215900>
- Ševčenko-Kozlovska, G., & Čižiūnienė, K. (2022). The Impact of Economic Sustainability in the Transport Sector on GDP of Neighbouring Countries: Following the Example of the Baltic States. *Sustainability (Switzerland)*, *14*(6). <https://doi.org/10.3390/su14063326>
- Sheth, A., & Sarkar, D. (2020). Socio-Economic Feasibility Analysis for Sustainable Mass Rapid Transit Project in Western India. *Journal of Construction in Developing Countries*, *25*, 129–151. <https://doi.org/10.21315/jcfdc2020.25.2.5>
- Shoup, D. (2005). *The High Cost of Free Parking*. Chicago: American Planning Association. *The High Cost of Free Parking*. Chicago: American Planning Association.
- Shafiullah, M., Rahman, S. M., Mortoja, M. G., & Al-Ramadan, B. (2016). Role of spatial analysis technology in power system industry: An overview. *Renewable and Sustainable Energy Reviews*, *66*, 584–595. <https://doi.org/https://doi.org/10.1016/j.rser.2016.08.017>
- Shao, C., Yang, H., Zhang, Y., & Ke, J. (2016). A simple reservation and allocation model of shared parking lots. *Transportation Research Part C: Emerging Technologies*, *71*. <https://doi.org/10.1016/j.trc.2016.08.010>
- Shoup, D. (1997). *The High Cost of Free Parking*. *Journal of Planning Education and Research*, *17*, 3–20.
- Sipahi, S., & Timor, M. (2010). The analytic hierarchy process and analytic network process: An overview of applications. *Management Decision*, *48*(5), 775–808. <https://doi.org/10.1108/00251741011043920>
- Spreng, R. K. P. and T. P. (2003). *The economic benefits of sustainable transportation*. TBRP 2005. (n.d.). 2005.
- Tucho, G. T. (2022). A review on the socio-economic impacts of informal transportation and its complementarity to address equity and achieve sustainable development

- goals. *Journal of Engineering and Applied Science*, 1–16. <https://doi.org/10.1186/s44147-022-00074-8>
- Üniversitesi, T., Fakültesi, İ., & Bölümü, İ. M. (2017). *Urban Accessibility and Affordability : A Case Study for Istanbul Kentsel Erişilebilirlik Ve Ödenebilirlik : İstanbul İçin Bir Durum*. 620–632. <https://doi.org/10.21205/deufmd>.
- Vale, D., Saraiva, M., & Pereira, M. (2016). Active accessibility: A review of operational measures of walking and cycling accessibility. *Journal of Transport and Land Use*, 9, 1–27. <https://doi.org/10.5198/jtlu.2015.593>
- Vaidya, O. S., & Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research*, 169(1), 1–29. <https://doi.org/10.1016/j.ejor.2004.04.028>
- Verma, A., Rahul, T. M., & Dixit, M. (2015). Sustainability impact assessment of transportation policies – A case study for Bangalore city. *Case Studies on Transport Policy*, 3(3), 321–330. <https://doi.org/https://doi.org/10.1016/j.cstp.2014.06.001>
- Wackernagel, W. E. R. and D. (2004). *The Economics of Sustainable Development*.
- Wang, X. (2017). *Analytic hierarchy process: a literature review*. *International Journal of Information Technology and Decision Making*, 16(05), 897-922.
- Waschefort, A. (2006). *Social Sustainability in Urban Transport*.
- Wells, C., County, T., Growth, U., & Area, M. (n.d.). Skinny Streets and One-sided Sidewalks: A Strategy for Not Paving Paradise. *Design*, 1(3), 135–137.
- Wikipedia. (n.d.). [https://en.wikipedia.org/wiki/Off-street\\_parking](https://en.wikipedia.org/wiki/Off-street_parking).
- Wong, K. Y. (2011). *An introduction to the analytic hierarchy process*. *Interfaces*, 41(2), 138-149.
- Wright, L. (2003). Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities Module 3b: Bus Rapid Transit. *Sustainable Transport: A Sourcebook for Policy-Makers in Developing Cities*, 1–48.
- Wu, J., Wang, B., Wang, R., Ta, N., & Chai, Y. (2021). Active travel and the built environment: A theoretical model and multidimensional evidence. *Transportation Research Part D: Transport and Environment*, 100, 103029. <https://doi.org/https://doi.org/10.1016/j.trd.2021.103029>
- Xiao, H., & Xu, M. (2018). How to restrain participants opt out in shared parking market? A fair recurrent double auction approach. *Transportation Research Part C: Emerging Technologies*, 93, 36–61. <https://doi.org/https://doi.org/10.1016/j.trc.2018.05.023>
- Xie, J., Ye, X., Yang, Z., Yan, X., Lu, L., Yang, Z., & Wang, T. (2020). Impact of risk and benefit on the suppliers' and managers' intention of shared parking in residential areas. *Sustainability (Switzerland)*, 12(1). <https://doi.org/10.3390/su12010268>
- Yazici, M. A., Levinson, H., Ilicali, M., Camkesen, N., & Kamga, C. (2013). A Bus Rapid Transit Line Case Study: Istanbul's Metrobüs System. *Journal of Public Transportation*, 16, 153–177. <https://doi.org/10.5038/2375-0901.16.1.8>
- Ye, X., Sui, X., Xie, J., Wang, T., Yan, X., & Chen, J. (2020). Assessment of the

- economic and social impact of shared parking in residential areas. *Information (Switzerland)*, 11(9). <https://doi.org/10.3390/INFO11090411>
- Yu, D., & Hwang, C. L. (1999). *Multicriteria decision-making theories and methods: a review of the literature (part I)*. *European Journal of Operational Research*, 120(3), 245-258.
- Zegras, C. (2006). Sustainable Transport Indicators and Assessment Methodologies. *Biannual Conference and Exhibit of the Clean Air Initiative for Latin American Cities. Sustainable Transport: Linkages to Mitigate Climate Change and Improve Air Quality*, 17.
- Zhang, C., Chen, J., Li, Z., & Wu, Y. (2018). Predicting Owners' Willingness to Share Private Residential Parking Spots. *Transportation Research Record: Journal of the Transportation Research Board*, 2672, 036119811877294.
- Zhu, Y., Skerlos, S., Xu, M., & Cooper, D. R. (2021). Reducing Greenhouse Gas Emissions from U.S. Light-Duty Transport in Line with the 2 °C Target. *Environmental Science & Technology*, 55(13), 9326–9338. <https://doi.org/10.1021/acs.est.1c00816>
- Zijlstra, T., & Vanoutrive, T. (2018). The employee mobility budget: Aligning sustainable transportation with human resource management? *Transportation Research Part D: Transport and Environment*, 61, 383–396. <https://doi.org/https://doi.org/10.1016/j.trd.2017.10.005>

**Books**

Inan, M., Inci, E., & Lindsey, R. (2019). Spillover parking. *Transportation Research Part B: Methodological*, 125, 197–228. <https://doi.org/10.1016/j.trb.2019.05.01>

**Thesis**

Final, C., Id, S., Drs, W., Ra, J., Tu, G. S., Pink, C. E. O., & Faculty, T. (2013). *Master Thesis Towards sustainable parking: decision making of governmental and commercial stakeholders.*

**Websites**

Ali, M. (2015). Smart parking system retrieved from

<https://blog.parkman.io/smart-parking-sustainable/>

Britannica, k. (2009). Pipeline of transportation retrieved from <https://kids.britannica.com/students/article/transportation/277414#:~:text=ship%20C%20and%20pipeline.-,The%20Need%20for%20Transportation,than%20it%20consumes%20of%20other%20s>

Jhon, S. (2021). Off street parking retrieved from

<https://link.springer.com/article/10.1007/s11625-018-0627-5/figures/1>

Maps, Google (2022). Coordinates of Islamabad retrieved from

[https://www.google.com/search?q=islamabad&source=lnms&tbn=isch&sa=X&ved=2ahUKEwiAmsKbiOj7AhVsTaQEHPtAKYQ\\_AUoAnoECAIQBA&biw=1350&bih=590&dpr=1](https://www.google.com/search?q=islamabad&source=lnms&tbn=isch&sa=X&ved=2ahUKEwiAmsKbiOj7AhVsTaQEHPtAKYQ_AUoAnoECAIQBA&biw=1350&bih=590&dpr=1)

Smith, K. (2022). Car lifting system retrieved from

<https://www.jagahonline.com/blog/wp-content/uploads/2022/02/Car-lifting.jpg>

Smith, K. (2022). Car lifting system retrieved from

<https://www.jagahonline.com/blog/wp-content/uploads/2022/02/Automated-Vertical-Car-Parking-System.jpg>

Zhu, K. (2022). Elevating car parking retrieved from

<https://www.jagahonline.com/blog/wp-content/uploads/2022/02/elavating-car-parking.jpg>

Zaako, M. (2010). Pillars of sustainability retrieved from

<https://apcpark.com/blog/automated-parking-and-the-three-pillars-of-sustainability/>

## APPENDIX

### APPENDIX A: Questionnaire of survey

The purpose of this appendix is to provide a detailed explanation of the questionnaire designed to gather information about the barriers to implementing sustainable parking systems. The appendix includes a copy of the questionnaire, a question-by-question explanation, results, validity and reliability information, and a list of references. The information contained in this appendix is intended to ensure that all respondents understand the questions being asked and that the questionnaire is valid and reliable. The appendix is organized in a clear and easy-to-follow manner, with the numbering of the questions in the questionnaire.

The questions explained in (Appendix A) consist of issues and problems related to the parking system in Islamabad, Pakistan. From improper parking systems causing the heat island effect, to congested and open-air parking systems causing noise and air pollution, to the lack of parking signs and public awareness, these problems highlight the need for proper planning and implementation of the parking system in Islamabad. Additionally, there is a need for proper training for drivers, adequate parking spaces, and a revision of parking policies, as well as considering parking criteria in town planning and building codes. The lack of off-street parking facilities and the presence of narrow streets also contribute to the traffic congestion problem in the city. Improving the parking system in Islamabad can help reduce these problems and promote sustainability.

1. The heat island effect mostly causes by improper parking systems in Islamabad.
2. Congested and open-air parking systems cause noise and air pollution in Islamabad.
3. Runoff from parking spaces causes water pollution.
4. Each family in Islamabad has three vehicles (the Islamabad population is about 1 million and the total number of registered vehicles is 0.7 million).
5. Residents of Islamabad prefer to use their vehicles rather than public transport.
6. The perception that the frequency of usage of automobiles by government institutes (bureaucrats, presiding bodies) is illogical.
7. The automobile industries in Pakistan are mainly dependent upon fossil fuels which provide an open-hand gateway for excessive emission of Greenhouse gases.
8. Excessive automobile usage by the residents of Islamabad is due to fewer public transportation facilities.
9. Relevant information and training are neither provided by the Driving Institute nor considered in the driving test.
10. The number of parking signs on roadways is minimum which ultimately leads to unwariness and violation of traffic rules.

11. The government of Islamabad is not fulfilling its moral duty to provide social awareness of the parking system to motorists (via social media, workshops, webinars, and advertisement screens).
12. Without providing adequate information to motorists a sustainable parking system cannot be achieved.
13. Designated parking areas are used for other services rather than parking (Islamabad stadium, a parking area used as a food street).
14. The existing parking systems have no adequate parking lanes which causes irregular manner in parking.
15. Existing parking spaces lack a focal person and guidelines, which results in in a lack of parking places and an increase in boarding and exiting times.
16. One of the frequent causes of overcrowding in parking lots is cadger's stalls.
17. Parking spaces are at undesirable walking distance from desired destinations (marketplace parking in the Saddar area).
18. Parking needs a lot of time due to the congested and improper design of roadways at entry and exit points which ultimately cause traffic congestion.
19. In open-space parking, drivers are liable for any damage or car theft.
20. There are no facilities for disabled motorists in parking spaces.
21. Existing towns have no proper planning regarding parking systems.
22. Decision makers tend to ignore parking criteria in town planning due to insufficient hope of revenue.
23. The perception that efficient parking places increase the productivity of the town and get the intention of investors and vendors.
24. Ignorance of parking criteria in town planning leads to sustainable development.
25. The lack of a parking system mostly causes a quarrel between drivers while parking.
26. Due to the excess time taking process while parking, a prominent negative change in drivers' attitudes is observed.
27. Parking policies are not revised since 2015.
28. The aforementioned policies are not obeyed by any department.
29. Implementation of these policies requires public awareness and government interest.
30. There needs to add more policies regarding parking criteria.
31. Only some authorized parking places require tickets for parking vehicles.
32. There are no electronic or digital ticketing technologies in parking zones.
33. Parking zones generate negligible revenue for the government of Islamabad.
34. Motorists mostly like to prefer free parking rather than paid one.
35. Parking pricing policies need to be revised according to consumers' costs and availability.
36. Islamabad also faces narrow streets problems like Rawalpindi.
37. Residential parking is the main reason for traffic congestion on the streets.
38. There are no policies to declare no parking zone in streets.

39. Parking in narrow streets is the main cause of fatal accidents.
40. Parking systems lead towards unsustainability due to less consideration of laws of parking on streets.
41. There is no check and balance of regulation of building construction codes in Islamabad.
42. Extension of roadsides and construction beside the edges of roads are common activities in Islamabad.
43. Building plannings and road models have a strong influence on the parking system.
44. There needs to be the addition of parking zone criteria in the building codes of Islamabad (International Building Code (IBC-2021)).
45. There are no off-street parking facilities in Islamabad.
46. New buildings with a handsome amount of availability need to be constructed in Islamabad.
47. All required parking spaces shall remain open and accessible for parking during peak hours.
48. Traffic congestion problems can be sorted out with the help of Off-street parking.
49. Parallel parking is a common activity on the service roads of Islamabad.
50. The parallel parking phenomenon wastes a lot of time boarding and exiting.
51. Parallel parking is a better way of parking because it requires less space compared to other parking systems but it requires much driving skills and knowledge.
52. There is no separate infrastructure for the parking system in Islamabad.
53. Marketplaces like shopping malls have inadequate planning for parking systems.
54. The perception is that the productivity of any kind of business is reduced due to the lack of infrastructure for a parking system.
55. Parking systems should be considered an important parameter for designing infrastructure.
56. There are no parking applications to book parking lots and to save time in Islamabad.
57. There are no electronic numbers to remember the parking lot.
58. There is no such technology that estimates total parking time and cost.
59. There are no electronic barriers to safety in parking spaces.
60. CCTV cameras are not installed in parking spaces.

## APPENDIX B: Responses with respect to strategies

The purpose of (Appendix B) is to provide information or supplementary materials for strategies, this appendix contains responses or data gathered while interviewing the decision-makers for different strategies discussed in the methodology chapter. The purpose of including this information in the appendix is to provide a more comprehensive and detailed understanding of the strategies and their outcomes. Based on the information gathered from decision makers, the tables of strategies for a sustainable parking system consists of different barriers such as environmental barriers, policies, infrastructure, and technology. Each of these barriers has been addressed by various strategies to create a more sustainable parking system. These tables provide a clear understanding of the impact of one strategy on other strategies.

Environment	S1			S2			S3			S4		
S1	1.0	1.0	1.0	2.0	3.0	4.0	4.0	5.0	6.0	9.0	9.0	9.0
S2	1.0	1.5	2.0	1.0	1.0	1.0	2.0	3.0	4.0	6.0	7.0	8.0
S3	0.5	0.5	0.5	1.0	1.5	2.0	1.0	1.0	1.0	9.0	9.0	9.0
S4	4.5	4.5	4.5	3.0	3.5	4.0	4.5	4.5	4.5	1.0	1.0	1.0

Infrastructure	S1			S2			S3			S4		
S1	1.0	1.0	1.0	9.0	9.0	9.0	5.0	6.0	7.0	2.0	3.0	4.0
S2	0.1	0.1	0.1	1.0	1.0	1.0	9.0	9.0	9.0	2.0	3.0	4.0
S3	0.2	0.1	0.1	0.1	0.1	0.1	1.0	1.0	1.0	2.0	3.0	4.0
S4	0.5	0.3	0.2	0.5	0.3	0.2	0.5	0.3	0.25	1.0	1.0	1.0

Technology	S1			S2			S3			S4		
S1	1.0	1.0	1.0	5.0	6.0	7.0	4.0	5.0	6.0	9.0	9.0	9.0
S2	0.2	0.1	0.1	1.0	1.0	1.0	4.0	5.0	6.0	9.0	9.0	9.0
S3	0.2	0.2	0.1	0.2	0.2	0.1	1.0	1.0	1.0	9.0	9.0	9.0
S4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.0	1.0	1.0

Policies	S1			S2			S3			S4		
S1	1.0	1.0	1.0	9.0	9.0	9.0	5.0	6.0	7.0	2.0	3.0	4.0
S2	0.1	0.1	0.1	1.0	1.0	1.0	2.0	3.0	4.0	9.0	9.0	9.0
S3	0.2	0.1	0.1	0.5	0.3	0.2	1.0	1.0	1.0	4.0	5.0	6.0
S4	0.5	0.3	0.2	0.1	0.1	0.1	0.2	0.2	0.1	1.0	1.0	1.0