EVALUATING SMART MOBILITY AND LAND USE DEVELOPMENT IN INDIA: A CASE STUDY ON THE CITY OF INDORE, INDIA

By

YASH NAGAL

A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF URBAN AND REGIONAL PLANNING

© 2017 Yash Nagal

To my loving family, friends, faculty members at University of Florida and everyone fighting for the love of learning, your efforts will never be overlooked

ACKNOWLEDGMENTS

I thank my parents Mr. Rajesh Nagal and Mrs. Saroj Nagal for always believing in me no matter what happens and teaching me that there is no power bigger than knowledge and wisdom. I am grateful for my sister Yashika Nagal for her unwavering support and teaching me it is never too late to learn. Apart from this I am thankful for the faculty members at University of Florida, especially, my chair Dr. Ruth Steiner, co-chair Dr. Abhinav Alakshendra and Dr. Paul Zwick for guiding me throughout this research. I would also like to thank the members of the Smart City Indore project for helping me through the data collection and collaboration process. Finally, I am grateful for all friends who have supported me throughout this journey and for their support in the future, especially Alyssa Henriquez for helping me with edits for the final document. None of this would have been possible without you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Master of Urban and Regional Planning

EVALUATING SMART MOBILITY AND LAND USE DEVELOPMENT IN INDIA: A CASE STUDY ON THE CITY OF INDORE, INDIA

By

Yash Nagal

December 2017

Chair: Ruth L. Steiner
Co-Chair: Abhinav Alakshendra
Major: Urban and Regional Planning

It is well recognized that the urban population in the world is growing rapidly and so are the issues in urban areas due to sprawl. Sustainable strategies are required alleviate these problems and sustain the rapidly growing economy. In modern times, smart planning, where city planning is done by integrating information and communication technologies and by largely using big data has emerged as one such strategies. This study focuses on evaluating smart transportation and land use in India and how they change the quality of life in cities both financially and environmentally. The research looks at conducting a case study on Indore, India and evaluating their current smart city program which is called Smart City Indore. India is estimated to have an urban population of 40% by 2030 and 50% by 2050 which calls for evaluation of smart city programs considering the large potential requirement of them in the future. Due to demand for these programs, it is important that these programs work efficiently and make full use of the funds allocated, especially in the case of India where funds always fall short (Jawaid & Khan, 2015). By looking at best practices, recommendations would be made to the current program. With the amount of money being spent on smart

city projects in India and growing need for new developments, evaluation of programs becomes more important. After analysis, the research would make recommendations for improvement in the ongoing program with respect to infrastructural changes for development and land use allocations by presenting ideas for mixed use and walkability centric options.

CHAPTER 1
INTRODUCTION

As estimated by the Indian Government, the GDP is largely contributed by the automotive sector. By the year 2026, its share is expected to be 12% which would make it one of the biggest employment sectors. In the past decade alone, 25 million jobs have been created in the automotive sector (Mehra & Verma, 2016). With increasing Gross Domestic Product per capita, there has been a constant increase in urbanization. Per World Bank data from 2014, 32% of the population is in urban areas and this number is expected to increase to 40% by 2030.

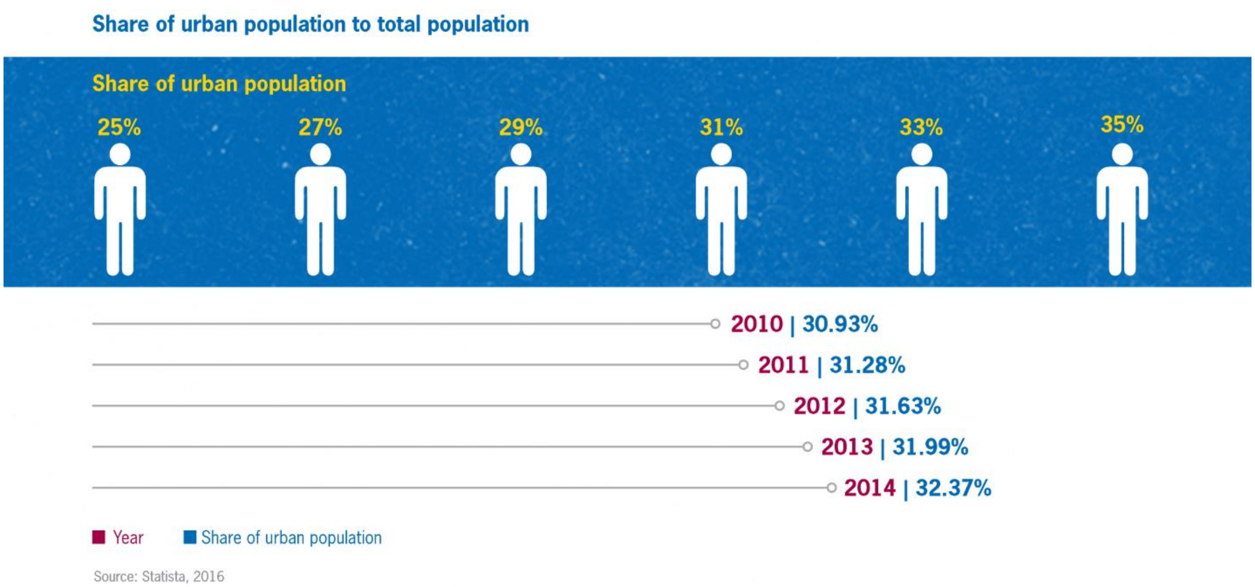


Figure 1-1. Population Share in India

Due to rising incomes and low car penetrations in India, the potential for growth in the auto and auto-component production is high. These factors have boosted the automobile manufacturing industry in India. Society of Indian Automobile Manufacturing estimates that the total production of vehicles from 2013-2014 to 2014-2015 was increased by 8.6% (Mehra & Verma, 2016). With a road network of 2.9 million miles

India has one of the largest road networks. The challenges in this area include road congestion, low usage of technology, inadequate means of public transportation, high air pollution due to vehicles running on combustible fuels and infrastructural flaws. Solutions to these problems are essential as around 65% of freight and 80% of passengers traffic is passed by the roads (Mehra & Verma, 2016).

It is well recognized that the urban population in the world is growing rapidly and so are the issues in urban areas due to sprawl. Sustainable strategies are required alleviate these problems and sustain the rapidly growing economy. In modern times, smart planning, where city planning is done by integrating information and communication technologies and by largely using big data has emerged as one such strategies (Durand et al., 2011). This study focuses on evaluating smart transportation in developing nations and how they change the quality of life in cities both financially and environmentally. Smart transportation includes an infrastructure that supports walkability and higher alternatives for public transport that are affordable for people of all economic levels (Ju et al., 2013). The research looks at conducting a case study on Indore, India and evaluating their current smart city program which is called Smart City Indore.

Analysis of smart city programs are necessary now more than ever because cities are expanding with new cities being formed by transforming villages and towns. With villages and towns lacking basic infrastructure in some places, it is essential that the infrastructural capacity of these places is evaluated. India is estimated to have an urban population of 40% by 2030 and 50% by 2050 which calls for evaluation of smart city programs considering the large potential requirement of them in the future (Smart

City Plan Indore, 2015). Due to demand for these programs, it is important that these programs work efficiently and make full use of the funds allocated, especially in the case of India where funds always fall short (Jawaid & Khan, 2015).

Current transportation infrastructure and transportation future growth plans would be analyzed along with the current and all future land use allocations. For comparative analysis, the research would use other cities which are socio economically comparable to Indore. By looking at best practices, recommendations would be made to the current program. With the amount of money being spent on smart city projects in India and growing need for new developments, evaluation of programs becomes more important. With growing use of technology, it is important to incorporate technology in development strategies and techniques for problem solving. By doing this research I hope to enhance the current program in its transportation initiatives and future transportation development projects. The goals and visions of the Smart City Program are meant be an effective policy instrument for smart growth and conduit for change. To access smart growth in communities, evaluation is essential. Calculating visions and goals include checking the clarity of statements and funding strategies that are being implemented. Apart from this, it is important to see whether the plans are keeping pace with the rhetoric. Research on smart growth has been going on for decades in the world and there sure are debates over its merits. Critics of smart growth claim that this process is costly and in some cases, leads to lack of personal choice and excessive regulations. Due to increased street connectivity in some areas an increase in crime rates was noticed. Evidence suggests that the term smart growth is used as a form of political cover in some policies for programs that have very little to do with the key concerns of smart growth (Mehra & Verma, 2016).

After analysis, the research would make recommendations for improvement in the ongoing program with respect to infrastructural changes for development and land use allocations by presenting ideas for mixed use and walkability centric options.

CHAPTER 2
LITERATURE REVIEW

For the five-year period of 2016 to 2021, the Indian Government has approved 599 highway projects with an expenditure of US $ 16.2 billion and covering approximately 8,064 miles (Mehra & Verma, 2016). For the development of first 20 smart cities, the government has designated US $ 7.6 billion for the project. Within the smart city scheme, resourceful urban mobility and public transit comprise a large part. The plan includes Bus Rapid Transport, Mass Rapid Transport, National Highways, pedestrian skywalks, walkways, cycle tracks and expressways and like all projects these come with challenges too (Smart City Plan, 2015). The table below displays some of the major challenges.

A shift in era towards smart transportation in India can be made by making advances in four major fields:

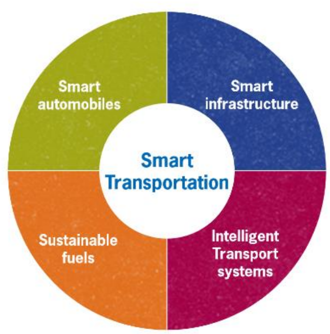


Figure 2-1. Major Fields in Transportation. Source: Smart Transportation - transforming Indian cities.

2.1 Smart Automobiles

2.1.1 Vehicle Technologies

With emphasis on refined engines, safe design, sustainable/ green fuels, better emission norms, connected cars, driverless vehicles and fuel efficiency technological advancements are helping the shift towards smart transportation one step at a time. As driver error is known to be one of the major causes for crash, automakers created a advanced technologies like driver assist systems. Some of these advanced technologies include-

Anti-lock braking system and electronic stability program. Per a study, ESP could result in saving approximately 10000 lives per year in India. This study states that 70 percent of accidents linking to vehicle skidding could be avoided by using ESP in automobiles. Currently, ESP is only enabled in 4-5 percent of new cars as compared to ABS which is fitted in almost 40% of new cars in India (Mehra & Verma, 2016). The manufactures need to increase this number drastically to improve safety.

Automated manual transmission. By using this technology, disengaging and engaging of the clutch is helped by the electronic transmission unit.

Crash testing. As of October 2017, the Indian Government has made crash testing mandatory for all new cars (Mehra & Verma, 2016).

Use of high strength steel. This material is light weight and meets the requirements for today's strict safety regulations at affordable prices.

While these technologies are being applied in India, technological advancements like vehicle to vehicle communication, driverless cars and pre-collision technologies are being used worldwide indicating great room for improvement in developing countries in India. This also gives developing countries a great amount of data to follow and research as best practices.

2.1.2 Electrical Vehicles

Figure 2-2. Types of Engines in Use for Light Vehicles

Per to a study by Center of Automotive Research, University of Duisburg-Essen, Germany, by 2030, only 56% of vehicles worldwide would use combustion engines, 35% would use hybrid technologies and 9% electric power which would reduce Green House Gas emissions substantially. Over the next 15-20% the ideal goal is to make a modal shift towards 100% battery-driven electrical vehicles (Mehra & Verma, 2016). Meanwhile in India, vehicles running on duel-fuel which petrol/diesel and CNG are gaining popularity. Brands like Toyota, BMW and Mahindra have a huge presence in the Indian market. Per the National Electrical Mobility Mission Plan 2020, huge incentives would be made for the adoption of green vehicles and domestic manufacturing. It has been estimated that as of 2017, 5% of the total cars in the Indian car market would be electric (Mehra & Verma, 2016). This would mean 175,000 electric cars in 2017 and this number is expected to reach20 million by 2020 (Mehra & Verma, 2016). With this being said, the slow pace of infrastructural development in India has to be considered as compared to the developed countries.

2.1.3 Connected Cars/Internet of Things (IoT)

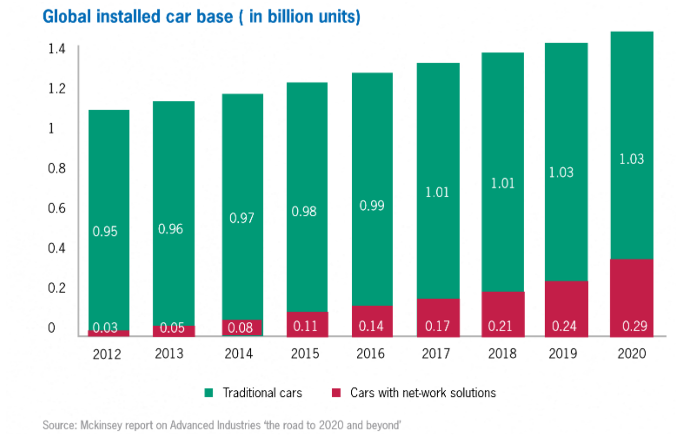


Figure 2-3. Traditional v/s Cars with Network Solutions

This technology uses the internet of things to create a communication network between the different electronic systems within the car as well as outside the car. The goal for the future is to create a communication platform between mobile or wearable devices and the electronic systems of the car through internet. The name for this concept is V2X.

While all these new global technologies are on the rise, there are still concerns amongst the consumers about security implications. Per Veracode, an application security firm, half of the drivers are concerned about driver aid applications like cruise control, self-parking, and collision avoidance systems. Apart from this cybersecurity is a huge concern for automobile manufactures. In 2015, United States came across a flaw in Jeeps equipped with Uconnect software which enabled hackers to take control of the vehicle (Mehra & Verma, 2016). Initiatives to overcome cybersecurity concerns has a major impact on the paradigm shift regarding technological advancements.

2.2 Smart Fuels and Better Emission Standards

2.2.1 Alternative Fuels

In recent years, greenhouse gas emissions have been on a rise leading to the expansion of carbon footprint. A major reason for this has been rapid urbanization which presents a strong need for sustainable and clean technology. Per Environmental Protection and Conservation Authority reports, the Supreme Court banning the sale of diesel engines of 2000cc and more in Delhi NCR resulted in a 19-20% fall in population levels. Unfortunately, this also resulted in job losses for manufacturers and dealers due to unsold inventories. Some well-known solutions to air pollution are use of electric and solar powered engines or use of bio fuels, compressed natural gas or ethanol. A lot of research has been done on biodiesel blending by Indian Oil, a state-owned company with Indian Railways, Haryana Roadways, and TATA group and their initial studies have proposed that the smoke density was reduced by use of biodiesel blends (Mehra & Verma, 2016). Biodiesel blends have the capacity to be used in all modes of transport including roads/BRTs, MRTs, railways, freight, waterborne transport and aviation.

2.2.2 Emission Standards

Based on European standards of emission, the Indian Government regulates the emission standards and follows Bharat Stage emission standards. 13 metro cities in April 2010 moved to Bharat Stage IV and the other cities went to Bharat Stage III and as of October 2014, 20 more cities are now on Bharat Stage IV (Mehra & Verma, 2016). The Government of India is adopting Bharat Stage VI directly after IV to stay updated amongst the high emission laws (Mehra & Verma, 2016). Besides new technologies for vehicles and higher emission standards, India still requires to maintain the current vehicles and better road and traffic standards.

2.3 Smart Physical Infrastructure

The basis for smart infrastructure development was set ten years ago, with the Jawaharlal Nehru National Urban Renewal Mission in India. With an impressive sea port network, second largest road network, four largest rail networks and ninth largest civil aviation market in the world, India is fast growing transportation economy (Mehra & Verma, 2016). In 2015, Prime Minister Narendra Modi launched Atal Mission for Rejuvenation for Urban Transformation which is an incentive based approach for states meeting targets for funding. The target proposed by this scheme is to make ministry of shipping, road transport and highways worth 2% of India's GDP while creating 15 lakh new jobs (Mehra & Verma, 2016). During these projects the total length of national highways is proposed to increase from 60,000 miles to 93,750 miles (Mehra & Verma, 2016). In 2012, India set up the High-Speed Rail Corporation considering the huge success of high speed rail in countries like Japan, China, France and other European Countries. Currently, feasibility studies are going on for connecting Delhi, Mumbai, Chennai and Kolkata and research has been pushed for the development of a segment between Ahmedabad and Mumbai to run bullet trains, a common term for high speed trains (Mehra & Verma, 2016). With decarbonized solutions for high speed trains in the future, United Nations Environment Program claims high speed rail to be a cleaner option compared to others bringing down carbon emissions. The same study also says that high speed rail has lower Green House Gas emissions than road and air transport for per passenger per mile. With increasing global warming concerns, initiatives like these could prove as a major step forward towards sustainable development.

Further, the Ministry is also putting a lot of focus on promoting coastal shipping as it reduces the cost by 25-30% and reduces carbon emissions (Mehra & Verma, 2016). Currently, work is being done to bring up 12 big ports with 3 small ports in West Bengal, Maharashtra and Tamil Nadu (Mehra & Verma, 2016).

2.4 Intelligent Transport Systems

Various Information and Communication Technology interventions combined in an effective manner constitute Intelligent Transportation Systems. Some of such systems are defined below.

Passenger information systems. These systems include providing expected time of arrivals on electric sign boards for bus stands, MRT, Railway stations or Airports while displaying other real time information. Some of these systems also provide information on mobile handsets to ease congestion at waiting areas.

Real-time parking management/ multi-level parking. Real time systems provide information for available parking spots on users mobile phones to reduce congestion on roads and multilevel parking minimize the land use while providing easy entry and exit options. Safety devices and multi sensors can be added at a low maintenance and operating cost.

Smart cards. This technology allows people to access all forms of public transport with one single card. Such technologies are already under consideration by New Delhi and other State Governments.

Electronic toll collection. This technology uses Radio Frequency Identification to read information from a distance and then deduct toll at each entry. By using this the fuel efficiency and traffic management can be enhanced by avoiding the stop-start at toll gates thereby also decreasing congestion.

Smart parking assist. By using censors and cameras in chassis and the driveline, parking can be assisted which also increases efficiency, safety and comfort for inexperienced drivers and learners.

Automated speed enforcement. Considering the congestion in India this technology can effectively reduce the heavy traffic. This technology has already been effectively implemented in other countries.

Airport surveillance and safety equipment. These initiatives include installation of CISF airport security, CCTV surveillance, high tech X-ray baggage inspection facilities and other surveillance systems.

Radio frequency identification in freight transportation. This technology has been growing slowly in India and Indian logistics sector still lags global standards while ranking 46th among 155 countries by International Journal of Multidisciplinary Research and Development.

As time goes on, the Carbon dioxide regulations would continue to get firmer which would create a lot of pressure on manufacturing industries. Promoting emission reducing vehicles in the market result in higher costs of manufacturing. This would also mean high costs for vehicles which would mean bigger profits for the manufacturers in the long run. There would be a push towards investment in e-mobility and alternate powerful technologies to stay up to date with the increasing emission standards. Apart from this, many policies are in place for now and the future to ensure good growth of smart transportation in India. Below is a list of policy interventions:

- National Urban Transport Policy, 2014
- Atal Mission for Rejuvenation and Urban Transformation (AMRUT)
- Automotive Mission Plan 2016-26 (AMP 2026)
- Smart Cities Mission

- Make in India
- Natural Manufacturing Policy
- Skill Development
- Fame India Scheme
- Voluntary Vehicle Modernization/End of Life Policy

With a growing economy of 7.4% in comparison to shrinking western economies, India is in a great spot for impressive growth and is a great destination for investment worldwide (Mehra & Verma, 2016). Apart from this, it has a young human capital base of 550 million with strong policy intervention (Mehra & Verma, 2016). A total of US$27 billion has been provided as budget for upcoming projects by the central government and by 2017, it is expected to provide another US$47 billion for road related projects. Considering these huge investments, India is on the verge of a giant transformation in the field of transportation (Mehra & Verma, 2016). Over the next decade, India plans to bring down carbon emissions while creating a larger job market using sustainable resources. The goal is to bring more and better investments while creating a world class transportation infrastructure which would include green fuels and higher qualities of life both economically and environmentally.

In line with the rising urban population and transportation needs, India still lacks investment. Per India Transport Report- Moving India to 2032, the number of total passengers has been estimated to reach 168,875 BPKPM in 2031 from 10,375 in 2011 which would be a large increase of 15% along with a 9% rail traffic growth and 15.4% road traffic growth per year. This report also estimates that to support a proper infrastructure for this kind of growth there would be requirement of US$ 570 billion funding by the year 2031. Considering the current scenario, most of these investments should go towards improvements towards the transportation infrastructure. The importance of smart transportation is no question in developed western countries, majorly in Europe. From use of electric cars in private transports to rapid metro rail, these countries have fast adopted these sustainable and easy transit technologies for growth. Improved vehicular movement is a huge part improving transportation infrastructure. Following the footsteps of European countries, India has been moving towards technology slowly but surely and while there is a huge difference of policy implementation between developed and developing countries, India has initiated several such programs. A prime example of this the upcoming metro rail network for capital cities with plans for electric cars on the way by 2030. In 2015-2016 Union Budget, US$119.24 million was allocated towards vehicles with hybrid technology. Hybrid vehicles have received a great response and expect more funding in the future.

With smarter policies and private/public partnerships these goals can be achieved faster and more awareness can be created for desired change.

2.5 Case Study City

In the past three years, Indore has made several efforts towards improving transportation conditions. The city has increased its daily ridership from 41,214 to 87,877 and bus fleet to 115 from 85 while introducing Bus Rapid Transit lanes of 7.15 miles (Smart City Plan Indore, 2016). Using ICT and GPS based AVL tracking, 50 bus stops have passenger information systems (Smart City Plan Indore, 2016). Pedestrian footpaths were increased by 13% and 19 miles of non-motor vehicle zone lanes were introduced (Smart City Plan Indore, 2016). Apart from this, the major road network of the city was increased from 43 miles to 61 miles (Smart City Plan Indore, 2016).

Under Safe City Initiative, street lighting coverage of roads has improved to 84% from a pervious of 66% and 165 cameras have been installed for surveillance on 15 intersections (Smart City Plan Indore, 2016).

Per the Smart City Mission Report for Indore, the city fuels the economic engine of the state for Automobile Industries. Along with good connectivity by Air, Rail and Road to all major cities, it also has connectivity to three National Highways NH-3, NH-59 and NH-598A and two state highways SH-27 and SH 34.

Even with these new advancements, the city still lacks spatial planning. Per the same report, industrial and residential areas have been developed without proper infrastructure and lack open public spaces, education, healthcare and adequate road networks. The informal sector is present in both residential and commercial fields with one out of three people being slum dwellers.

2.5.1 Urban Transport Scenario

In the past three years, there has been a 60% increase in traffic congestion and air quality has deteriorated due to more than 10% growth in privately owned vehicles (Smart City Plan Indore, 2016). Furthermore, increased road traffic and safety issues have been raised by poor pedestrian and road facilities. Excluding AICTSL bus services, public transport has been in poor condition with only 0.045 buses per 1000 people while the benchmark is 0.4-0.6 buses per 1000 people (Smart City Plan Indore, 2016). Apart from this, organized road network is exhibited only in 95.3 miles out of possible 222.2 miles (Smart City Plan Indore, 2016).

While all these situations present an enormous opportunity for growth, it is important to keep a check on the developments. As development takes place, there is projected to be a rise in private owned vehicles and with the lack of proper multi-modal transport, this would further exacerbate the traffic congestion problem in the city. Along with this, these would also lead to deteriorate the air quality and adversely impact public health with increased commute times.

Per Smart City evaluation report for Indore, a SWOT analysis was performed and a strategic blueprint for development was made for the next 5-10 years to increase livability and sustainability. The core focus of the strategic road map for Indore is Transit Oriented Development. This strategy is expected to rejuvenate urban form, maintain architectural integrity, cultural inheritance, economic development and digitization (Smart City Plan Indore, 2016).

By using TOD, the aim is to promote compact redevelopment by providing adequate housing for every income group. These also include decreasing travel cost and commute time, dependency on private vehicles, traffic congestion and pollution and crash rates. Apart from this, there is a great emphasis on promoting non-motorized transport options and walking zones to decongest the core of the city. Metro Rail project for the city has been approved along with proposed schemes such as bike sharing systems and park and ride to increase active ridership for alternate modes of public transport (Smart City Plan Indore, 2016).

2.5.2 City Vision and Goals

Urban Mobility is another sector of concern as the lack of public transport options and poor road infrastructure. The foot path coverage is 27.62% as compared to the required standards which are 50-75% as per MoUD SLB (Smart City Plan Indore, 2016). The city has goals to improve these conditions by introducing new provisions. Metro rail has been proposed of 64.05 miles along with 7 miles of BRT in operation (Smart City Plan Indore, 2016). Along with this, intelligent transport systems for traffic management, parking and electronic toll payment methods are in the proposal while improving nodes and interchanges. The aim to create a modal shift from private vehicle towards public transport.

To measure the progress of these transportation goals and advancements, the following indicators can be used:

- Increase in ridership of public transport.
- Better health index
- Improved air quality
- Reduction in carbon footprint

2.6 Walkability and Bicycling as an Economic Alternative

10-20% of total transportation trips are completed by non-motorized modes with links to public transit and privately-owned vehicles (Litman, 2017). Considering walkability as an economic alternative provides mobility to citizens combined with benefits of exercise. Apart from this, is there evidence towards the fact that even when motorized travel has increased, people have been still using bicycling and walking as recreation (Litman, 2017). Improving conditions and infrastructure for bicycling and walking provides an economically feasible way to improve urban transport.

Walking and bicycling have been traditionally more affordable than motorized options. A major value is placed on driving in comparison to walking in conventional planning which reflects how transport is measured (Litman, 2003). As most travel surveys ignore short trips like non-motorized links, walkability is not given a high value in the modes of transportation chain. The figure below shows how walkability is an affordable and convenient mode of travel.

Table 2-1.Affordability in Modal Share. Source: Economic Value of Walkability

Affordable and Efficient	Own and operate an automobile
Walk and bike for exercise	Join a health Club
Walk and bike children to school	Chauffer children to school
Build sidewalks	Build roads and parking facilities

The table below shows the difference between communities considering only walking and communities showing walking linked with other modes of transport.

Table 2-2. Walking Linked to Other Modes of Transport. Source: Economic Value of Walkability.

	Car Only	Walking All or Part	Transit All or Part
Winnipeg	73%	16%	15%
Vancouver	72%	20%	12%
Calgary	72%	21%	12%
Canada	69%	22%	10%
Toronto	61%	24%	20%
Ottawa	60%	33%	16%
Average	68%	23%	14%

Only 7% of Canadian urban communities are entirely by walking although 23% of them involve walking, similarly in Germany, 70% of the trips involve walking but only 22% are completely done by walking (Brog. Erl and James 2003). People on the sidewalks, skaters or skateboarders usually go ignored in the surveys leading to the ignorance of pedestrian activity in traffic surveys (Haze 2000). Per the 2009 National Household Travel Survey, there has been an increase of 25% showing 10.9% of personal trips showing walking and 1% showing bicycling which is twice as indicated by any travel survey. Apart from this, a study shows the number of nonmotorized trips are actually six times greater than indicated by conventional surveys (Rietveld 2000).

When compared in terms of distance of trips, walking looks insignificant but if it is evaluated in terms of number of trips or travel time, it sums up to a huge part of an average travel journey. Per a survey in the U.K., due to slower speeds and waiting periods at bus stops, travelers only constitute 5% of the person trips but 40% of the person minutes (Litman, 2017). Per the same survey, 2.8% of the total mileage is represented by walking but it represents 17.7% of the travel time and 24.7% of the trips (Litman, 2017).

Undervaluing walkability and other non-motorized travel can be detrimental as transportation decisions usually involve adjustments between different travel modes (Litman, 2003). These trends lead to automobile dependent communities because of the funding leading towards creation of wider roads, high speed zones and large parking facilities ("Evaluating Nonmotorized Transportation," VTPI 2008). Major transportation planning is done in a standardized way by using computer models like Highway design and Maintenance Model which assume that a person is better off spending 5 minutes driving to run an errand than walking or cycling for 10 minutes since it gives an equal or greater cost value to non-motorized than motorized trips but these calculations ignore health and recreation benefits of nonmotorized travel (Litman, 2017).

Reasons why walking is undervalued. Difficultly of measurement**.** Measuring walking is relatively a difficult task when compared to motorized travel modes. Counting the number of vehicles and speeds for traffic information is comparatively easy to count than the walkability parameters, especially considering the ignorance in traffic surveys for non-motorized mode of travels. Due to these reasons there is a lack of data on non-motorized travel methods for transportation planners to analyze.

Perception of walking as low status. As traditionally walking has been a mode of travel of the low income communities, especially in developing countries, it is often not valued high and is lesser consideration while selecting a mode of travel.

Ignorance of benefits. Often health and recreation benefits of active transportation are ignored in economic analysis of transportation modes. Apart from this walkability tends to increase mobility for people that cannot afford other modes of transport like privately owned vehicles and even public transport in some cases.

Cost benefits. One of the major reasons for not having an organized walking industry is the inexpensiveness of it as a mode of travel. In developing countries, the funding for walkability tends to be as low as 0.5 % of the total transportation budgets ignoring the chances of consumer cost savings but the prediction of these savings is still tough to predict (Smart City Plan Indore, 2015).

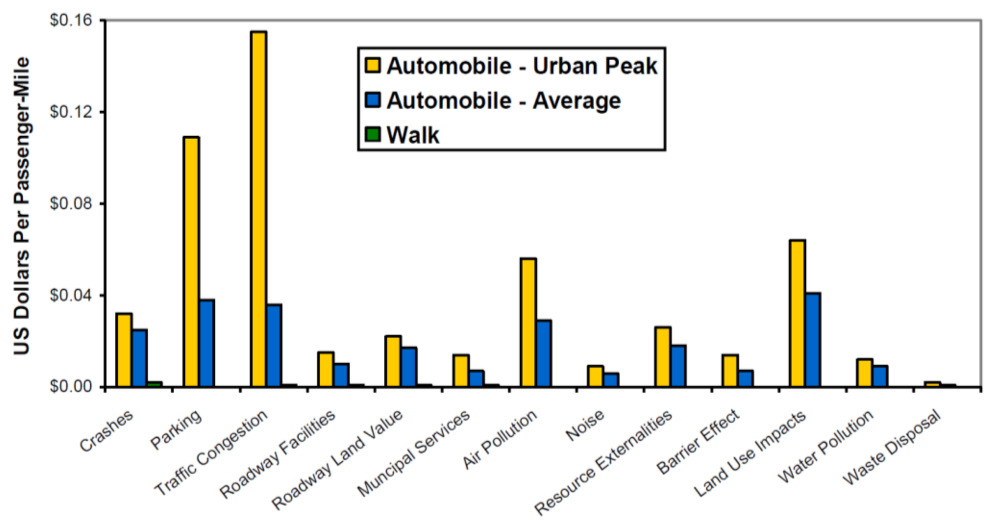
Assuming walkability takes care of Itself. Amongst decision makers, walking is often taken as granted and assumed that it will take care of itself (Goodman and Tolley, 2003). A great example of this is the lack of availability of sidewalks in communities often scaring people away from walking due to safety issues.

Types of economic impacts. The lack of resources for calculating economic benefits leads to ignorance of considering their benefits. The Active Transport Quantification tool (ICLEI 2007) is one such tool to measure benefits like savings from shifting to walking from driving, public health benefits like more exercise, decrease in pollution, accidents and congestion (Litman, 2017).

Accessibility. The ability to reach desired goods, activities and services has been traditionally defined as accessibility (Litman, 2003). Providing basic mobility needs for people who transportation disadvantaged can be achieved by increasing walkability in neighborhoods. Public transportation is a huge part of increasing effectiveness of urban mobility which is why connecting people to public transport is an important issue that needs to be addressed. Transportation disadvantaged people include people with disabilities, low incomes, elderly population and children (Litman, 2017). There are various methods to evaluate accessibility while considering the quality of pedestrian conditions and the geographic distribution of destinations (FDOT 2002; “Evaluating Nonmotorized Transportation,” VTPI 2008).

Consumer cost savings. Improved walkability infrastructure provides consumers to make more savings on vehicle expenses (“Affordability,” VTPI 2008). According to a study, households in car-dependent neighborhoods spend 50% more on transportation related expenses (more than $8,500 annually) than households in neighborhoods with better mixed use patterns and more alternatives for travelling like public transit, bicycling and walking (less than $5,500 annually) (McCann 2000). These savings can be evaluated based on potential savings from other transportation methods. In some cases, improvements in walkability infrastructures lead to reduced vehicle ownership and maintenance costs (Litman, 2017).

Reducing externalities of transport. Use of motorized vehicles leads to various public costs which include costs for parking facilities, gas expenses, risk of crash and environmental damages (Murphy & Delucchi, 1998). To reduce these externalities, a shift from motorized to non-motorized modes of transport has been proved to be an efficient idea. For shorter vehicle trips, which usually tend to have higher vehicle dollar per mile costs, walking can be substituted to bring down costs. When vehicle engines get cold, the energy consumption increases rapidly increasing both the cost as well as environmental damages caused by the vehicles (Litman, 2017). In lieu with this relationship, a long motorized vehicle can be easily substituted by a potential short walking trip reducing externalities especially under peak urban conditions where the engines are running for a long time with minimum to no movement due to traffic congestion.



This figure compares the estimated external costs of automobile and pedestrian travel. Shifting from driving to walking provides savings averaging approximately 25¢ per vehicle-mile reduced, and 50¢ per vehicle-mile reduced under urban-peak conditions.

Figure 2-4. External Costs of Automobile and Pedestrian Travel. Source: Economic Benefits of Walkability

The above figure explains the run down for cost savings on transport externalities by switching from driving to walking. Estimated savings according to this model range from 25 cents per vehicle-mile in normal traffic conditions to 50 cents per vehicle-mile in peak urban traffic conditions (Litman, 2009).

Enhanced mixed land use initiatives. Various economic, environmental and social costs are imposed with the creation of low-density development including large amounts of land surfaced for wide roads and parking facilities (Burchell, 1998).

Improvements in walkability infrastructure can help reduce these costs by supporting Smart Growth initiatives which involve decreasing the amount of land required for transportation facilities and creating neighborhoods more accessible for walking and promoting mixed use patterns (Ewing et al., 2002).

Evaluating these initiatives mandate an understanding of how transportation, especially walkability impact land use patterns (Litman, 2002). Promoting walkability reduces traffic noises and land required for travel and parking while creating more clustered land use patterns. Walkable communities result in high density neighborhoods and reduce per capita land consumption taking a step towards building non-automobile dependable societies. It is important to understand the economic, environmental and social reimbursements of different forms of land use patterns and high density developments (Arnold & Gibbons, 1998).

Livability standards in a community. Community Livability Standards refer to the social and environmental quality of a community for residents, visitors or employees of the community (Weissman & Corbett, 1992). Social Capital refers to the value of community relationships which include intra neighborhood interactions and community participation rates, especially between people of different economic and social backgrounds (Forkenbrock & Weisbord, 2001). These factors create indirect benefits in the society including an increased sense of security and better property values as well as economic growth (Litman, 2011). Community livability increases with more safe and walkable streets in a neighborhood making walkability infrastructure a major contributor for better living standards (Forkenbrock & Weisbrod, 2001). Residents living on high speed and traffic streets have a lesser possibility of interacting with their neighbors than the residents living on less congested and lower speed streets (Appleyard, 1981). In addition, residents living on streets with less traffic show more consideration for the environment (Appleyard, 1981). The increase in property values and business due to better community livability conditions can be evaluated by methods like contingent valuation and hedonic pricing (Litman, 2001). The value of walkability can still be affected by factors community design (Eppli and Tu, 2000), automobile dependency, vehicular street traffic as a factor of pedestrian safety and closeness to public trails (NBPC, 1995). Although it is difficult to establish a direct relationship between reduced crime and walkability, increased community interaction can still be used a measure to lessen crime rates and relatable social issues in neighborhoods (Litman, 2002).

Health. Insufficient physical exercise has been a major cause in creating health problems worldwide. According to health experts, at 30 minutes of moderate exercise is recommended at least 5 days a week with ten minute intervals (Surgeon General, 1999).

According to Killingsworth and Lamming in 2001, the following diseases are directly related to lack of physical exercises,

- Obesity
- Heart disease
- Some forms of Cancer
- Osteoporosis
- Diabetes
- Stroke
- Hypertension
- Depression and dementia

Walking is one of the easiest forms of physical activities and with an increasing population which include children being at a risk of inadequate physical activity, it is the most practical way to avoid this problem (Litman, 2017). According to health experts, better balanced transportation systems enhance public health by promoting active transport, especially for older people who are particularly at a higher risk of diseases (Sallis, et al. 2004). There is research that displays the quantified health benefits of land use planning supporting walkability and bicycling increasing daily physical exercises (Litman, 2009). Per a research by Boarnet, Greenwald and McMilan in 2008, improvements in street design that promote walking lead to reduced fatality rates. The table below gives the quantified framework of the research.

Per a research in 2004 by ECU, 43% of people acquire the recommended physical activity when they live within a ten-minute radius of safe walkable places while only 27% achieve adequate physical exercise when they live in places without safe walkable places. In 2009, Tomalty and Haider conducted a study on how design principles in a community like land use mix and density, street connectivity, availability of sidewalks, walkability index, etc. affect bicycling and walking in a neighborhood and their health benefits across 16 different and diverse neighborhoods. Per this evaluation, there is a statistically significant relationship between increased bicycling and lower body mass indexes as well as lower hypertension while explaining that people living in a more walkable neighborhood have a high probability to walk at least 10 minutes every day while decreasing their chances of being acquiring obesity.

Per a model developed for public health cost savings by Stokes, MacDonald and Ridgeway in 2008, the light rail system in Charlotte, NC is estimated to save a sum of $12.6 million over a period of nine years including the cost savings in health by increased walking and bicycling to the transit stations. New Zealand's Economic Evaluation Manual for Land Transport gives monetary values to the benefits received in health caused by active transportation methods and infrastructure (LTNZ 2010). This evaluation assumes that half of the total benefit is received by the people opting to walk and bike while the other half is received by the society which include savings like hospital cost savings. The table below displays the values.

Table 2-3. Health Benefits of Active Transportation. Source: Economic Benefits of Walkability

		Internal	External	2007 USD/mile
	Low	0.05	0.05	0.1
Cycling	Mid	0.1	0.1	0.19
	High	0.19	0.19	0.38
	Low	0.12	0.12	0.24
Walking	mid	0.24	0.24	0.48
	High	0.48	0.48	0.96

This survey found higher weekly expenditures by consumers who travel by walking than those who drive or rider transit to downtown shopping districts in the UK.

Per international research, a modal shift from motorized vehicles to non-motorized vehicles result in an overall increase in road safety (Litman & Fitzroy, 2005). A prime example of this is the Netherlands, where a great amount of transport is non-motorized and per capita traffic deaths and bicyclist death rate per kilometer is much less than other motorized vehicle dependent countries (Pucher and Dijkstra, 2000). A great evaluation method for calculating public health benefits of walking and biking are public surveys to determine the average daily walking and bicycling miles completed by a person in a neighborhood after improvements in walkability infrastructure (Boarnet et al., 2008).

Growth in economy. Walkability can impact economic growth in an area in various ways which include progression in a community's economic goals, increased business activity in the neighborhood attracting more investments (Leinberger & Alfonzo, 2012). In 2011, Tolley calculated the financial impacts of improved walking and bicycling infrastructure on vendors and residents of the neighborhood. In this study, he discovered that there is an increase in property values and rents and native financial activities with increased businesses opportunities following improved infrastructure for walking and bicycling. Comparing parking space requirements for bicycles and cars, he determined that bicycle parking spaces create a much better retail spending as compared to the spending attained when the same space was used as car parking because of the higher spending trend of people walking or bicycling throw the shops as compared to people driving through the shops (Tolley, 2011). For a person driving through the businesses there is an extra effort involved for finding a parking spot and then walking from the parking spot to the shop as compared to a person that walks or bikes to the store.

In 2009, Sztabinski analyzed the impacts on retailers by creation of bike lanes in Seattle, Washington. Though these resulted in loss of parking on street spaces, the sales went up by 400%. The results of this research were as follow:

- Out of all the customers going to the shops, 90% either walk, bike or use public transit.
- Only 80% of the parking spots were used, even in peak hours.
- Customers who walk or bike spend most compared to customers to drive or use public transit.

- The number of retailers believing wider bike lanes and sidewalks improve business than otherwise is significantly higher.
- Loss in on-street is easily replaced by nearby off-street parking spots.

Table 2-4. Expenditure on Goods by Mode of Travel. Source: Economic Benefits of Walkability

Mode	Weekly Expenditure (£)
Bus	63
Car	64
On foot	91
Train/tube	46
Taxi/cycle	56

This survey found higher weekly expenditures by consumers who travel by walking than those who drive or rider transit to downtown shopping districts in the UK. Source: Economic Value of Walkability

Consumer spending provides better employment and business opportunities in comparison to the spending on fuel and vehicles (Litman, 2004). To evaluate the benefits of walkability on retailers, market surveys and property assessments can be used to analyze the impact on commercial activities, competition, property values and employment opportunities.

Equity. The dispersal of opportunities and resources is defined as equity (Litman, 2017). Equity issues can be divided into several types, two of which are horizontal equity and vertical equity. Horizontal equity prefers to assume that all people should be treated equally whereas vertical equity emphasizes that disadvantaged people deserve extra support (Litman, 2001). Using walkability, fair distribution of public resources can be ensured for non-drivers and better financial circumstances and economic opportunities can be provided for economically and physically challenged people while ensuring basic mobility.

Table 2-5. Indicators of Transportation Equity. Source: Economic Benefits of Walkability

Indicator	Description
Treats everybody equally	This reflects whether a policy treats each group or individual equally.
Individuals bear the costs they impose	This reflects the degree to which user charges reflect the full costs of a transportation activity.
Progressive with respect to income	This reflects whether a policy makes lower-income households better or worse off.
Benefits transportation disadvantaged	Whether a policy makes people who are transportation disadvantaged better off by increasing their options or providing financial savings.
Improves basic mobility and access	This reflects whether a policy favors more important transport (emergency response, commuting, basic shopping) over less important transport.

This table describes five indicators of transportation equity that can be used when evaluating walkability equity impacts.

Source: Economic Value of Walkability

It is crucial to consider various factors while calculating equity impacts of transportation due to the various types of equity. Defining equity objectives and performance indicators is the most practical method for calculating impacts of equity (VTPI, 2008). Though equity benefits are tough to monetize, several neighborhoods place a great value on achieving them (Forkenbrock & Weisbrod, 2001).

2.7 Land Use Conflict Identification Strategy

The LUCIS model has the five following steps:

- Defining goals and objectives
- Data inventory and preparation
- Defining and mapping land-use suitability
- Integrating community values for land use preference
- Identifying potential land-use conflict

In this land use conflict methodology, the preference layers are classified into the low, moderate and low. The resulting matrix includes 27 possible preference values. Firstly, the community weighted values are aggregated for major land use categories as high, moderate and low. This research used the reclassify tool to cover that process.

Hillsborough County in Florida, is the fourth largest county in the state and with Tampa's steadily growing wealth since 2006 it holds as a center for bioscience, financial services, and technology in the international trade market with 96% of its population living in urban areas. The County has used GIS-based decision making tools since 2002 and it has proved beneficial in lieu with the rapid pace of development (Zwick et. al. ,2016).

With intense increase in population numbers, especially in developing countries, there is an increased demand to intensify resources. Tabriz County in Iran used land suitability analysis for their decision-making process to optimize utilization of their agricultural production. Land evaluation techniques were used to develop models to predict land's suitability for various agriculture types (Feizizadeh & Blaschke, 2013). By using this technique, Tabriz County had a clear indication of which areas should increase, decrease or be at the same intensity for agricultural land use. Land use suitability methods provided them with an opportunity for cross-comparison between current land use map and the one created with GIS-assisted suitability analysis.

Developing countries face a major challenge when it comes to using GIS based tools not in technology but in data availability and organization structure (Yeh, 2007). A comprehensive staff training is needed in developing countries to make it a more useful resource in urban and regional planning. This creates a great opportunity for International assistance agencies and GIS software companies (Yeh, 2007).

Cuitzeo Lake Basin, Mexico performed a land use suitability analysis for sanitary landfill sitting with the aim of locating areas in compliance with environment codes and inter-municipality accessibility (Delgado et. at, 2008). Using GIS, biophysical and socio-economic data was processed and the analysis resulted in four potential areas for the site. This GIS based approach turned out to be a low-cost alternative while benefitting and strengthening the decision-making process in developing countries (Delgado et al., 2008).

CHAPTER 3
STUDY AREA

The study selected for this research is Indore, India. In the following figure, demographics are further explained. With a current population of 3.8 Million and geographic area of 130966, it is most densely populated metropolitan in Central India (Census, 2016). Indore has been selected as one of first 100 smart cities to be established in the country. Following the selection, it has also qualified as in the first round of cities to receive funding and resources for development. Recently, it was elected as the cleanest city in India as per Clean India Initiative 2017.

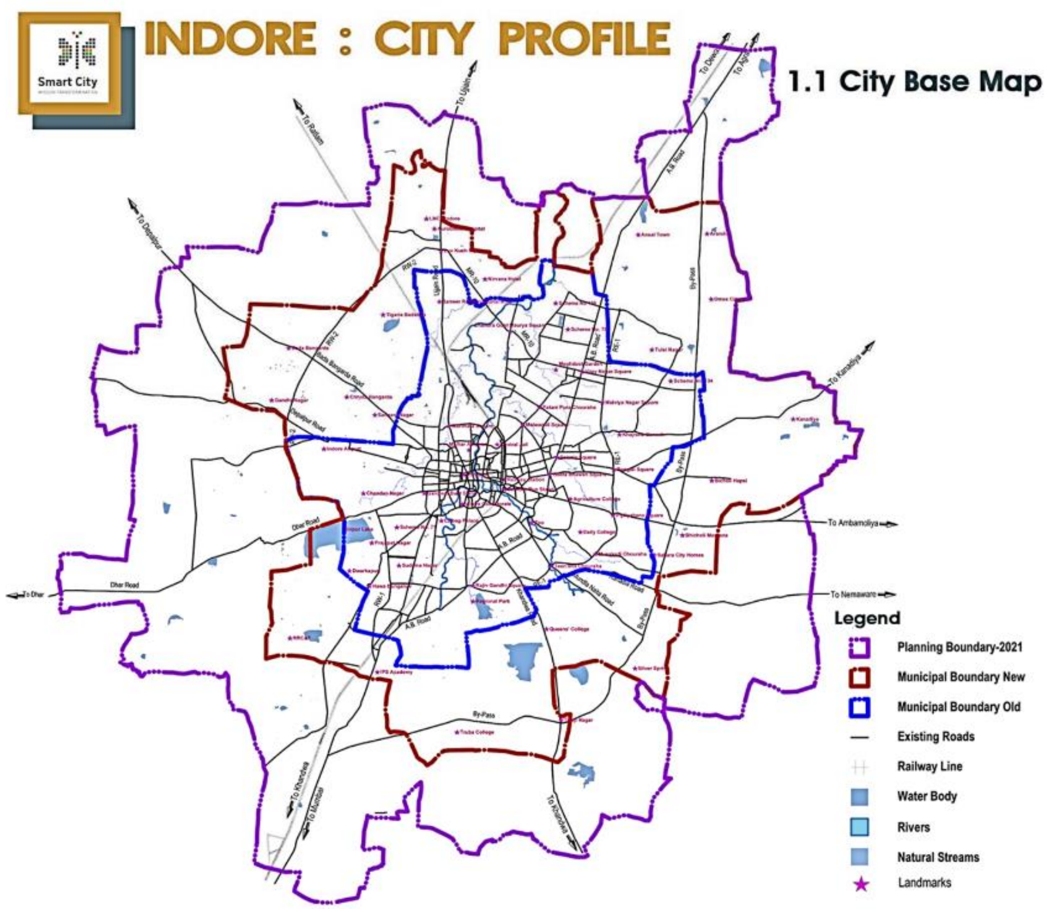


Figure 3-1. Indore, India City Base Map. Source: Smart City Mission Indore

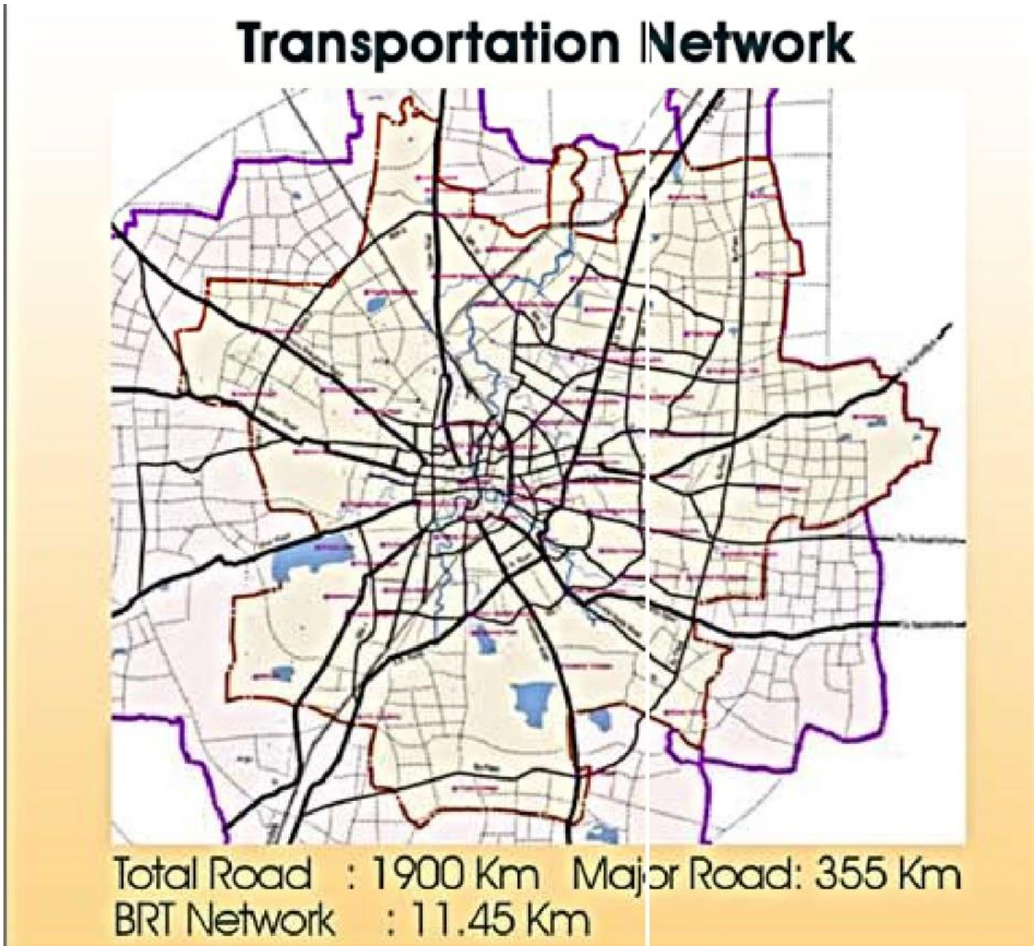


Figure 3-2. Transportation Network in Indore. Source: Smart City Mission Indore

The development to be performed in this project is an area based development. The selected area would be developed into a smart city which would include all essential elements as presented in the Smart City Mission Guidelines. Within this area, approximately 500 acres has been allocated for retrofitting, 50 acres have been allocated for redevelopment and 250 acres for green field development. This area is called Rajwada and the project is called Rajwada Rejuvenation with goals for turning the historic inner city, market areas, riverfront and public spaces to mixed use and sustainable neighborhoods by retrofitting and redevelopment. By creating smarter transit linkages and using TOD strategies, the goal is to bring down traffic congestion in the area and increase walkability.

3.1 Selection of Study Area

Rajwada is considered as the downtown of Indore and selecting this area for an economic transformation was the most lucrative choice. Business centers in Rajwada are on a decline and real estate values are now getting stagnant. Apart from this, the ever-increasing traffic has led to deteriorating traffic conditions and parking problems in the area. Most of public spaces are in close vicinities with slums and lack mass transit which further degrade the quality of living for citizens. By strategically transforming the study area, a domino effect is expected for the transformation of the rest of the city.

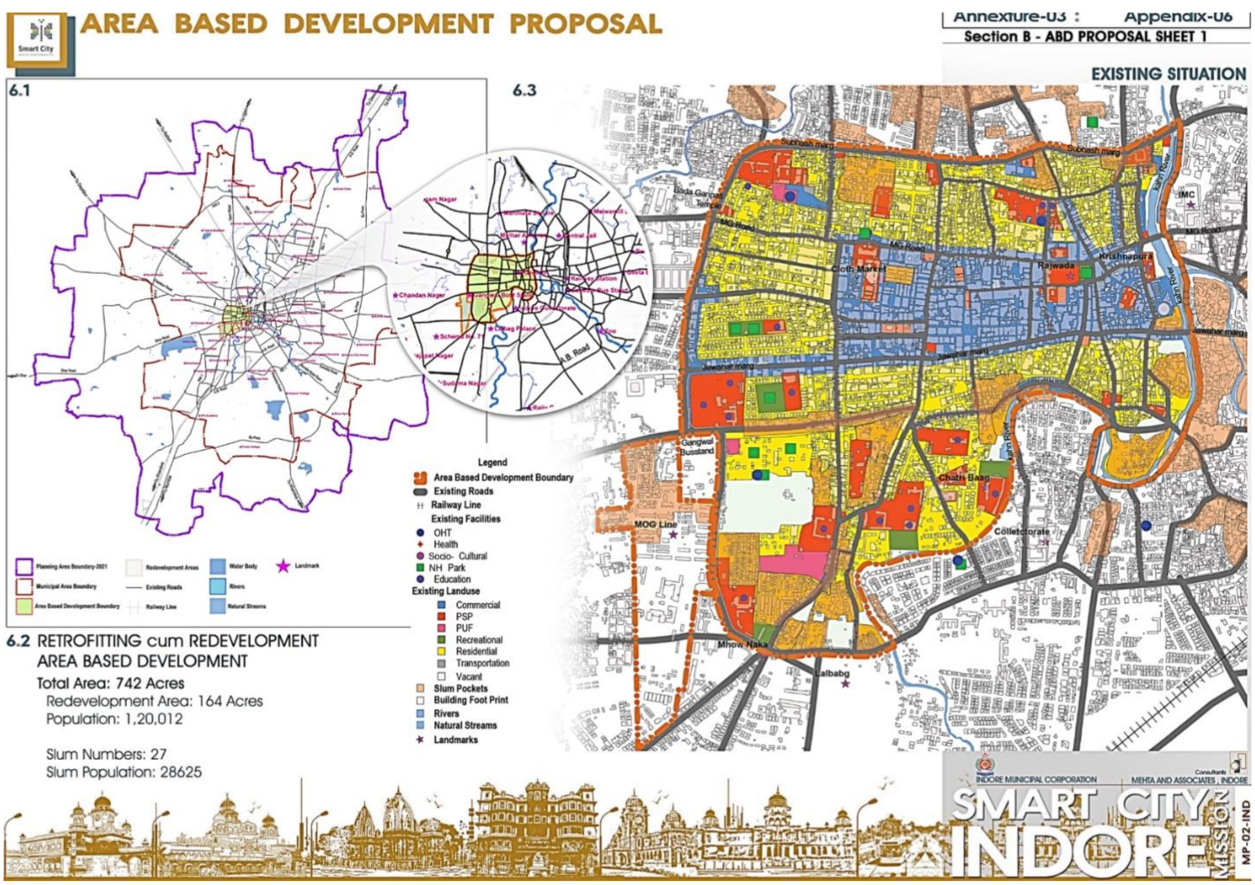


Figure 3-3. Area Based Development Proposal for Indore City. Source: Smart City Mission Indore

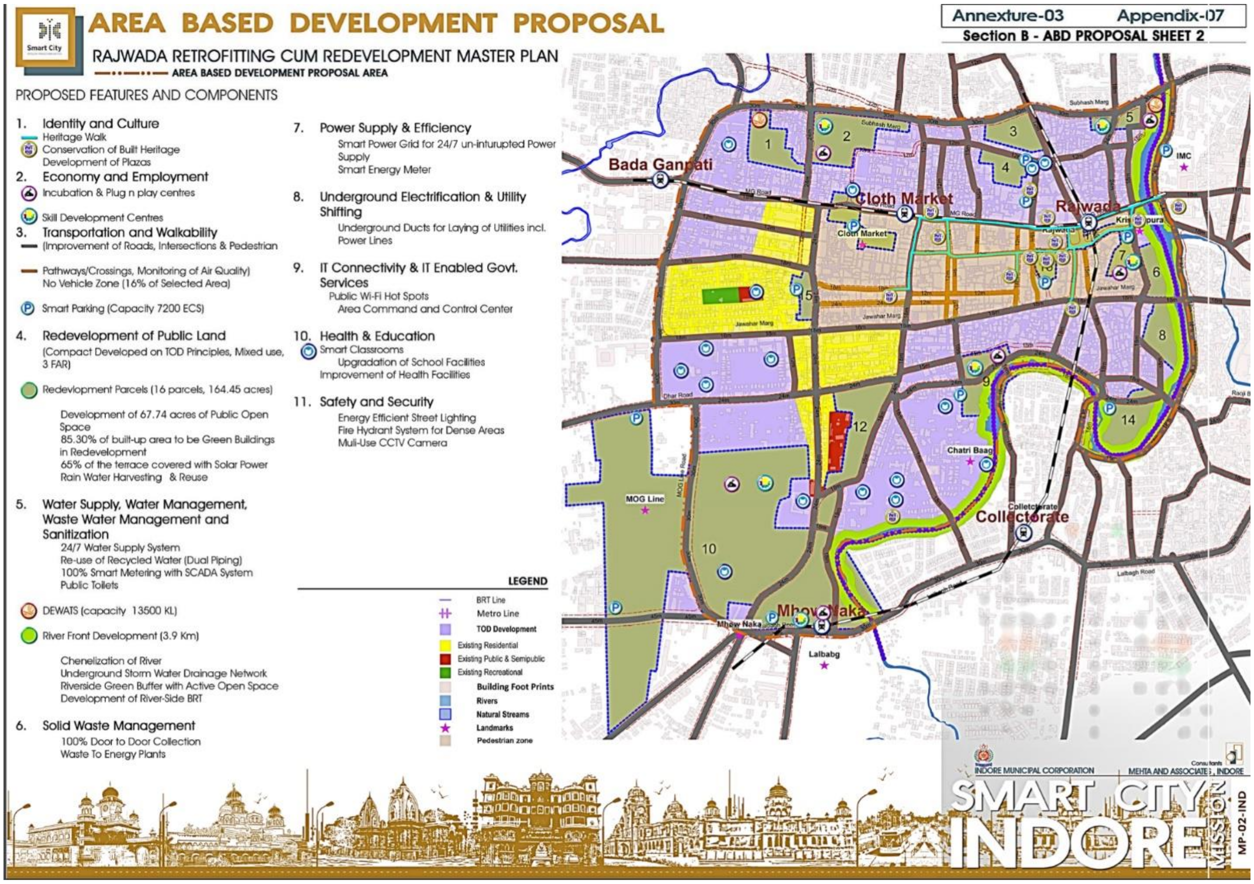


Figure 3-4. Pilot Area for Development in Smart City Indore Plan. Source: Smart City Mission Indore

3.2 City Profile

The key strengths of Indore include Trade and Commerce as it is a center for business and various social groups coexist in the city and these qualities are inherited from Rajwada area. Some weaknesses of Indore include insufficient environmental services, traffic congestion and parking issues. Rajwada best displays both weaknesses and strengths for the city and would be the best prototype for the city. The selected region for Area Based Development, Rajwada is 742 acres in area. The delineation of the area has been done with respect to transit linkages, physical features, coverage of traditional markets and a mix of social and income groups. Most of the areas would best suit retrofitting strategy for transformation to smart city areas. Along with retrofitting, some areas would undergo redevelopment. By redeveloping selected government parcels, land can be monetized making Smart City Proposal financially viable.

The selection of the project being Area Based was constructed with variety of expertise from technical, financial, policy making personals which included planners and experts from the sectors of MoUD, UADD(MP), DFID, Development Authorities and experts from chambers of commerce. The selection of this area is expected to improve the economy and create more jobs. The study area is densely populated and displays the values of Indore very closely. Per financial experts, going forward with this study area would solve two major issues, first, land monetization can be performed, and two, land can be made available to introduce smart features.

The proposal for the study area includes road development, intersection improvements, increased pedestrian safety, promoting TOD designs, smart parking facilities, battery operated alternate modes of public transport, real-time air quality monitoring and Intelligent Traffic Management. Redeveloped land is estimated to include high density mixed use and walkable communities with affordable prices while protecting the aesthetics of current buildings.

CHAPTER 4
METHODOLOGY

Land-Use Conflict Identification Strategy (LUCIS Model). LUCIS is defined as a aim-driven GIS model responsible for providing a spatial illustration of possible patterns of future land use (Zwick & Carr, 2007). This approach is based on the work of Eugene P. Odum.

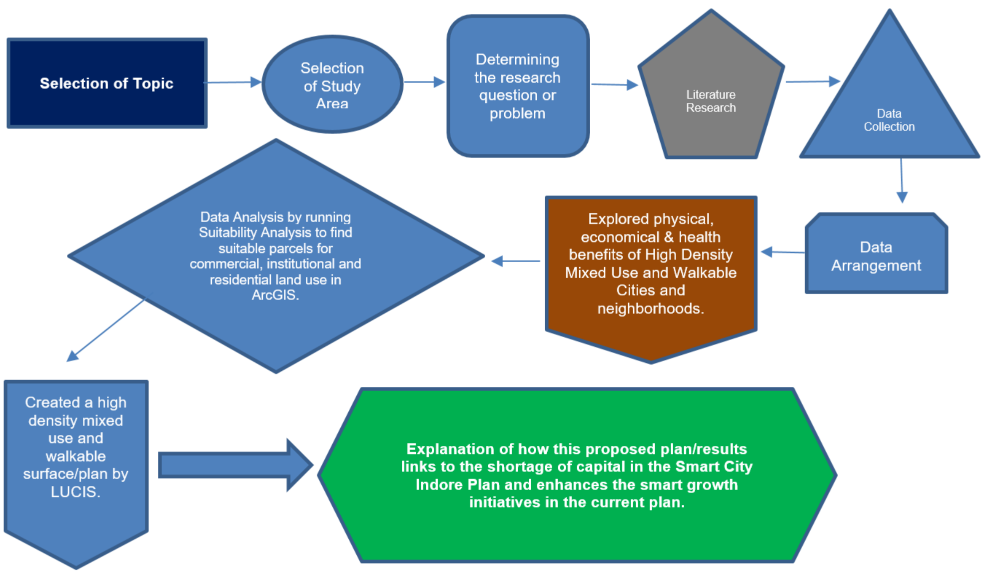


Figure 4-1. Work Flowchart Model

The LUCIS model includes five steps while requiring three stakeholder groups to represent each of the following groups: agriculture, conservation and urban (Zwick & Carr, 2007). All the three groups have the same defined area for study and further their respective suitability is compared for potential conflict. The process is accomplished through the following five steps:

- Goals and objectives are defined for development.
- Data sources are identified for achieve the goals and objectives.
- Data collected is further analyzed to relative suitability.

- Resulting suitability for different land uses is combined using a weighting model, preferably Analytic Hierarchy Process.
- Different land-use preferences are compared to create future land-use conflict.

All land uses generally found in the canopy of urban use are included under the urban-land use category which include residential, office and commercial, retail, wholesale warehouses, institutional, industrial and recreational uses (Zwick & Carr, 2007).

Suitability is defined as the degree to which the land parcel is fit for a specific land use which is measured on a scale of 9 to 1 in this model, 9 being highly suitable and 1 being least suitable (Zwick & Carr, 2007).

Preference is calculated by combining land-use suitability by using a weight that decides the importance of that particular land use and measures to what degree a land-use is preferred for a land use.

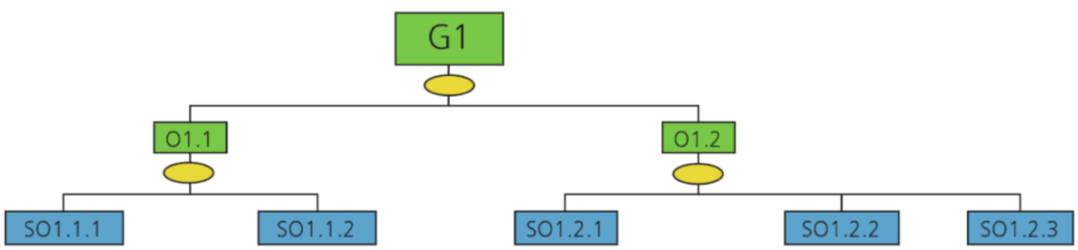


Figure 4-2. Hierarchy of Goals, Objectives and Sub-Objectives in LUCIS

Analyzing Interval/Ratio Data. Assigning utility values to interval data is comparatively easier than nominal data since the values already have known intervals. ArcGIS Reclassify tool easily assigns values ranging from 1 to 9.

S...	Range	Label
	7,525 - 14,213.88889	9
	14,213.88889 - 20,902.77778	8
	20,902.77778 - 27,591.66667	7
	27,591.66667 - 34,280.55556	6
	34,280.55556 - 40,969.44444	5
	40,969.44444 - 47,658.33333	4
	47,658.33333 - 54,347.22222	3
	54,347.22222 - 61,036.11111	2

Figure 4-3. Assigned Values in Reclassify Tool

The above figure explains the property values for commercial parcels in Indore, India with 9 representing the highest suitable value (lowest price) and 1 representing the least suitable value (highest price) for developing land commercially.

Analyzing nominal/ordinal data. There are four methods to assign utility values to nominal/ordinal data (1) group voting technique (2) modeler assignment (3) modified Delphi process (4) pairwise comparison of separate features (Zwick & Carr, 2007).

This research uses pairwise comparison which is a generic form of the analytical hierarchy process (Zwick & Carr, 2007). To begin this process, a model is created and the goal is stated and then all features of the dataset are inserted, finally all the components are compared for their usefulness in supporting the first category (Zwick & Carr, 2007). Categories are compared from 1 to 9, 1 being equally important and 9 being extremely important.

The weights define the preferences for different land uses considering commercial suitability. In this example, proximity to roads is given highest preference while proximity to railway stations is given the least preference for building commercial establishments.

Rescale by function. This ArcGIS tool is used to range values per their respective suitability. The tool uses lower threshold and upper threshold uses to calculate suitability which is calculated by using Zonal Statistics as a table, another ArcGIS tool. Using Zonal Statistics as a table, mean and standard deviation of the data set is calculated. The mean is used as the lower threshold and the sum of mean and twice the standard deviation is used as the upper threshold.

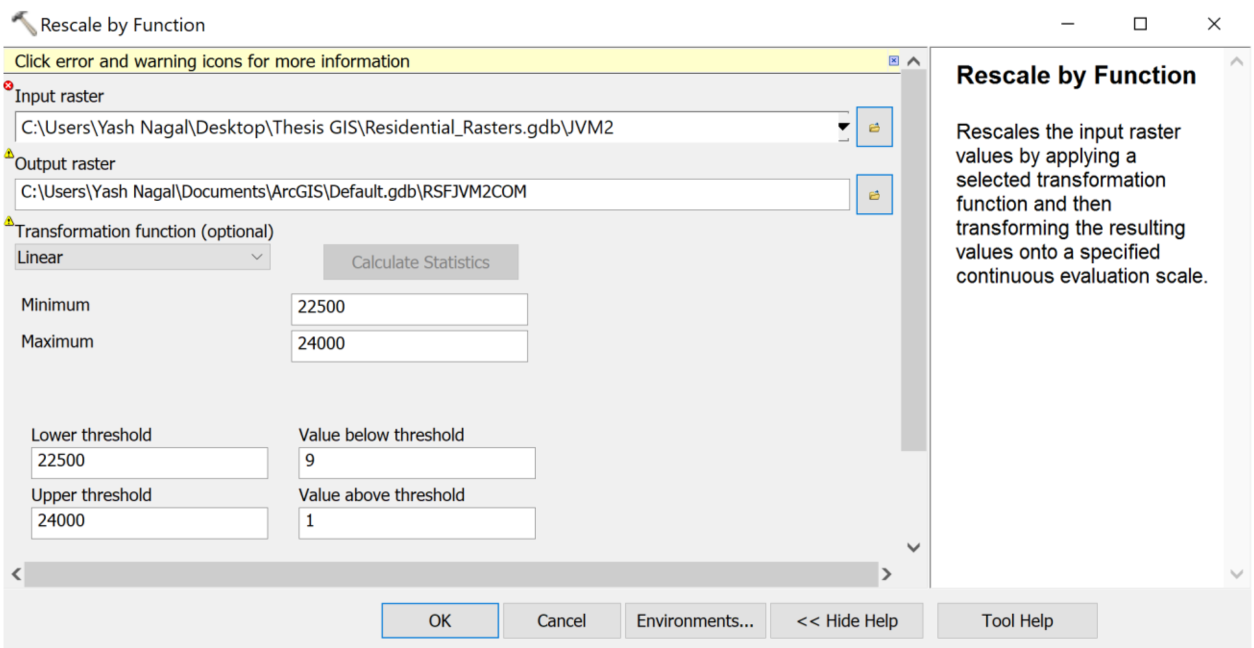


Figure 4-5. ArcGIS Tool Rescale by Function

In the above example, mean of all commercial property values in Indore, India is Rs. 22,500 and the standard deviation is Rs.750 making upper threshold Rs. 24,000 and lower threshold Rs. 22,250. In this example, lower threshold gets highest suitability 9 and upper threshold gets lowest suitability 1 as low value properties for commercial development are preferable.

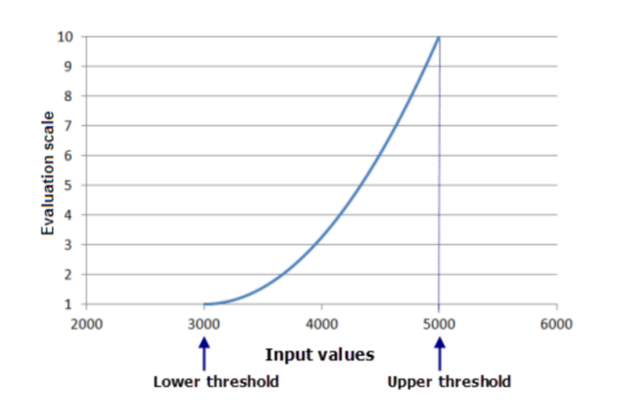


Figure 4-6. Suitability Values Versus Input Values in Rescale by Function. Source: ArcGIS.com

Mapping and defining land-use suitability case studies. The suitability model consists of four major steps as follows:

- Statement of Intent
- Goals
- Objectives
- Sub-Objectives

The figure further explains the hierarchy of the above stated steps.

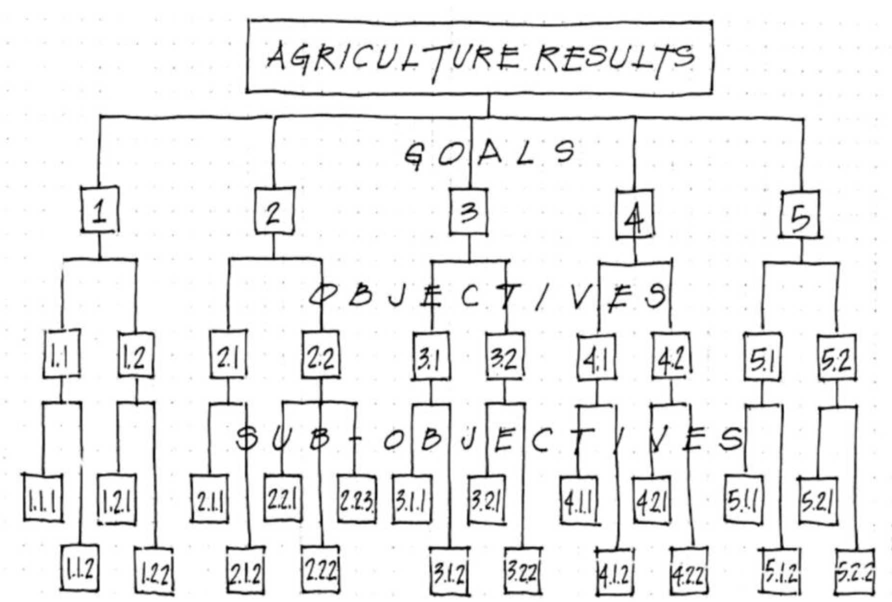


Figure 4-7. Hierarchy of Steps in Suitability Analysis. Source: Overview of Suitability

To perform suitability, one has to perform the modelling process from bottom up meaning starting with sub-objectives. The figure below is an example for residential suitability based flood potential.

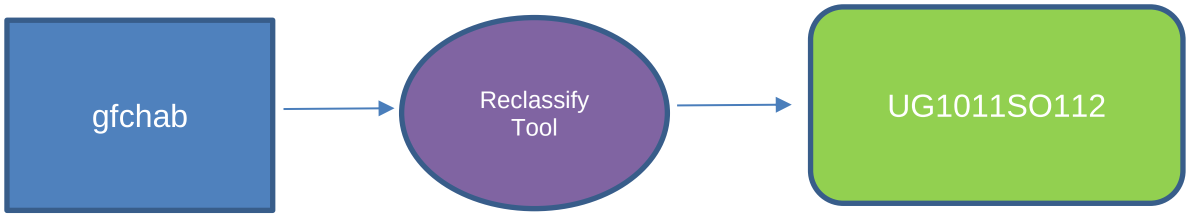


Figure 4-8. Analysis model for the urban sub-objective “Identify lands free of flood potential”. Source: Smart Land Use Analysis

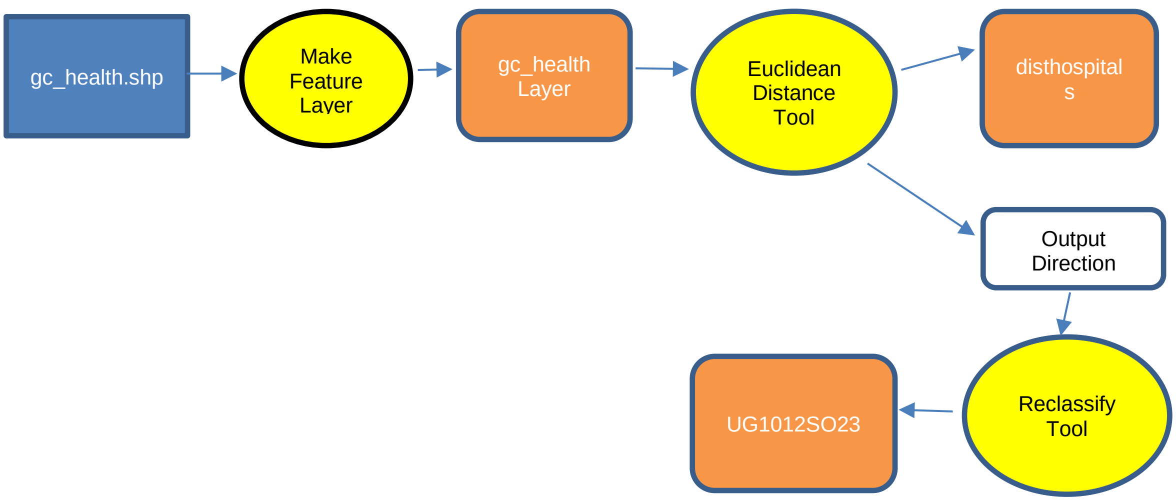


Figure 4-9. Analysis Model for the Urban Sub-Objective “Identify Lands Proximal to Hospitals”

The above model shows the selection of suitable lands based on proximity to hospitals. A health care facilities dataset was used as input layer and Euclidean Distance was performed on it (Zwick & Carr, 2007). After performing Euclidean Distance, Zonal Statistics was used to determine the mean and standard deviation of existing residential areas from the selected hospitals and medical centers and these values were used as suitability values, cells with 0 to the mean value get 9 which is highest suitability because they are closer to existing residential units and further the values decrease to 1 which is the sum of the mean and twice the standard deviation (Zwick & Carr, 2007).

Table 4-1. LUCIS Urban Mixed-Use Opportunity Matrix

Mixed-Use Value	**Description**
111	Mixed Use with Low Preference
112	Residential Moderate Preference
113	Residential High Preference
121	PSP Moderate Preference
122	Residential and PSP Moderate Preference
123	Residential High Preference
131	PSP High Preference
132	PSP High Preference
133	PSP and Residential High Preference
211	Commercial Moderate Preference
212	Commercial and Residential Moderate Preference
213	Residential High Preference
221	Commercial and PSP Moderate Preference
222	All with Moderate Preferences
223	Residential High Preference
231	PSP High Preference
232	PSP High Preference
233	PSP and Residential High Preference
311	Commercial High Preference
312	Commercial High Preference
313	Commercial and Residential High Preference
321	Commercial High Preference
322	Commercial High Preference
323	Commercial and Residential High Preference
331	Commercial and PSP High Preference
332	Commercial and PSP High Preference
333	All with High Preferences

The above matrix explains multiple preferences in this research in one matrix. The greenfield conflict matrix has been used here to identify different land use opportunities in an existing urban core.

The values in the table have been formed by reclassification of the suitability layers based on the following formula. LUCIS mixed-use raster = ((commercial preference* 100) + (PSP preference* 10) + (Residential preference* 1)).

CHAPTER 5
RESULTS and DISCUSSION

Statement of Intent. Identify suitable for urban development within the city of Indore, India.
Main Goals

- Identify suitable land for residential land use.
- Identify suitable land for commercial land use.
- Identify suitable land for public and semi-public land use (Institutional land use)

Table 5-1. Goals, Objectives and Sub-Objectives for Commercial Development

GOAL 1	Description
1	Identify suitable land for commercial land use.
1.1	Identify physically-suitable land for commercial land use
1.1.1	Suitable land values.
1.2	Identify land proximally-suitable land for commercial land use.
1.2.1	Proximity to major roads.
1.2.2	Proximity to commercial development.
1.2.3	Proximity to bus stands
1.2.4	Proximity to public and semi-public development (Institutional).
1.2.5	Proximity to airports.
1.2.6	Proximity to railway stations.

Table 5-2. Goals, Objectives and Sub-Objectives for Institutional Development

GOAL 2	Description
2	Identify suitable land for public and semi-public land use (Institutional Land Use)
2.1	Identify physically-suitable land for PSP land use.
2.1.1	Suitable land values.
2.2	Identify land proximally-suitable land for PSP land use
2.2.1	Proximity to major roads.
2.2.2	Proximity to bus stands.
2.2.3	Proximity to PSP development.
2.2.4	Proximity to commercial development.
2.2.5	Proximity to PUF (Public Utility Facilities).
2.2.6	Proximity to airports.
2.2.7	Proximity to railway stations.

Table 5-3. Goals, Objectives and Sub-Objectives for Residential Development

GOAL 3	Description
3	Identify suitable land for residential land use.
3.1	Identify physically-suitable land for residential land use
3.1.1	Suitable land values.
3.2	Identify land proximally-suitable land for residential land use
3.2.1	Proximity to major roads.
3.2.2	Proximity to commercial development.
3.2.3	Proximity to bus stands
3.2.4	Proximity to Residential
3.2.5	Proximity to Public Utility and Facility
3.2.6	Proximity to public and semi-public development
3.2.7	Proximity to airports.
3.2.8	Proximity to railway stations.

General method. Specific parameters were modified to suit certain analyses however, the basic structure of this model was used for the majority of the project. Use Euclidean Distance (Density) as the value raster, then use Zonal Statistics by Table to calculate the value range of specific land uses. Use Summary Statistics to calculate the $\bar{x}$mean and stdmean respectively. Use Rescale by Function, using $\bar{x}$mean as the lower threshold, and [$\bar{x}$mean + 2(stdmean)] as the upper threshold.

5.1. Goal 1 Identify Suitable Land for Commercial Land Use

5.1.1. Identify Physically Suitable Lands

Land values.

Based on historical data, found out the mean of mean land value of commercial developments in the city (₹ 22878/ square meter) and standard deviation (₹7941/ square meter). Used mean of mean as the lower threshold and mean of mean plus twice the standard deviation as the upper threshold**.** Lower threshold holds highest suitability (9) and upper threshold has lowest suitability as land values are preferred low cost.

- High = ₹38,760/sqm and low= ₹22,878.

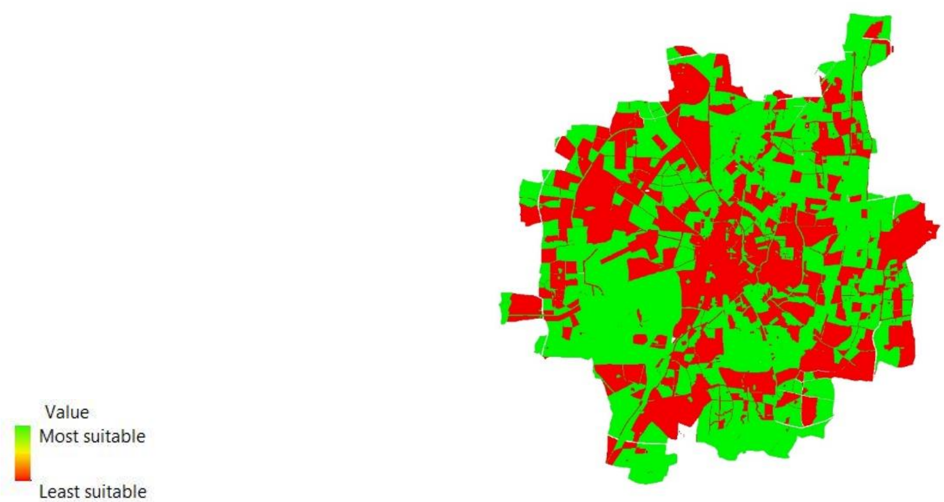


Figure 5-1. Suitable Land Values for Commercial Development in the City

5.1.2. Identify Proximally Suitable Land for Commercial Land Use

5.1.2.1 Proximity to major roads

Method.

- Found the mean distance of current commercial establishments from major roads based on historical data and used it as minimum distance (121m).

- Ran statistics based on historical data and calculated the maximum distance away from major roads (351m).

- Ran suitability analysis and proposed suitable land for commercial land proximal to major roads.

- Tools used: Euclidean Distance, Zonal Statistics, Rescale by Function.

- Rationale: Commercial establishments would benefit from being near major roads so the scale ranges from anything at the minimum distance as being HIGHLY SUITABLE to anything at the maximum distance being LEAST SUITABLE.

Figure 5-2. Suitable Land Proximal to Major Roads in the City

5.1.2.2. Proximity to commercial development

Method.

- Found the mean distance of current commercial establishments from commercial developments based on historical data and used it as minimum distance (0m).

- Ran statistics based on historical data and calculated the maximum distance away from commercial developments (700m).

- Ran suitability analysis and proposed suitable land for commercial land proximal to commercial development.

- Tools used: Euclidean Distance, Zonal Statistics, Rescale by Function.
- Rationale: Commercial establishments would benefit from being near current commercial developments so the scale ranges from anything at the minimum distance as being HIGHLY SUITABLE to anything at the maximum distance being LEAST SUITABLE.

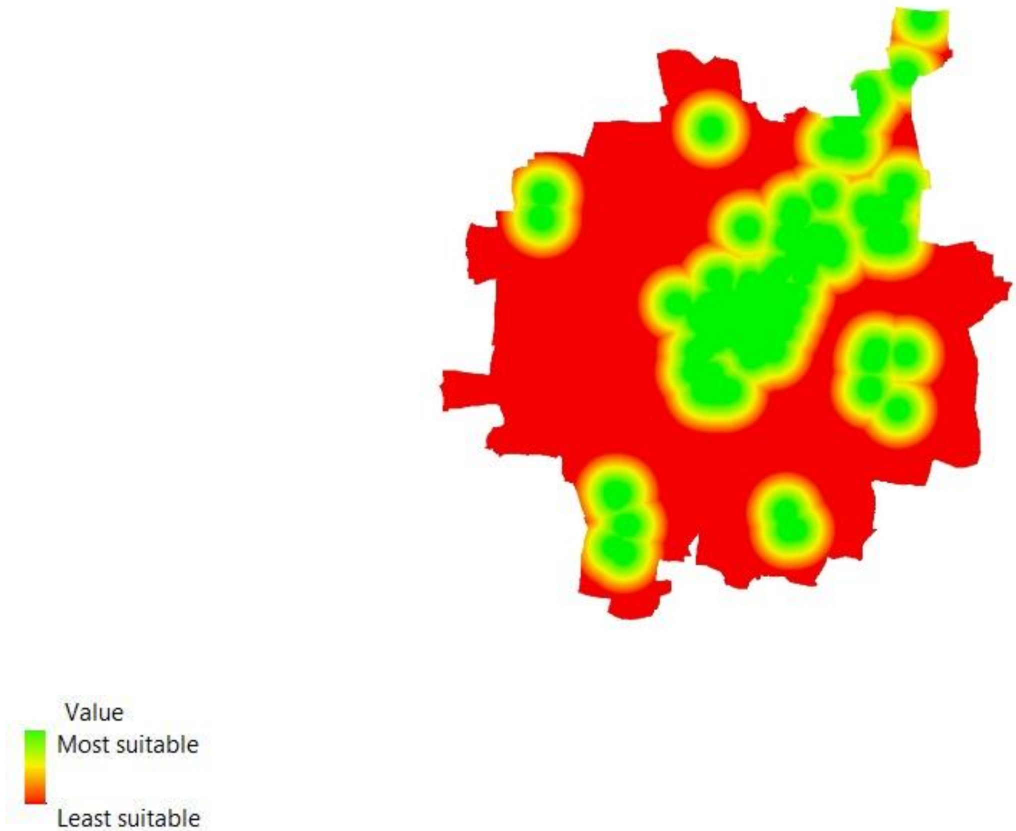


Figure 5-3. Suitable Land Proximal to Commercial Development

5.1.2.3. Proximity to bus stands

Method:

- Found the mean distance of current commercial establishments from bus stands based on historical data and used it as minimum distance (4950m).
- Ran statistics based on historical data and calculated the maximum distance away from bus stands (12,000m).
- Ran suitability analysis and proposed suitable land for commercial land proximal to bus stands.
- Tools used: Euclidean Distance, Zonal Statistics, Rescale by Function.

- Rationale: Commercial establishments would benefit from being near current bus stands so the scale ranges from anything at the minimum distance as being HIGHLY SUITABLE to anything at the maximum distance being LEAST SUITABLE.

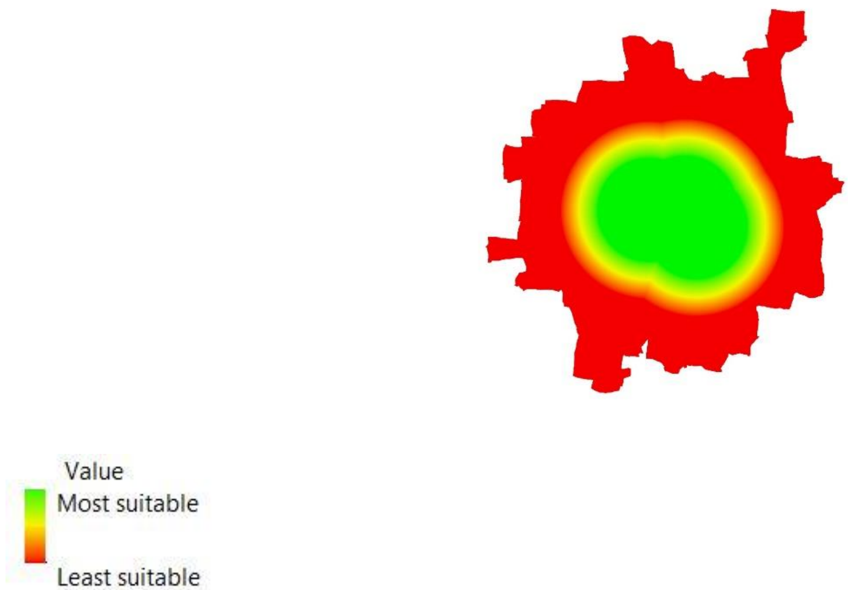


Figure 5-4. Suitable Land Proximal to Bus Stands

5.1.2.4. Proximity to public and semi-public development (Institutional)

This step follows the same method and rationale as the above steps.

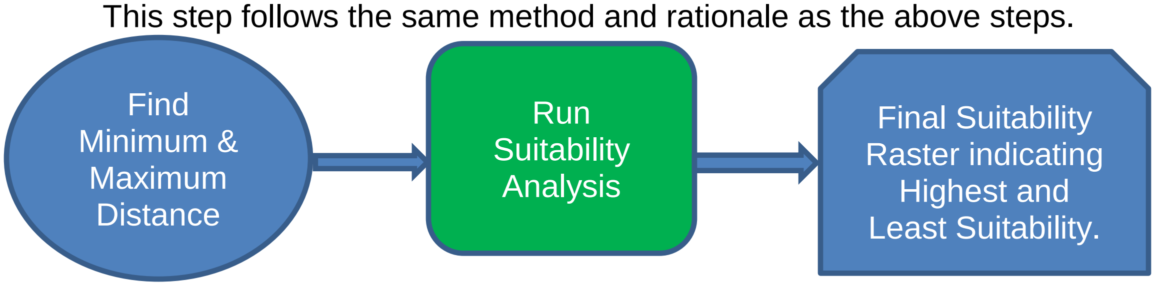


Figure 5-5. General Steps in Suitability Analysis for PSP

- Tools Used. Zonal Statistics and Rescale by Function
- Minimum Distance away from PSP (9) = 458m
- Maximum Distance away from PSP (1) = 1198m

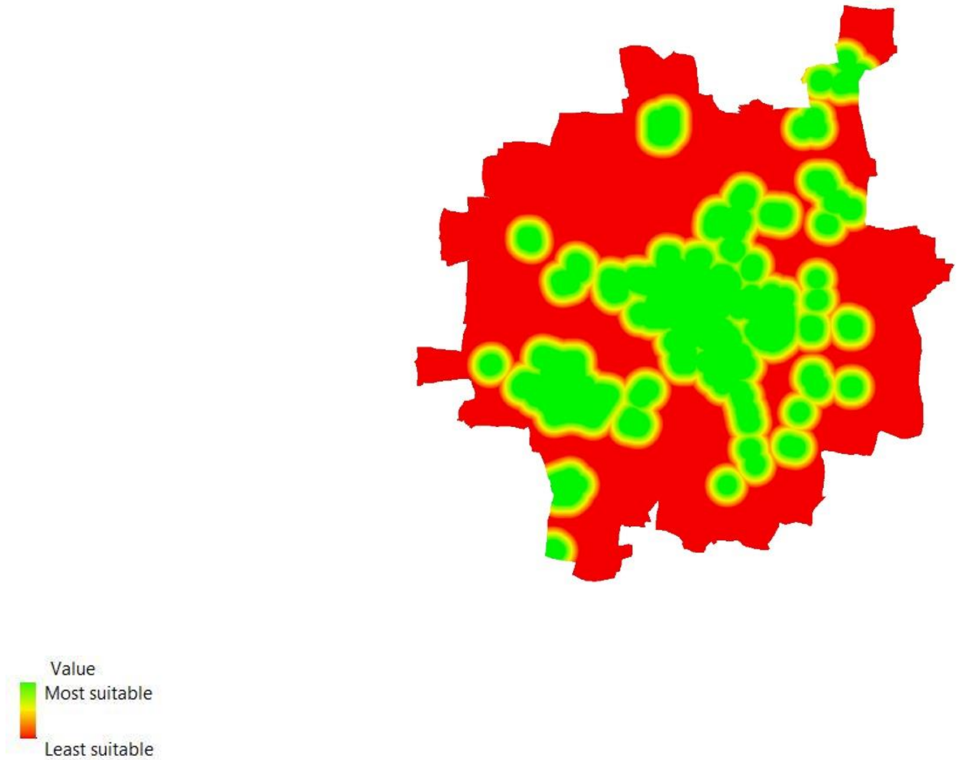


Figure 5-6. Suitable Land Proximal to PSP

5.1.2.5. Proximity to the airport

This step follows the same method and rationale as the above steps.

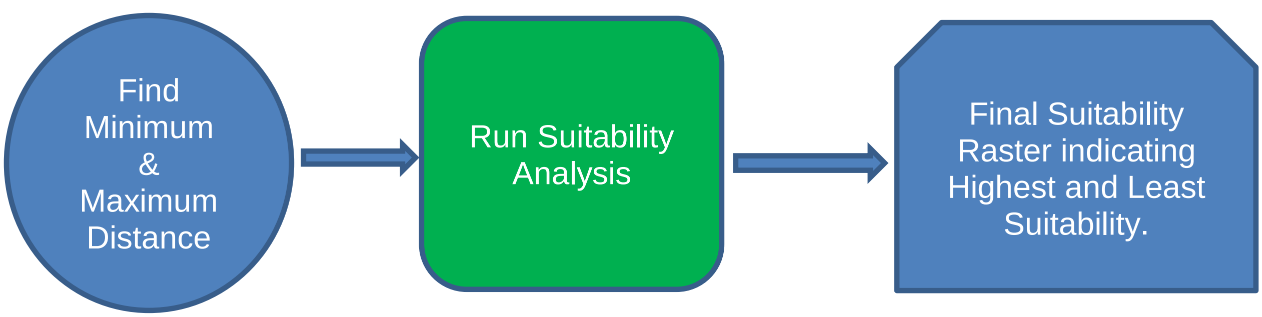


Figure 5-7. General Steps in Suitability Analysis for Airport

- Tools Used. Zonal Statistics and Rescale by Function
- Minimum Distance away from Airports (9) = 500m
- Maximum Distance away from Airports (1) = 12,000m

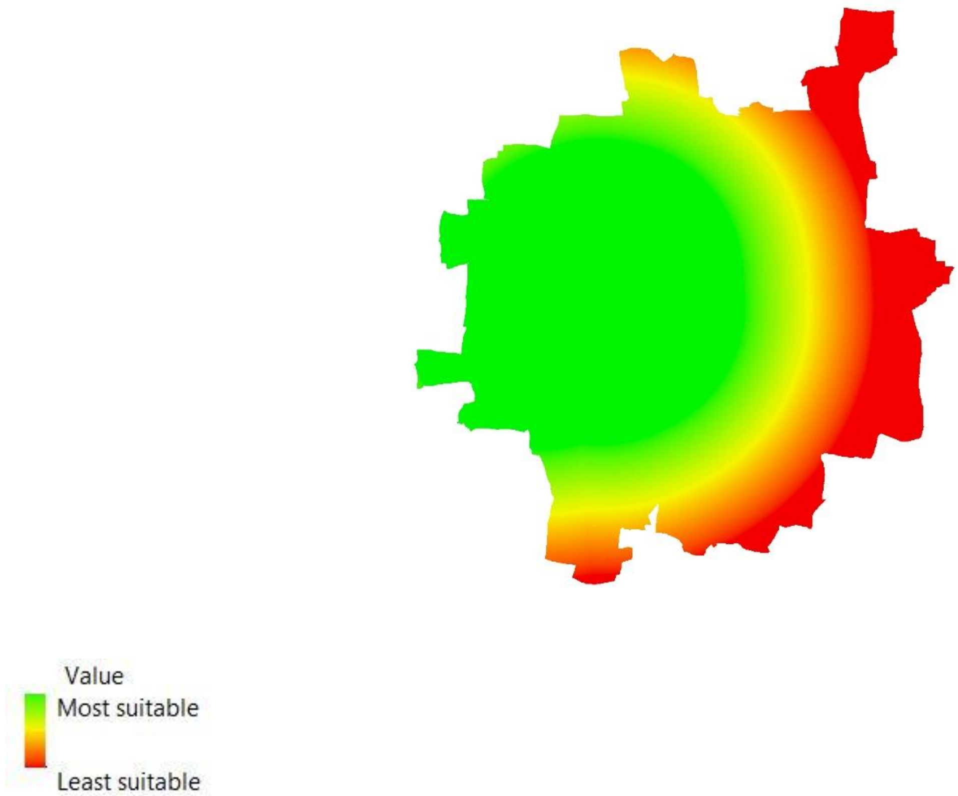


Figure 5-8. Suitable Lands Proximal to the Airport

5.1.2.5. Proximity to the rail lines

This step follows the same method and rationale as the above steps.

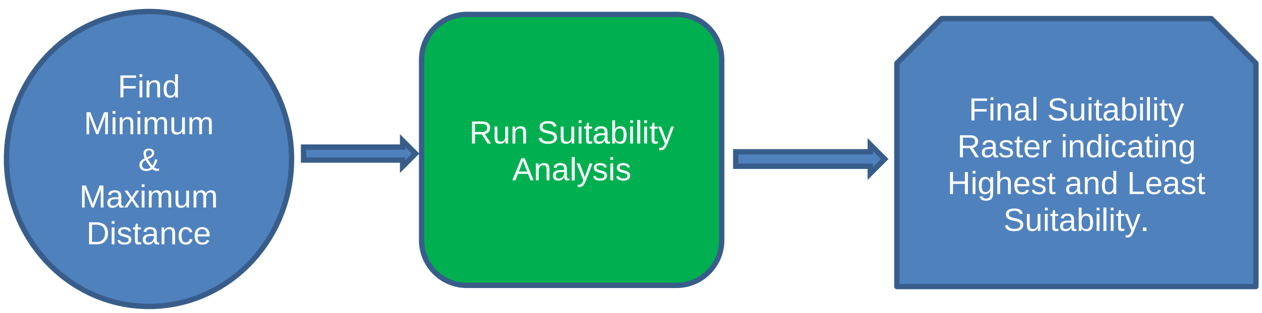


Figure 5-9. General Steps in Suitability Analysis for Airport

- Tools used. Zonal Statistics and Rescale by Function.
- Minimum Distance away from rail lines (9) = 2138m
- Maximum Distance away from rail lines (1) = 5738 m

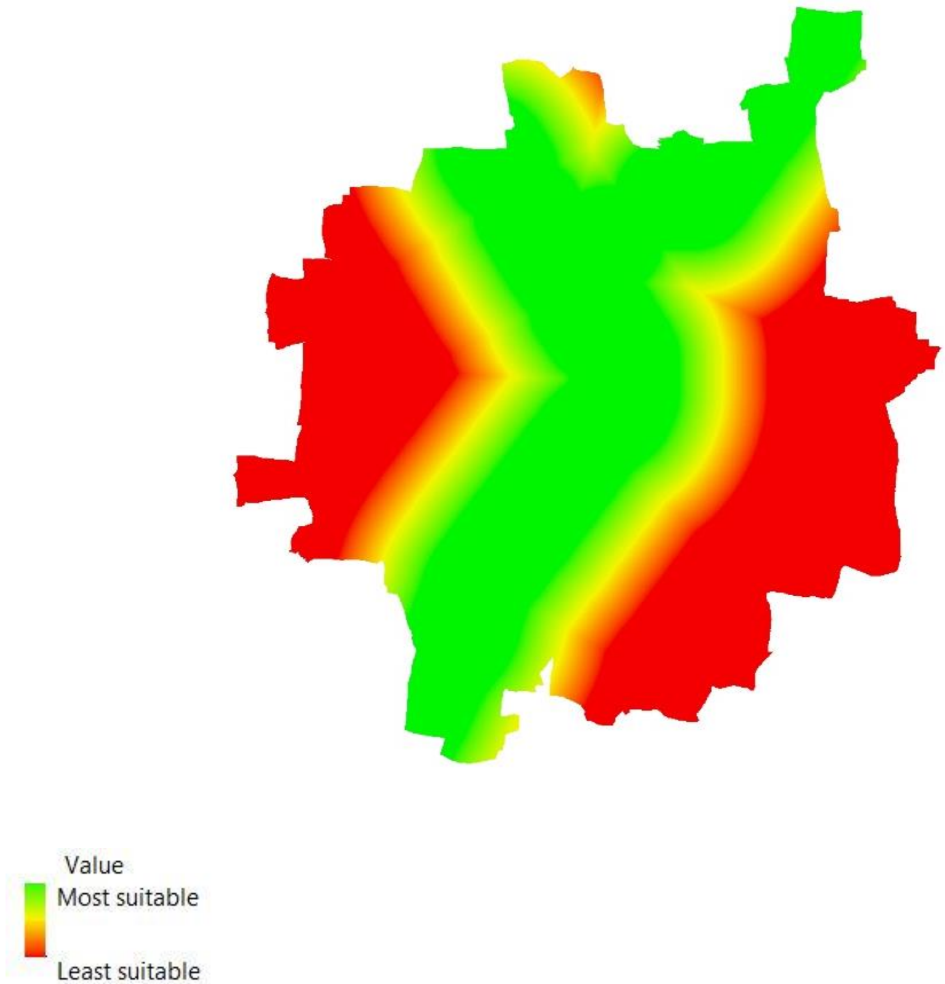


Figure 5-10. Suitable Land Proximal to Rail Lines

Identify land proximally suitable for commercial land use.

To find proximally suitable land we combine all the sub-objectives during weighted sum tool in ArcGIS. To combine the rasters, Analytic Hierarchy Process was used to provide weights to the layers. The following table explains the process further.

Using the weights from AHP, the result was this following raster which indicates proximally suitable land for commercial development. The table displaying results for AHP weighting are at the end of the chapter.

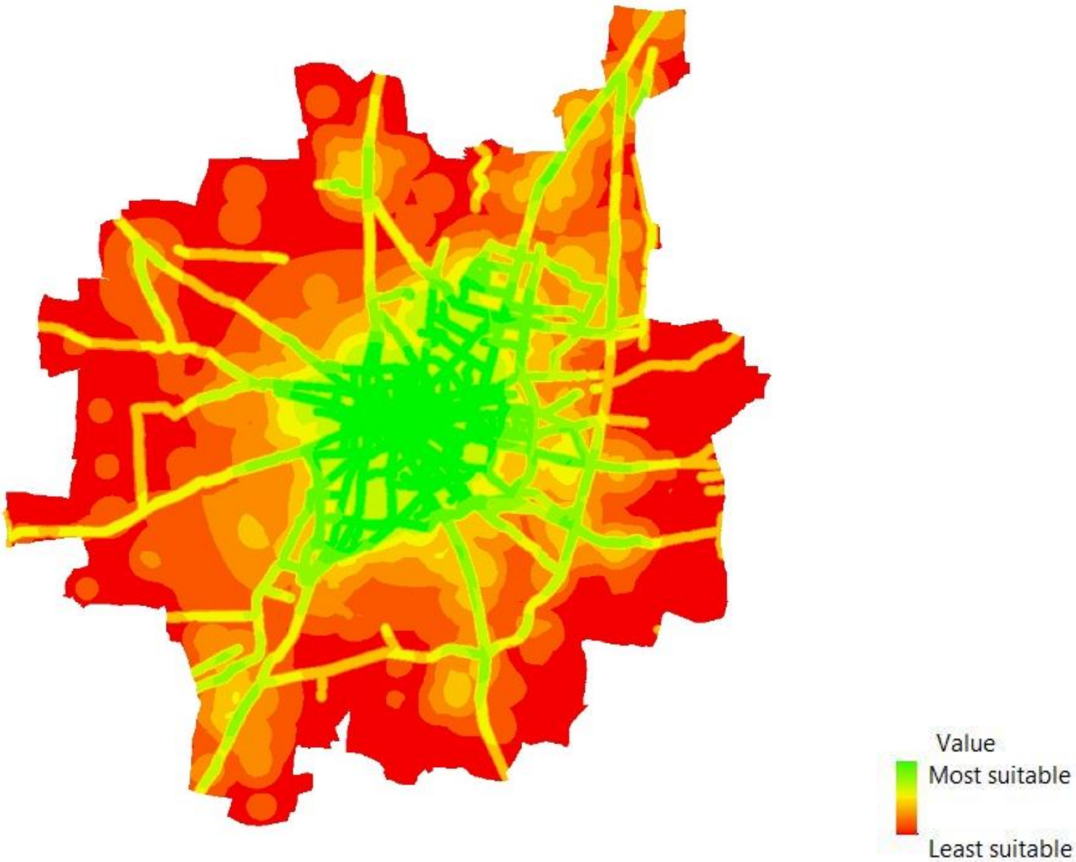


Figure 5-11. Proximally Suitable Land for Commercial Development

Identify suitable land for commercial development. Resulting Raster = Physically Suitable Land + Proximally Suitable Land

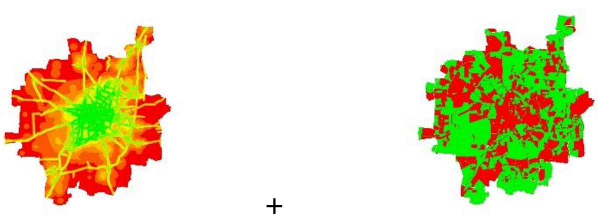


Figure 5-12. Physically and Proximally Suitable Land for Commercial Development

While weighing the two rasters, proximity was given 65% and physical suitability was given 35% to combine. The resulting raster is as follows.

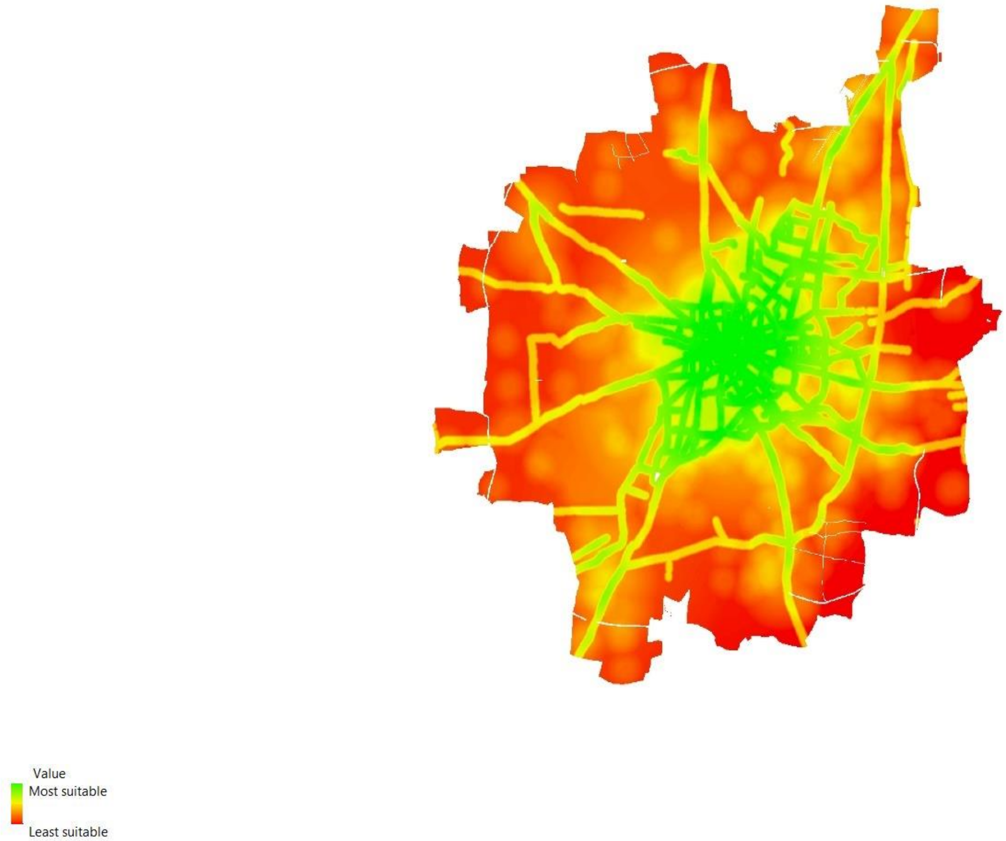


Figure 5-13. Suitable Land for Commercial Land Use

5.2. Identify Suitable Land for Public and Semipublic Land Use

5.2.1. Identify Physically Suitable Land for Public and Semipublic Land Use

Suitable land values.

Method.

- Based on historical data, found out the mean of mean land value of public and semipublic developments in the city (₹19432/ square meter) and standard deviation (₹1365/ square meter).
- Used mean of mean as the lower threshold and mean of mean plus twice the standard deviation as the upper threshold.
- Lower threshold holds highest suitability (9) and upper threshold has lowest suitability as land values are preferred low cost.
- High = ₹19,342/sqm and low= ₹23,432.

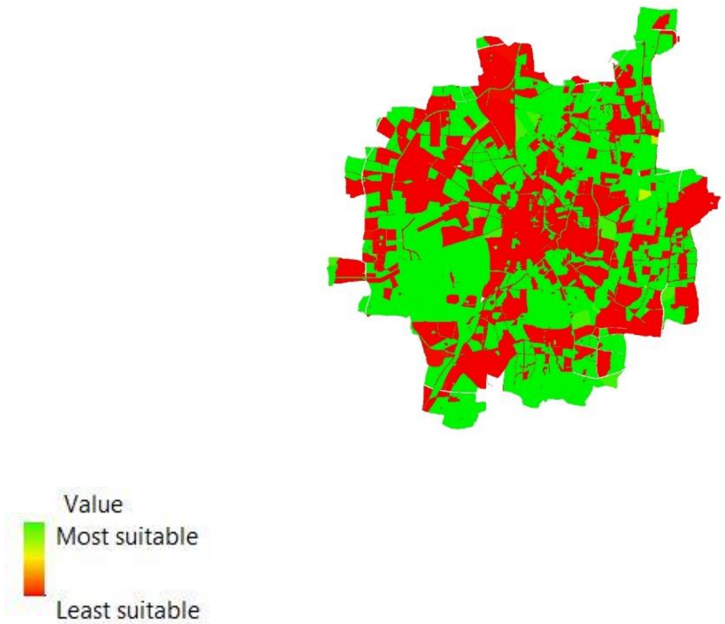


Figure 5-14. Suitable Land Values for PSP Development in the City

5.2.2. Identify Proximally Suitable Land for PSP Land Use

5.2.2.1. Proximity to major roads

Method.

- Found the mean distance of current PSP establishments from major roads based on historical data and used it as minimum distance (620m).
- Ran statistics based on historical data and calculated the maximum distance away from major roads (2020m).
- Ran suitability analysis and proposed suitable land for PSP land proximal to major roads.

Tools used: Euclidean Distance, Zonal Statistics, Rescale by Function.

Rationale: PSP establishments would benefit from being near major roads so the scale ranges from anything at the minimum distance as being HIGHLY SUITABLE to anything at the maximum distance being LEAST SUITABLE.

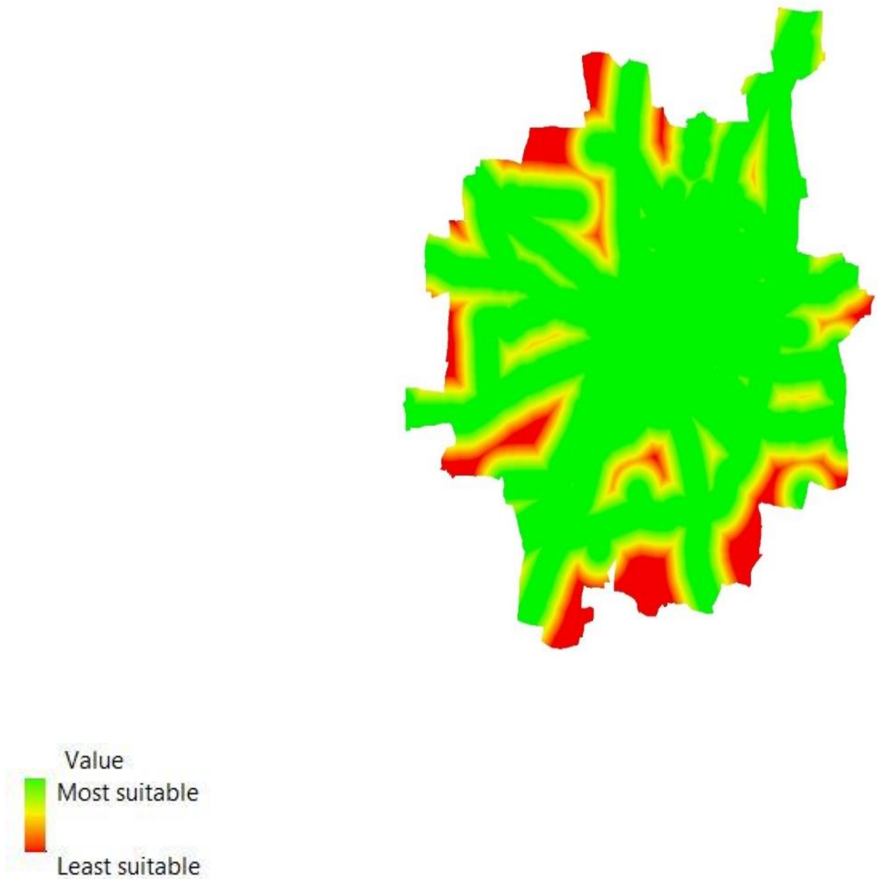


Figure 5-15. Suitable Land proximal to Major Roads in the City

5.2.2.2. Proximity to bus stands

Method.

- Found the mean distance of current PSP establishments from bus stands based on historical data and used it as minimum distance (761m).
- Ran statistics based on historical data and calculated the maximum distance away from PSP developments (1760m).
- Ran suitability analysis and proposed suitable land for PSP development proximal to bus stands.

Tools used: Euclidean Distance, Zonal Statistics, Rescale by Function.

Rationale: PSP establishments would benefit from being near current bus stands so the scale ranges from anything at the minimum distance as being HIGHLY SUITABLE to anything at the maximum distance being LEAST SUITABLE.

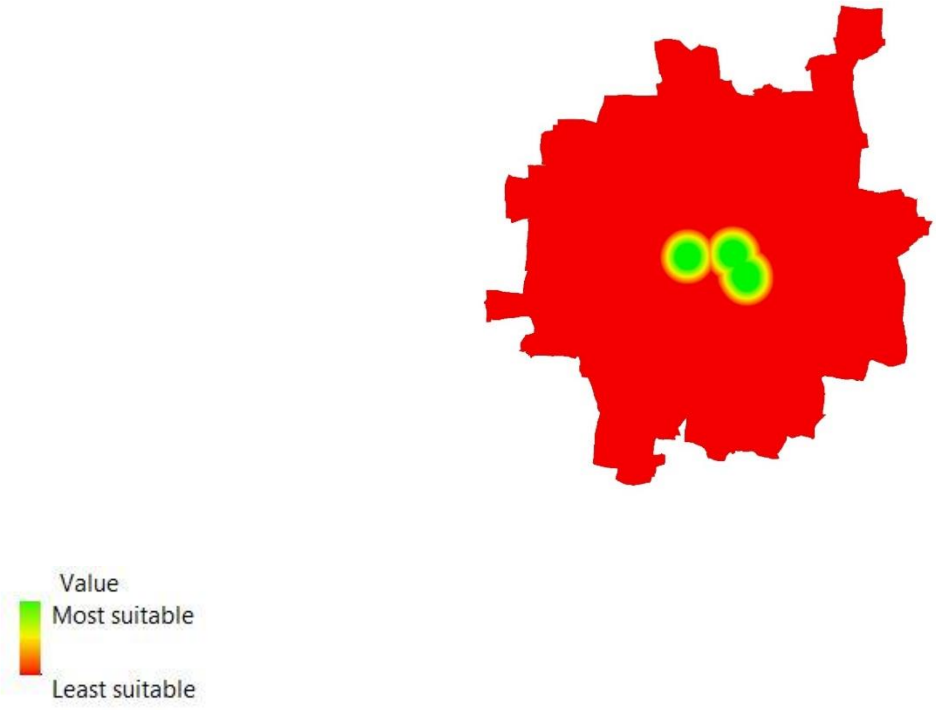


Figure 5-16. Suitable Land proximal to Bus Stands

5.2.2.3. Proximity to PSP

Method.

- Found the mean distance of current PSP establishments from PSP establishments based on historical data and used it as minimum distance (100m).
- Ran statistics based on historical data and calculated the maximum distance away from bus stands (2,000m).
- Ran suitability analysis and proposed suitable land for PSP land proximal to PSP establishments.

Tools used: Euclidean Distance, Zonal Statistics, Rescale by Function.

Rationale: PSP establishments would benefit from being near current PSP establishments so the scale ranges from anything at the minimum distance as being HIGHLY SUITABLE to anything at the maximum distance being LEAST SUITABLE.

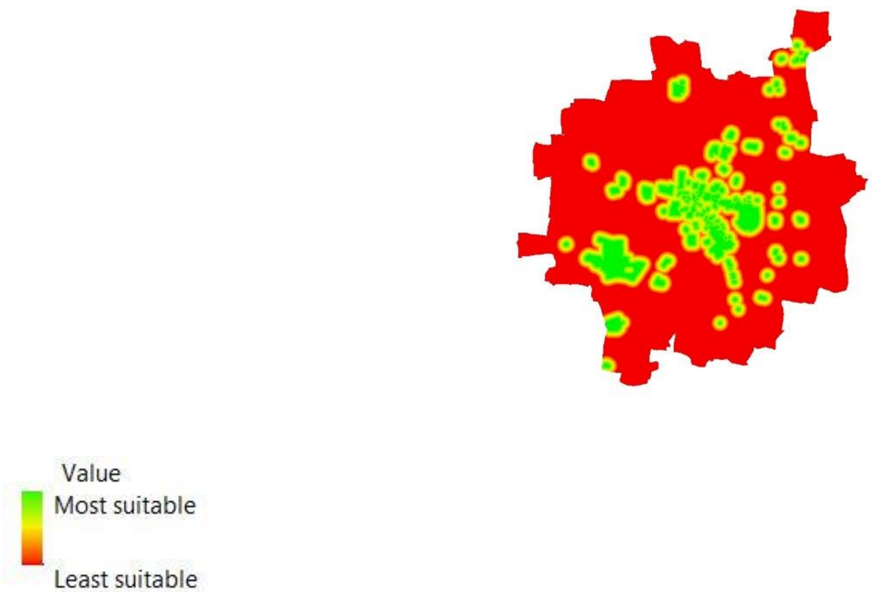


Figure 5-17. Suitable Land Proximal to PSP establishments

5.2.2.4. Proximity to commercial development

This step follows the same method and rationale as the above steps.

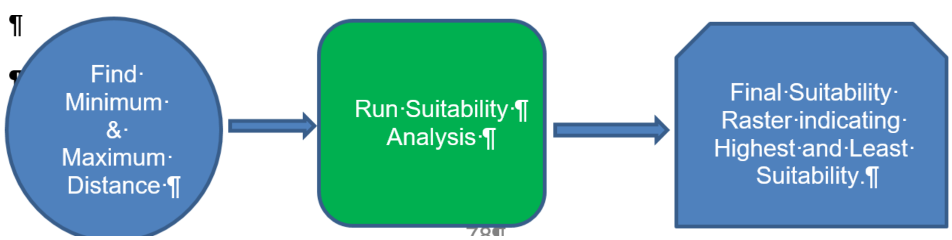


Figure 5-18. General Method for Commercial Development

Tools used. Zonal Statistics and Rescale by Function.

Minimum Distance away from PSP (9) = 2117m

Maximum Distance away from PSP (1) = 5277m

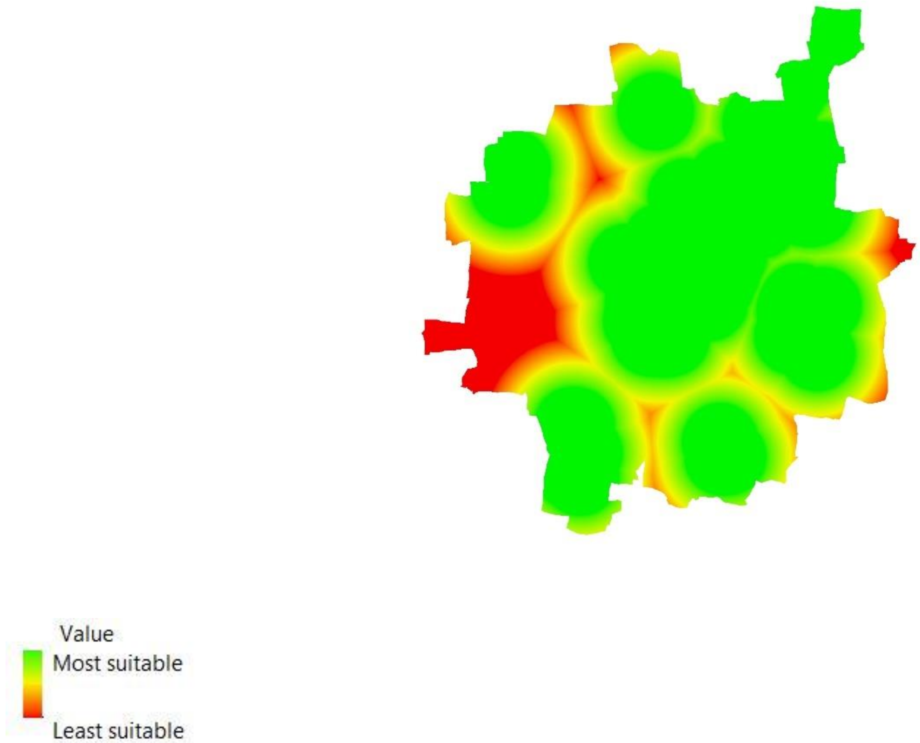


Figure 5-19. Suitable Land Proximal to Commercial Development

5.2.2.5 Proximity to public utility and facilities (PUF)

This step follows the same method and rationale as the above steps.

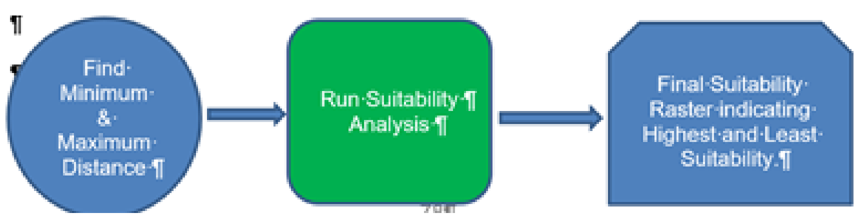


Figure 5-20. General Method for PUF

Tools Used. Zonal Statistics and Rescale by Function.

Minimum Distance away from PUF (1) = 1695m

Maximum Distance away from PUF (9) = 2750m

Rationale: PSP establishments would benefit from being further away from PUF establishments

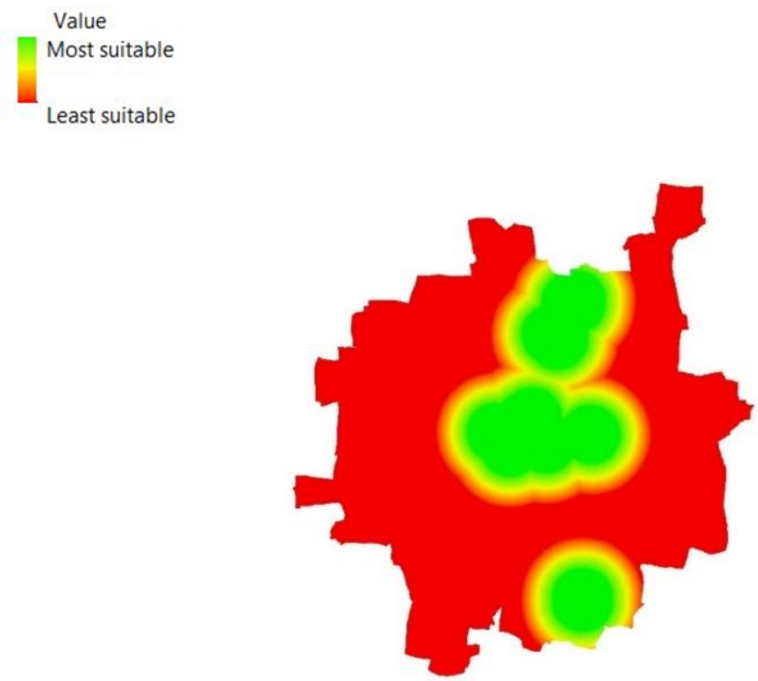


Figure 5-21. Suitable Lands Proximal to PUF

5.2.2.6. Proximity to the airports

This step follows the same method and rationale as the above steps.

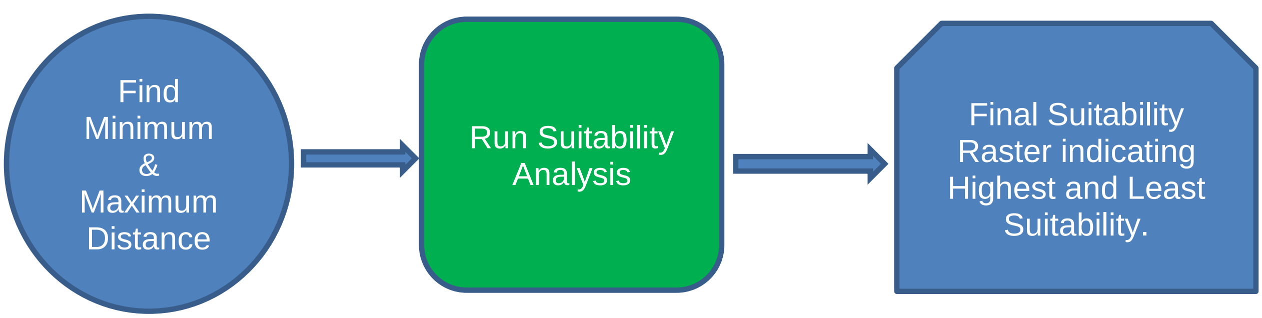


Figure 5-22. General Method for Airports

Tools Used. Zonal Statistics and Rescale by Function.

Minimum Distance away from the airport (9) = 384m

Maximum Distance away from the airport (1) = 683m

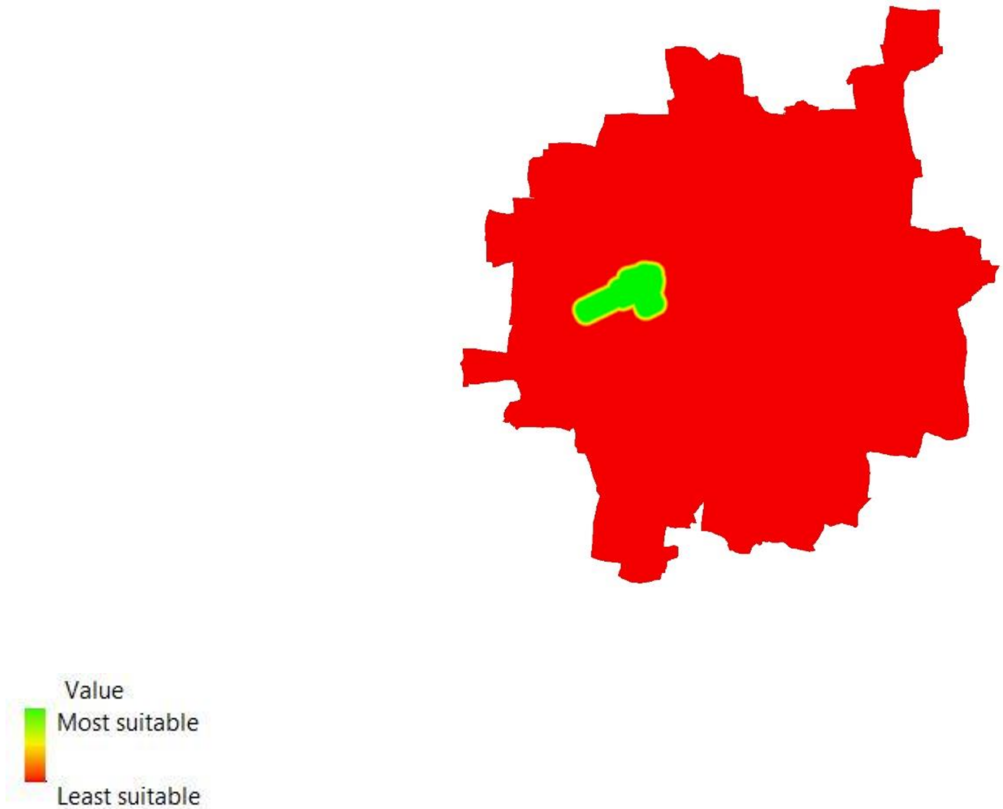


Figure 5-23. Suitable Land Proximal to the Airport

5.2.2.7. Proximity to rail lines

This step follows the same method and rationale as the above steps.

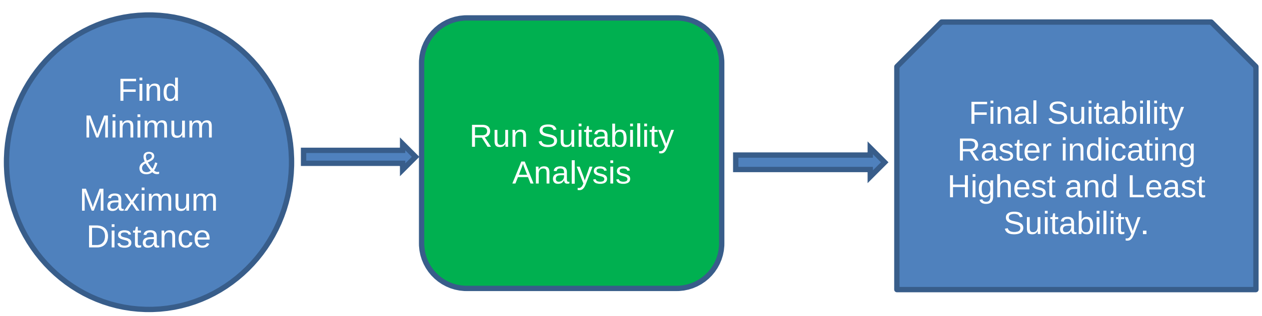


Figure 5-24. General Method for Rail Lines

Tools Used. Zonal Statistics and Rescale by Function.

Minimum Distance away from rail lines (9) = 2919m

Maximum Distance away from rail lines (1) = 5738 m

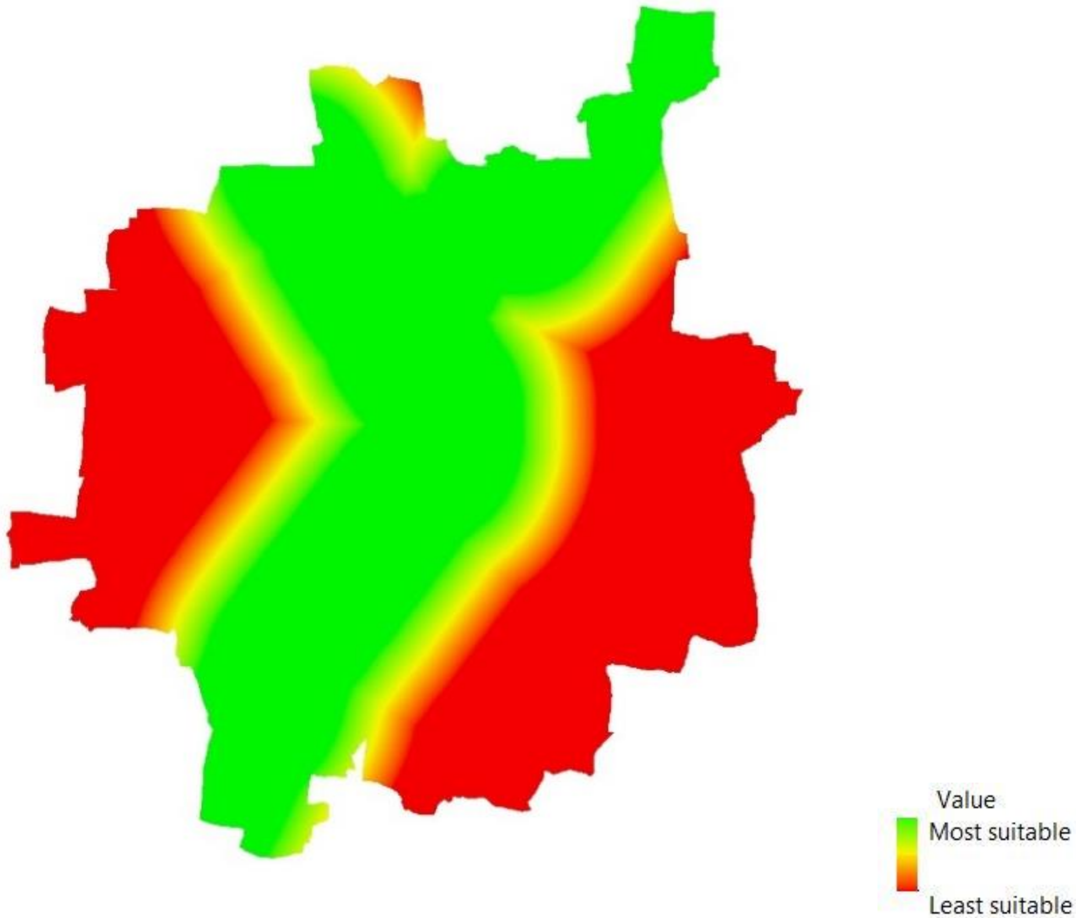


Figure 5-25. Suitable Land Proximal to Rail Lines

To find proximally suitable land we combine all the sub-objectives during weighted sum tool in ArcGIS. To combine the rasters, Analytic Hierarchy Process was used to provide weights to the layers. The following table explains the process further.

Using the weights from AHP, the result was this following raster which indicates proximally suitable land for commercial development. The results from AHP weighting are displayed at the end of the chapter.

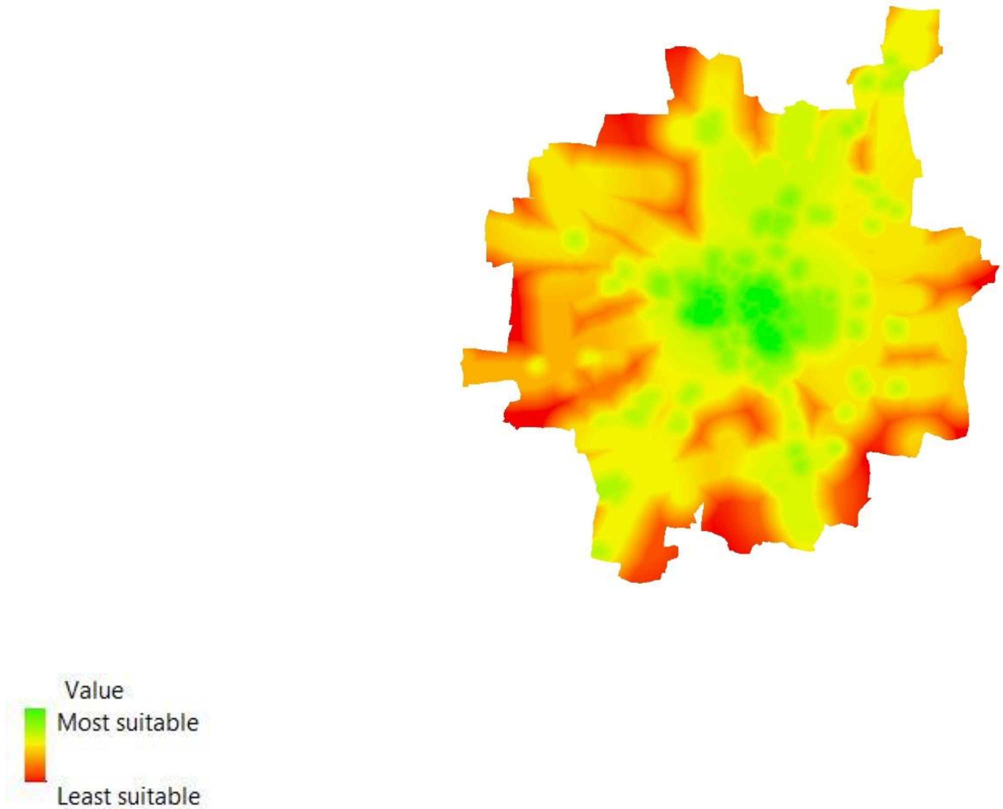


Figure 5-26. Proximally Suitable Land for PSP Development

Identify suitable land for PSP development

Resulting Raster = Physically Suitable Land + Proximally Suitable Land

Figure 5-27. Physically and Proximally Suitable Land for PSP Development

While weighing the two rasters, proximity was given 65% and physical suitability was given 35% to combine. The resulting raster is as follows which combines both physically and proximally suitable surfaces.

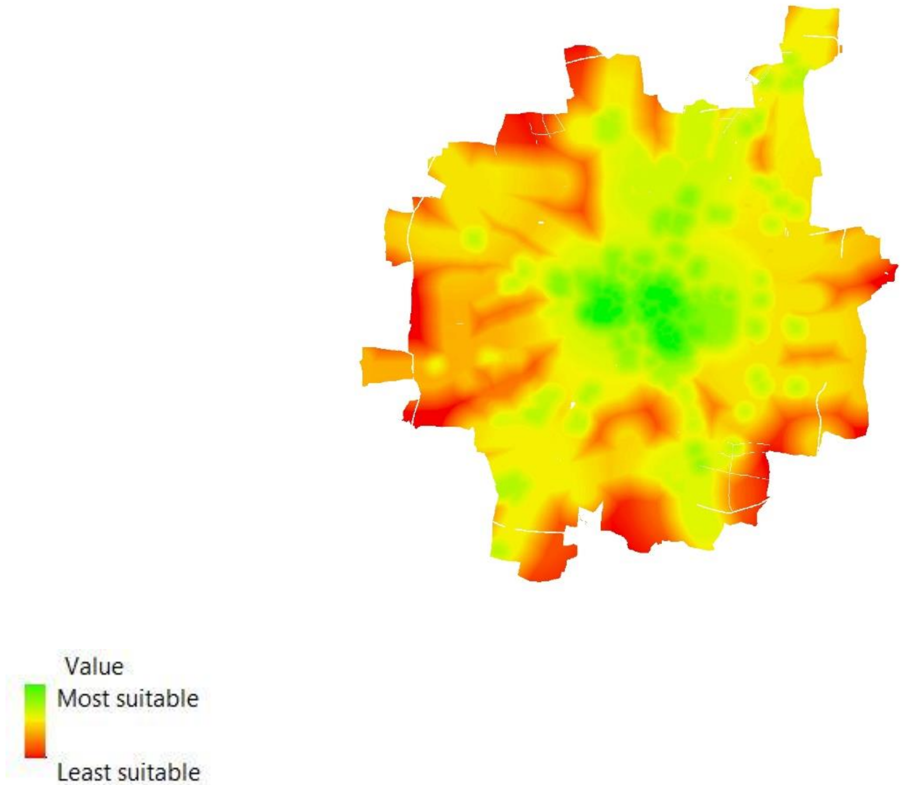


Figure 5-28. Suitable Land for PSP Land Use

5.3. Identify Suitable Lands for Residential Development

5.3.1. Identify Land Physically Suitable for Residential Development

Suitable land values.

- Based on historical data, found out the mean of mean land value of public and semipublic developments in the city (₹26,439/ square meter) and standard deviation (₹28,899/ square meter).
- Used mean of mean as the lower threshold and mean of mean plus twice the standard deviation as the upper threshold.
- Lower threshold holds highest suitability (9) and upper threshold has lowest suitability as land values are preferred low cost.
- High = ₹28,899/sqm and low= ₹26,439.

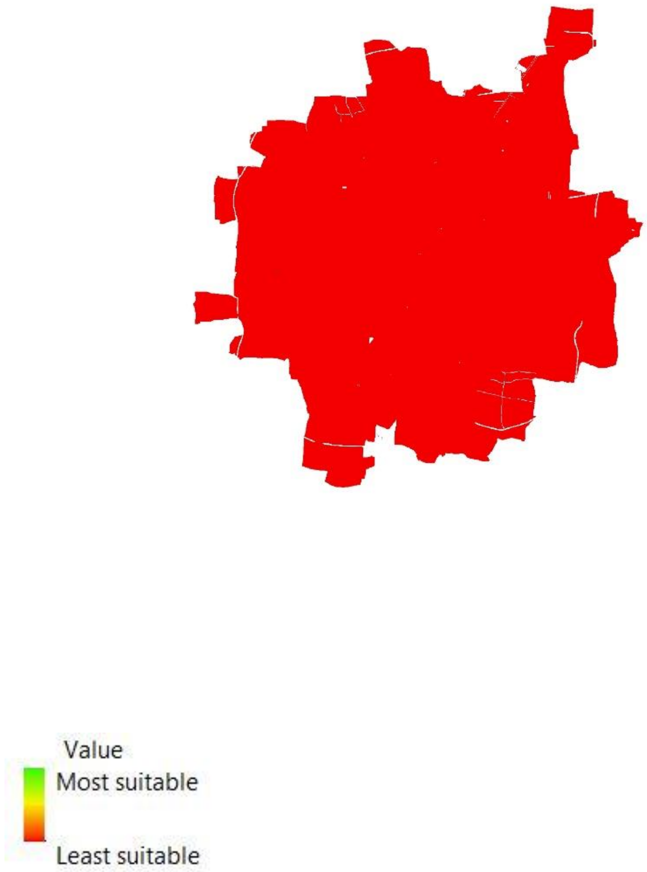


Figure 5-29. Suitable Land Values for Residential Development in the City

5.3.2 Identify Proximally-Suitable Lands for Residential Development

5.3.2.1 Proximity to PSP development

This step follows the same method and rationale as the above steps.

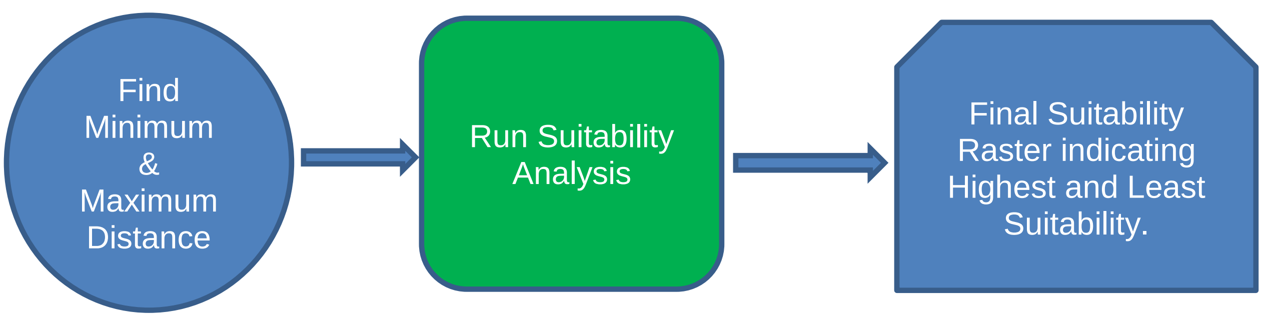


Figure 5-30. General Method for PSP

Tools used. Zonal Statistics and Rescale by Function.

Minimum Distance away from PSP (9) = 611m

Maximum Distance away from PSP (1) = 1650m

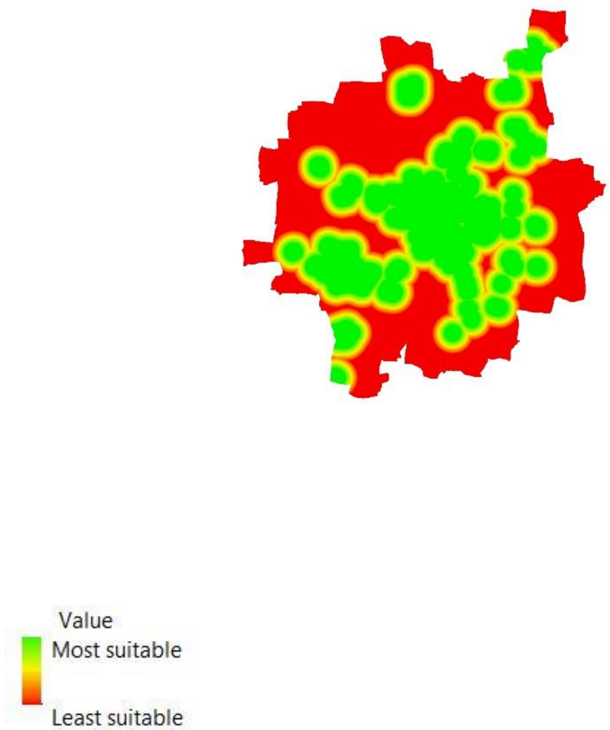


Figure 5-31. Suitable Land proximal to PSP Development

5.3.2.2 Proximity to major roads

This step follows the same method and rationale as the above steps.

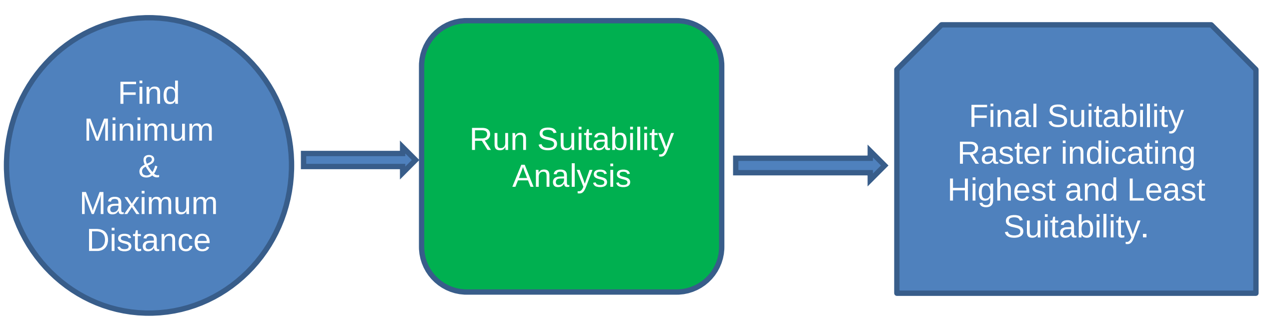


Figure 5-32. General Method for Roads

Tools used. Zonal Statistics and Rescale by Function

Minimum Distance away from Major Roads (9) = 200m

Maximum Distance away from Major Roads (1) = 650m

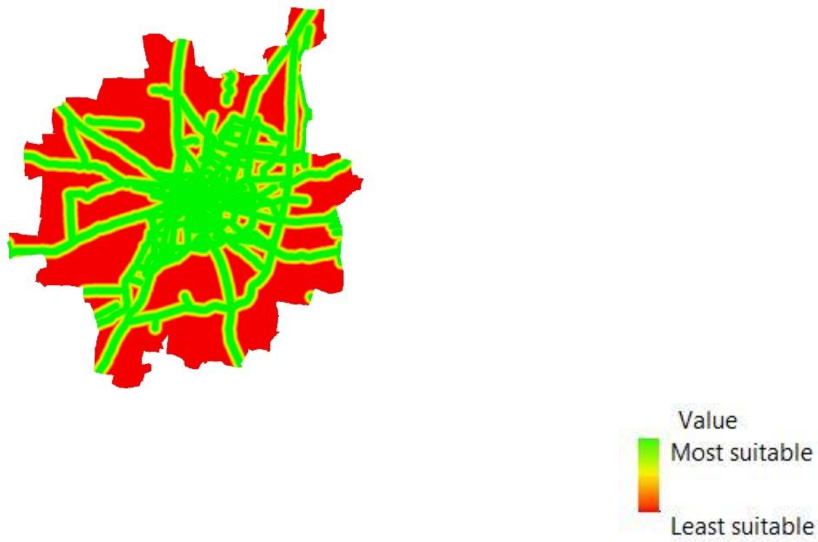


Figure 5-33. Suitable Lands Proximal to Major Roads

5.3.2.3 Proximity to bus stands

This step follows the same method and rationale as the above steps.

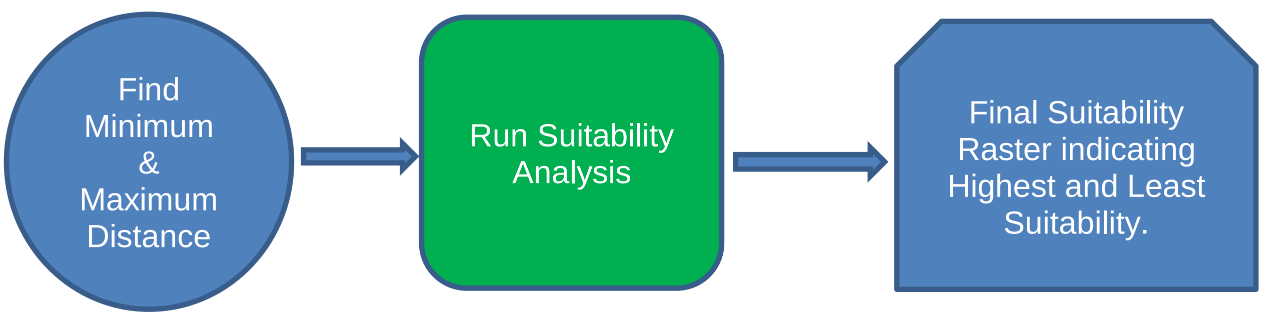


Figure 5-34. General Method for Bus Stands

Tools used. Zonal Statistics and Rescale by Function

Minimum Distance away from the airport (9) = 951m

Maximum Distance away from the airport (1) = 1851m

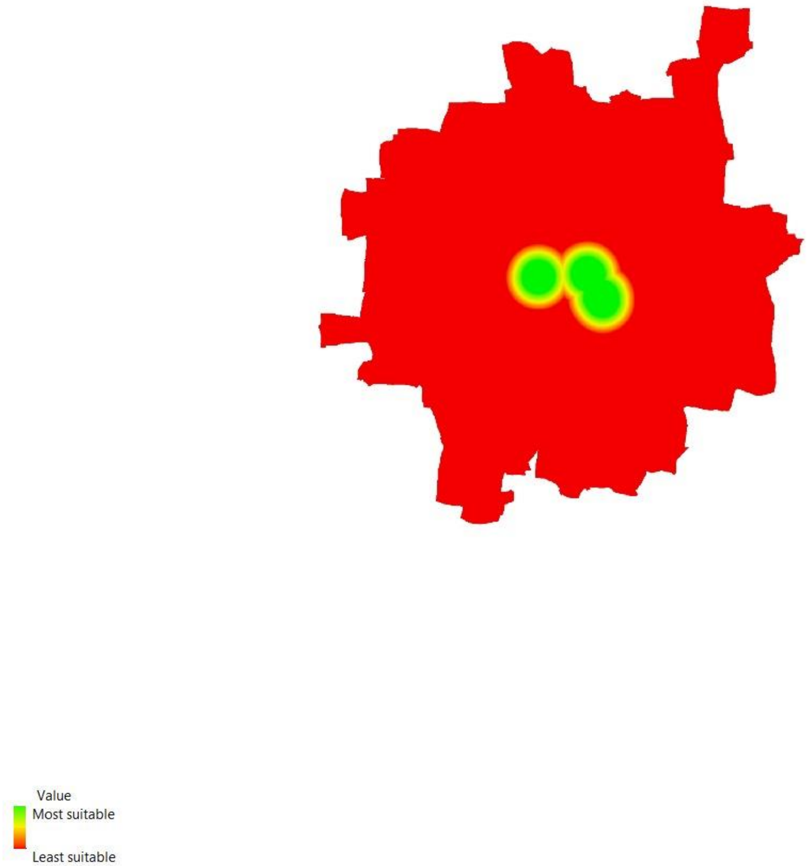


Figure 5-35. Suitable Land Proximal to the Bus Stands

5.3.2.4 Proximity to commercial establishments

This step follows the same method and rationale as the above steps.

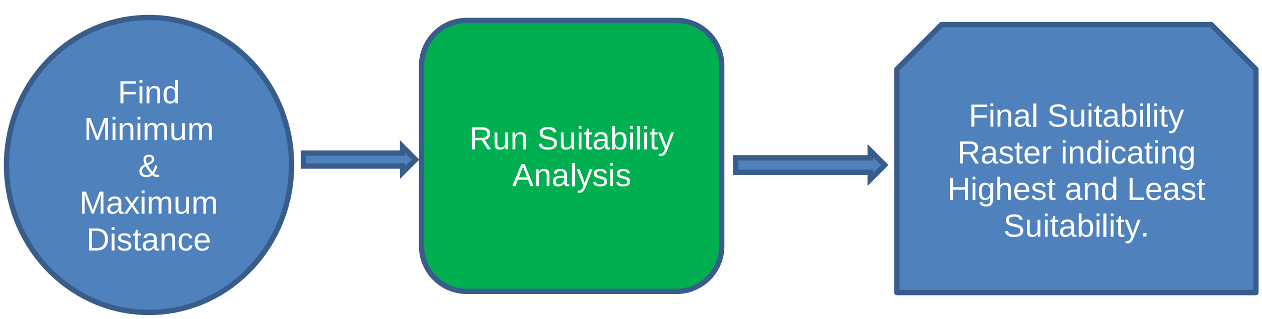


Figure 5-36. General Method for Commercial Development

Tools used. Zonal Statistics and Rescale by Function

Minimum Distance away from commercial establishments (9) = 957m

Maximum Distance away from commercial establishments (1) = 2350m

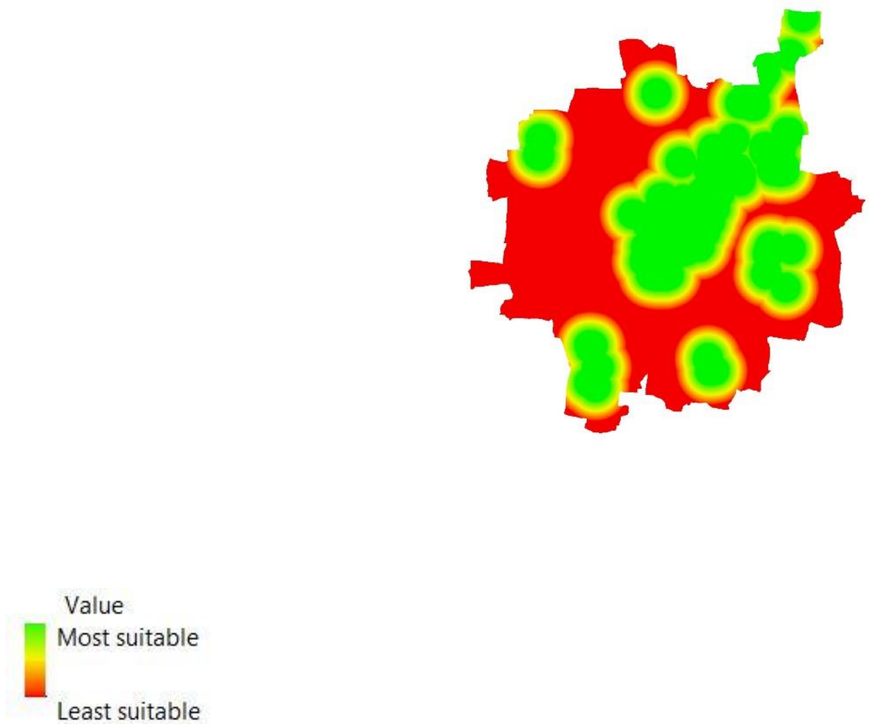


Figure 5-37. Suitable Land Proximal to Commercial Establishments

5.3.2.5 Proximity to PUF establishments

This step follows the same method and rationale as the above steps.

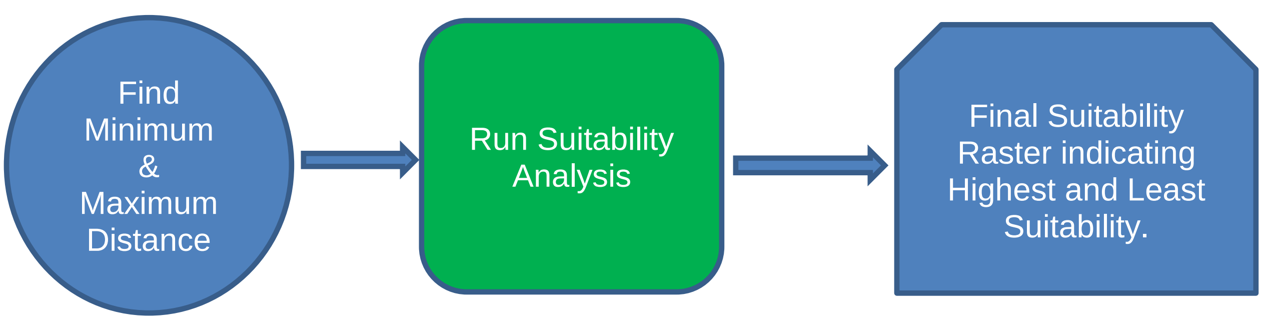


Figure 5-38. General Method for PUF establishments

Tools used. Zonal Statistics and Rescale by Function

Minimum Distance away from PUF establishments (1) = 1249m

Maximum Distance away from PUF establishments (9) = 2800m

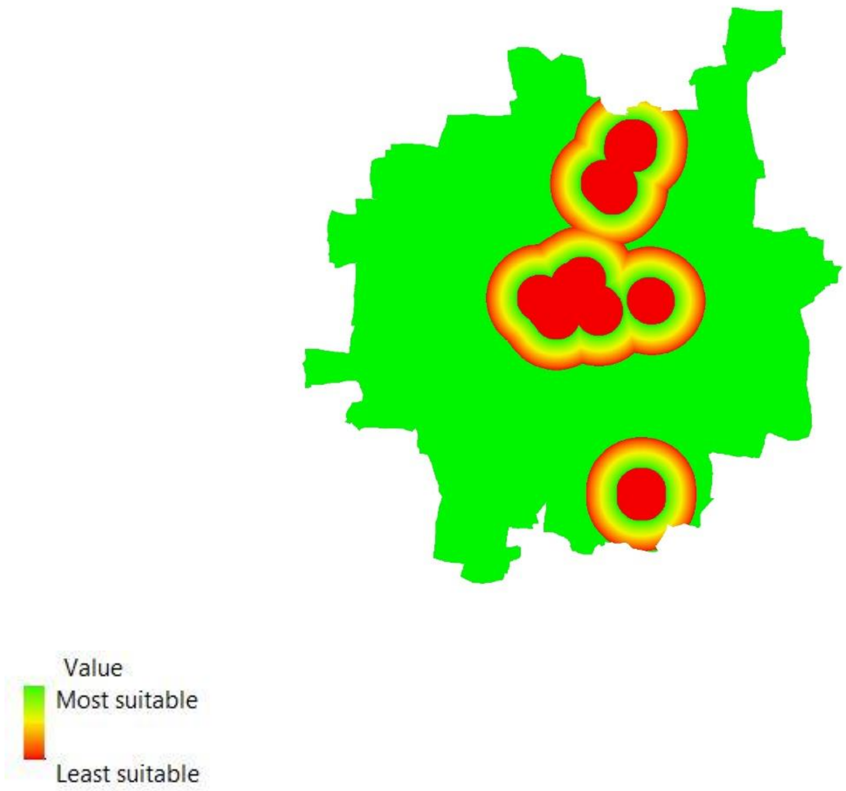


Figure 5-39. Suitable Land Proximal to PUF Establishments

5.3.2.6 Proximity to residential establishments

This step follows the same method and rationale as the above steps.

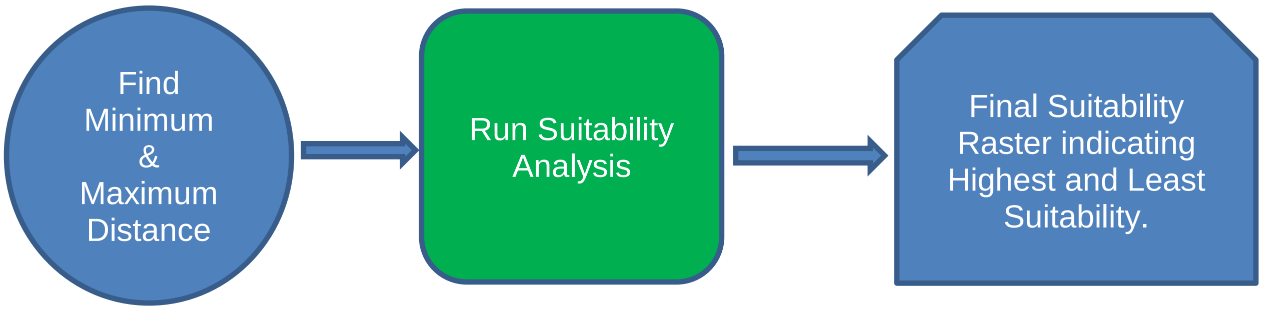


Figure 5-40. General Method for Residential Establishments

Tools Used. Zonal Statistics and Rescale by Function

Minimum Distance away from residential establishments (9) = 0m

Maximum Distance away from residential establishments (1) = 800m

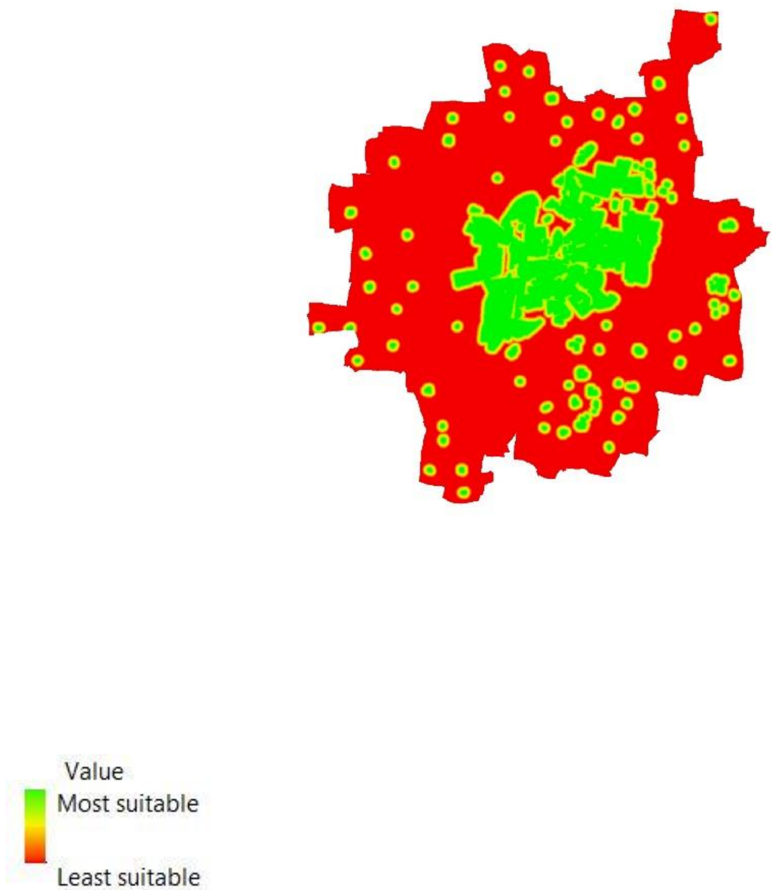


Figure 5-41. Suitable Land Proximal to Residential Establishments

5.3.2.7 Proximity to the airport

This step follows the same method and rationale as the above steps.

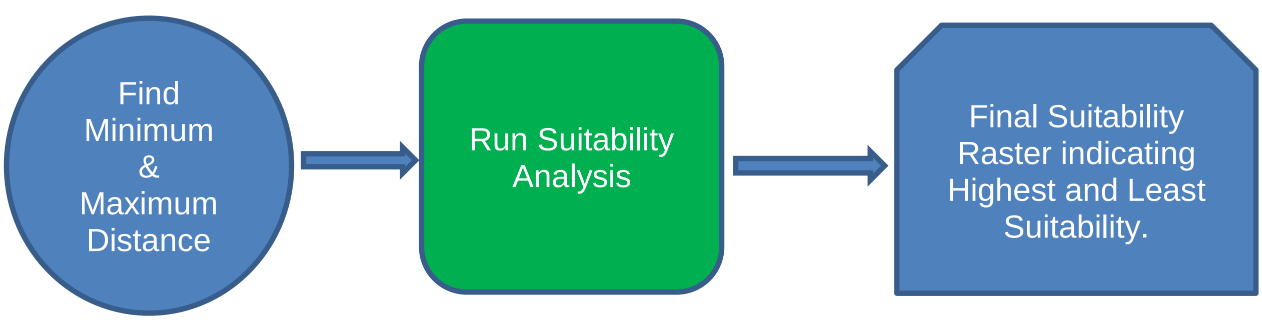


Figure 5-42. General Method for Airport Suitability

Tools Used. Zonal Statistics. Rescale by Function.

Minimum Distance away from the airport (9) = 400m

Maximum Distance away from the airport (1) = 12000m

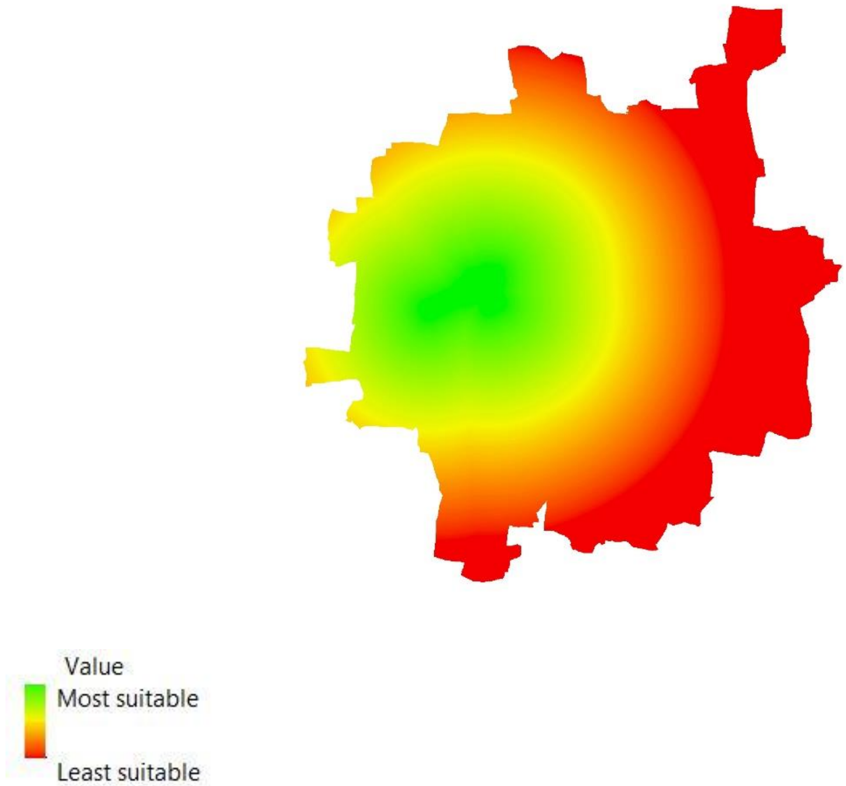


Figure 5-43. Suitable Land Proximal to the Airport

5.3.2.8 Proximity to rail lines

This step follows the same method and rationale as the above steps.

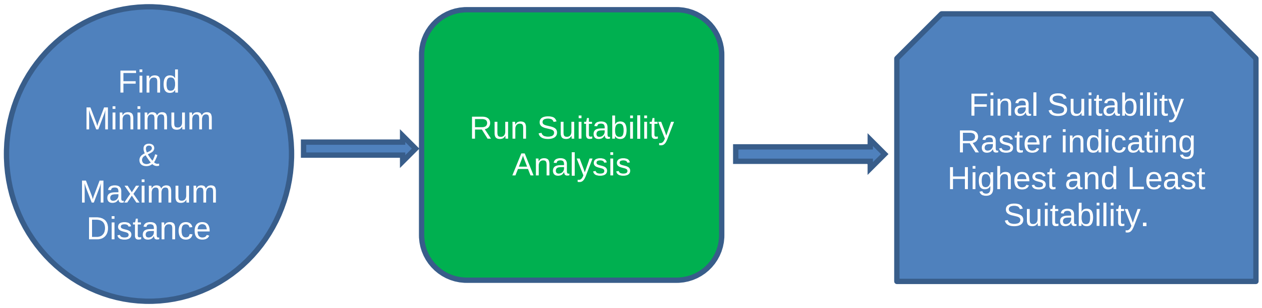


Figure 5-44. General Method for Rail Line Suitability

Zonal Statistics. Rescale by Function.

Minimum Distance away from rail lines (9) = 2426m

Maximum Distance away from rail lines (1) = 4250m

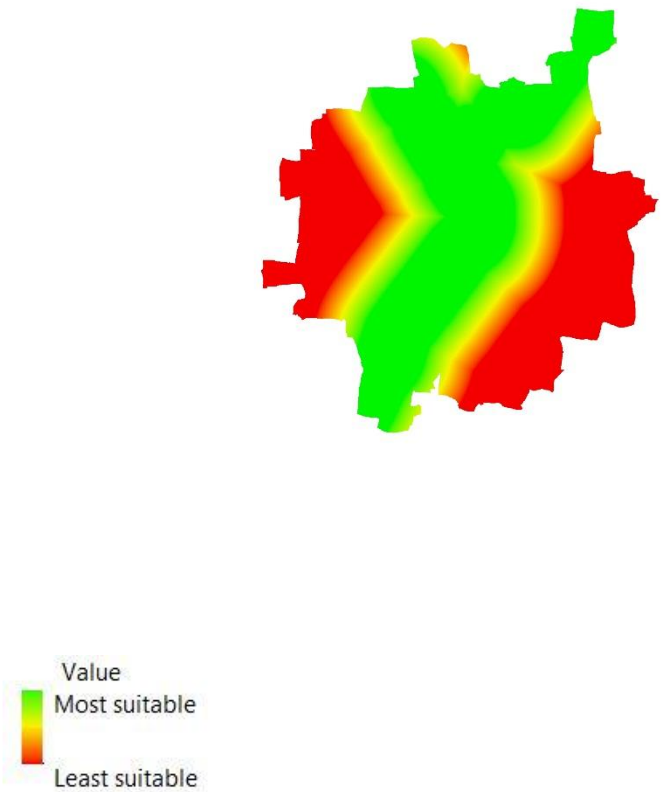


Figure 5-45. Suitable Land Proximal to Rail Lines

To find proximally suitable land we combine all the sub-objectives during weighted sum tool in ArcGIS. To combine the rasters, Analytic Hierarchy Process was used to provide weights to the layers. The following table explains the process further.

Using the weights from AHP, the result was this following raster which indicates proximally suitable land for commercial development.

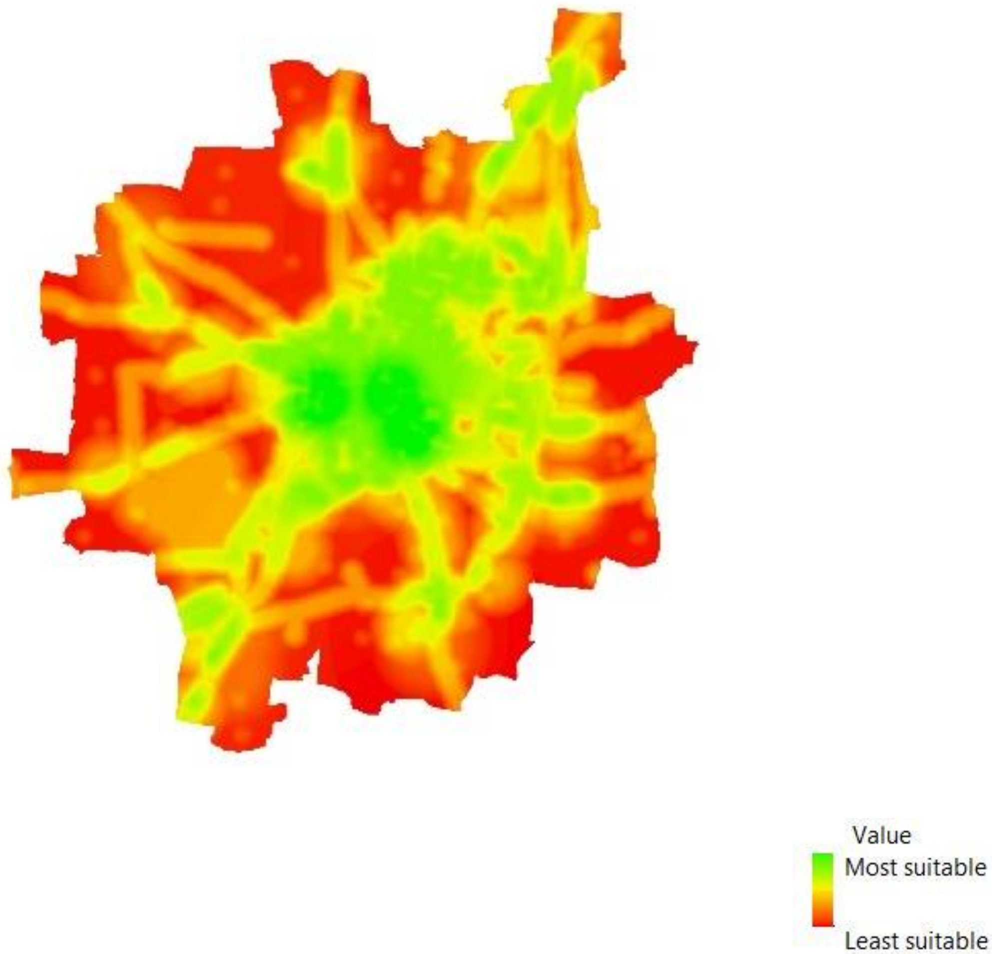


Figure 5-46. Proximally Suitable Land for Residential Development

Resulting Raster = Physically Suitable Land + Proximally Suitable Land

+

Figure 5-47. Physically and Proximally Suitable Land for Residential Development

While weighing the two rasters, proximity was given 65% and physical suitability was given 35% to combine. The resulting raster is as follows.

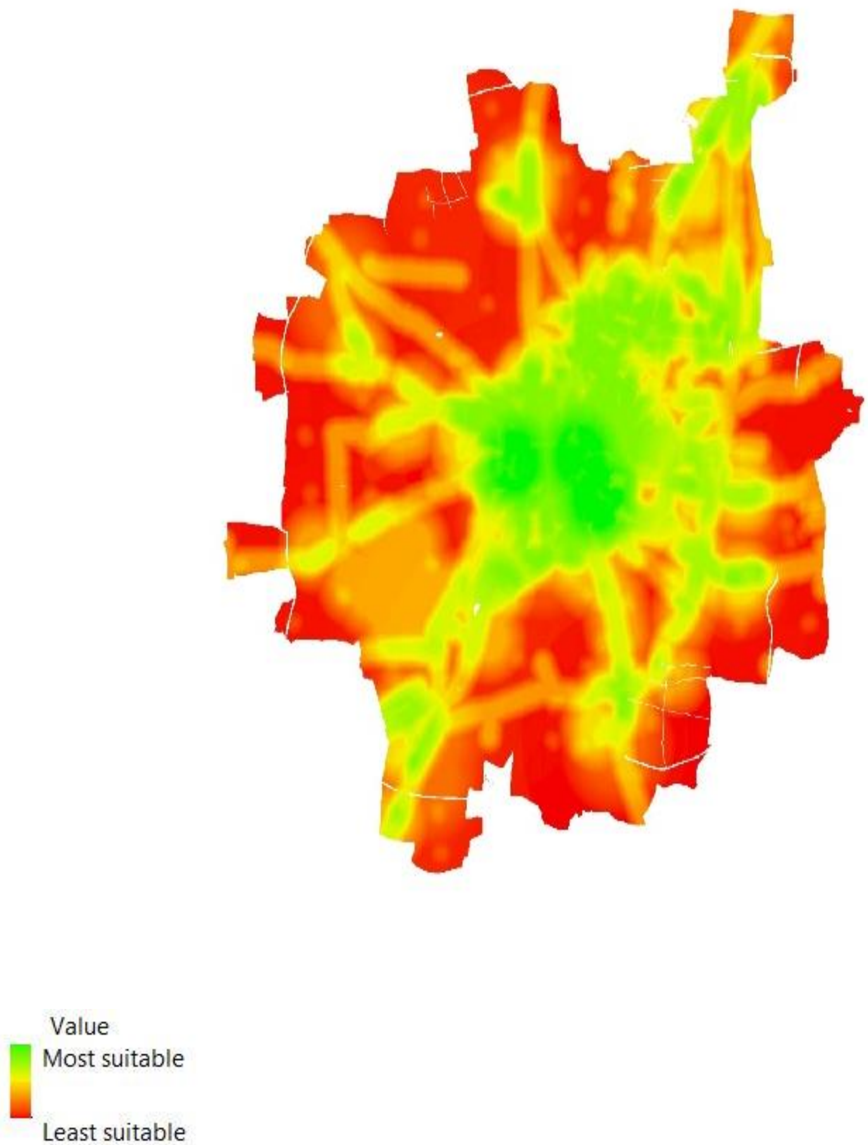


Figure 5-48. Suitable Land for Residential Land Use

5.4. Conflict Surface

This research creates a conflict surface by combining commercial, institutional and residential suitability surfaces. The suitability surfaces must be changed from a scale of 9 to 1 to a scale of 3 to 1 by using the reclassify tool in ArcGIS. The mixed-use pattern represented by the conflict surface scales from 333 (highly suitable for all three land uses) to 111 (least suitable for all three land uses).

Figure 5-49. Reclassified Commercial Suitability Surface

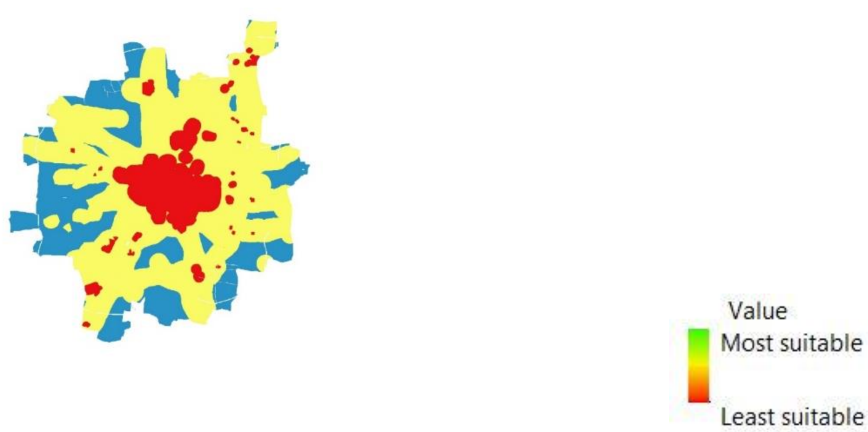


Figure 5-50. Reclassified Institutional Suitability Surface

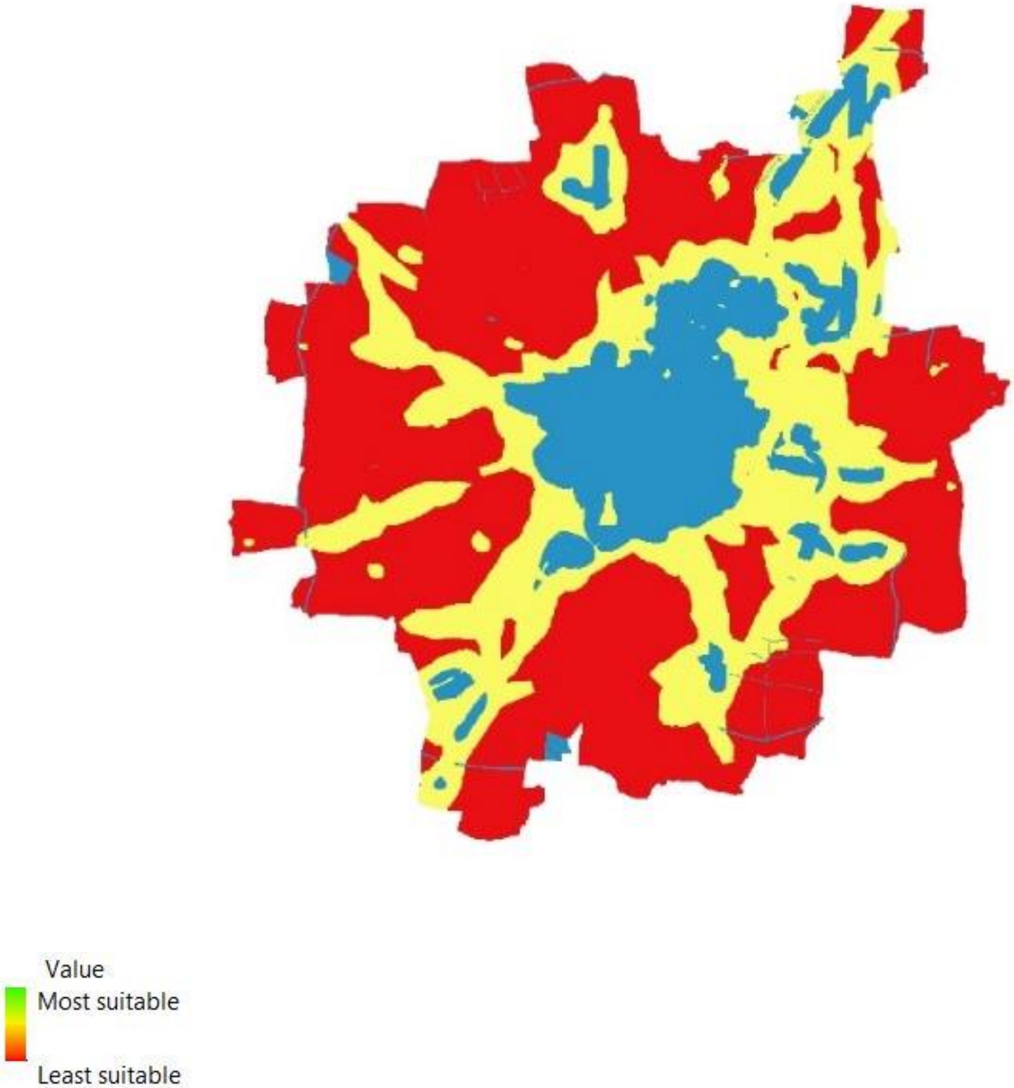


Figure 5-51. Reclassified Residential Suitability Surface

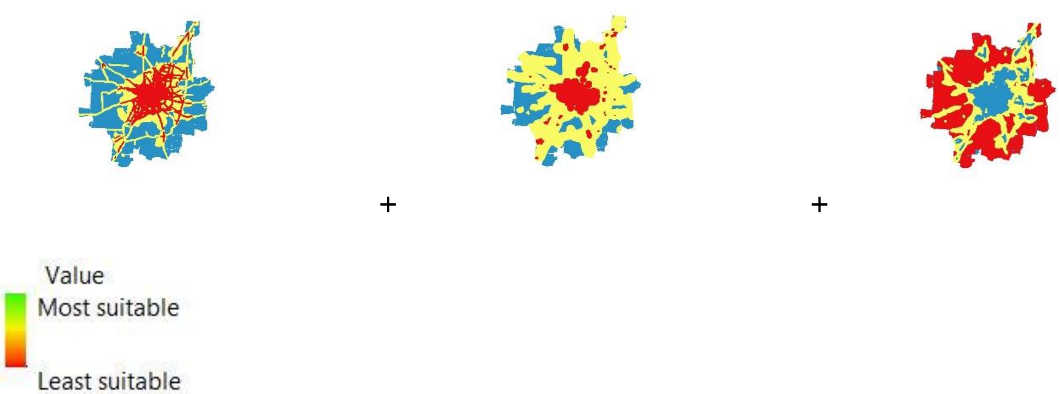


Figure 5-52. Combining the Above Three Surfaces gives the Final Conflict Surface.

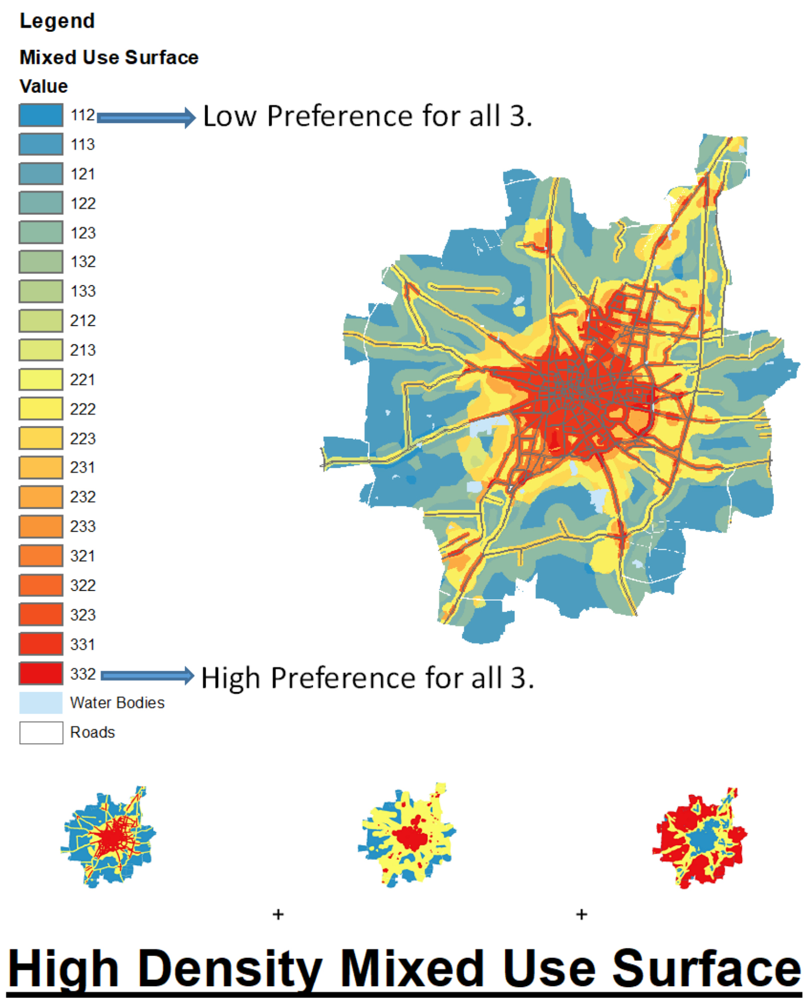


Figure 5-53. Final Conflict Surface for High Density Mixed Land Use

This proposed mixed use development promotes walkability and bicycling by increasing accesibility to decrease overall costs. By maximizing the economic benefits of walking this research establishes the rationale for creating a dense mixed use land use in the city. This research shows the financial limitations for the Smart City Indore initiative and provides recommendations on how better strategies can be used to increase the overall effiency financially and physically. Table 5-4 shows the area alloted to particular land uses.

Table 5-4. Area Available for Different Land Uses

Value	Count	Area in Sq.M	Area in Acres
112	2708	2437200	602
113	127247	114522300	28287
121	29	26100	6
122	36688	33019200	8156
123	129788	116809200	28852
132	1120	1008000	249
133	63	56700	14
212	2477	2229300	551
213	6815	6133500	1515
221	8794	7914600	1955
222	90614	81552600	20143
223	33907	30516300	7538
231	6397	5757300	1422
232	9691	8721900	2154
233	11	9900	2
321	20025	18022500	4452
322	22948	20653200	5101
323	497	447300	110
332	3857	3471300	857

5.5. Applications of Walkability in Planning

Proportional Share. This method is based on allocating transport resources according to the mode share of travel, for example, if walking represents 2% of the travel, it gets 2% of the funding and other resources. As seen before 5 to 10 percent of the travel involves walking and 15 to 30% percent of urban trips involve at least a walking link and following a proportional share a great part of transportation resources would be dedicated to walking (Litman, 2017). Currently, it is tough to see what percentage of transportation funding goes towards non-motorized vehicles since budget separations are vague in most cases. Local governments in United States provide approximately 5-15% of the budget towards walking infrastructure but the federal and state governments significantly less support (Litman, 2017). Even the state of Oregon which is considered as a global leader in non-motorized travel promotion, provides 2% of its budget to transportation while other states on average spend less than 1% (Litman, 2017). The table below further shows budget allocation disparity towards walking and bicycling infrastructure.

Table 5-5. United States Roadway Expenditures. Source: Economic Value of Walking

	Roadway Expenditures(billions)	Walking Facility Expenditures(billions)	Estimated Portion Devoted to Walking
Federal	$30.80	$0.21	0.60%
Local	$31.30	$3.10	10%
Totals	$128.50	$4.60	3.50%

With inclusion of public resources like parking facilities and traffic services, the discrepancy further increases. Walking and bicycling in addition to the above benefits also provide recreational benefits. If proportional share is followed, the budgets for walking and bicycling would increase by 10 times increasing opportunities for recreation as well.

Transportation Cost Allocation. Cost allocation refers to the amount of spending done by a user group on the mode of transport facility and its service which include road tolls, fuel spending and other vehicle maintenance costs (FHWA, 1997). It is largely believed that people with motorized vehicles pay more taxes towards the transportation infrastructure. While vehicle related taxes and fees pay for major highways, the local roads are still paid by the general tax payers regardless of vehicle ownership (Litman, 2017). The average American household pays hundreds of dollars in tax money for traffic services and local road while paying hundreds for parking subsides as well (Litman, 2017). After considering all factors, motorists on an average pay less than non-motorists while walking still receives less share in funding and other resources (Litman, 2009).

Cost-Benefit Evaluation. Cost-Benefit analysis is considered the most efficient method analyzing transportation programs and policies (Litman, 2001). Rigorous application of cost-benefit analysis provides better resources for walking for the following reasons:

- Improved calculations of walking trips will increase the recognition for the benefits and demands for more walkable neighborhood and infrastructure (Litman, 2017).

- Comprehensive analysis of walkability to explore its benefits would provide better justification for investments in non-motorized transportation opportunity. (Litman, 2017).

- Smart growth land use management strategies have been recently gaining recognition placing high values on walking and bicycling (VTPI, 2008).

To evaluate the environmental and equity impacts of walking and bicycling more comprehensive cost-benefit analysis is required for improvements in budgets for walking and bicycling as a part of the transportation budget (Litman, 2017).

The following figure indicates that walking is found to be involved in quarter of all trips and sometimes as high as half of the trips in India making Indian cities highly suitable for walking, high density mixed use and non-motor vehicle zones.

City Category	Description	Trip Mode Share						Average Trip Length
		Walk	Cycle	2-Wheeler	Public	Car	IPT	
Category-1 a	<0.5 million, Plain Terrain	**34**	3	26	5	27	5	2.4
Category-1b	<0.5 million, Hilly Terrain	**57**	1	6	8	28	0	2.5
Category-2	0.5 to 1 million	**32**	20	24	9	12	3	3.5
Category-3	1-2 million	**24**	19	24	13	12	8	4.7
Category-4	2-4 million	**25**	18	29	10	12	6	5.7
Category-5	4-8 million	**25**	11	26	21	10	7	7.2
Category-6	>8 million	**22**	8	9	44	10	7	10.4
National		**28**	**11**	**16**	**27**	**13**	**6**	**7.7**

Figure 5-54. Trip Mode Shares in Indian Cities. Source: MOUD. 2008. Study on Traffic and Transportation Policies and Strategies in Urban Areas in India.

Per a survey conducted on six Indian cities by Clean Air Asia, Indian cities have relatively low walkability scores due to poor infrastructure and unsafe environment with average score being 47 where 20 is minimum and 100 is maximum. A comparison of cities in India and cities in developed countries can provide better context to the lack of walking in India. The following figure displays the results of the survey.

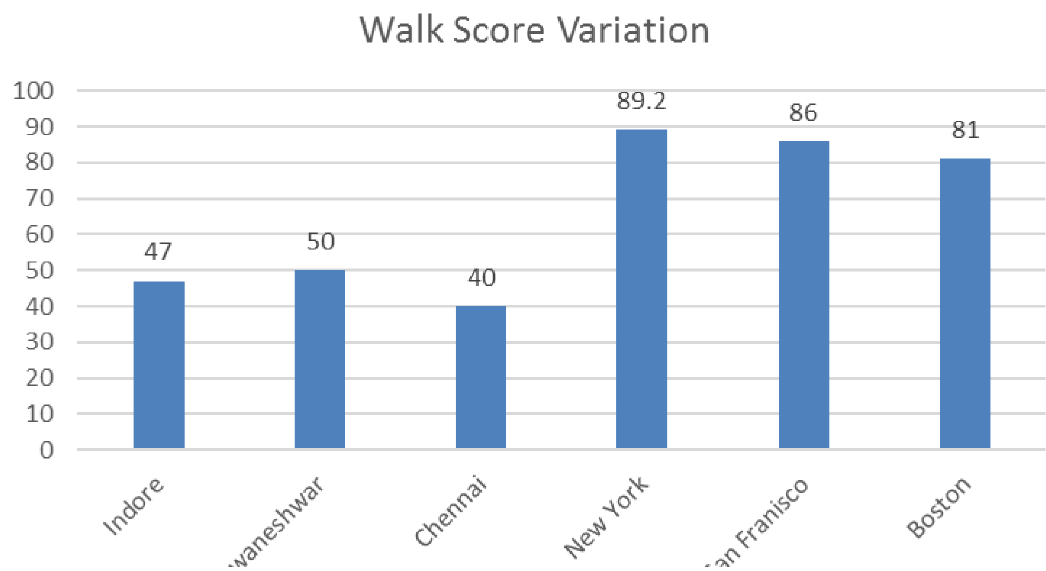


Figure 5-55. Variation in Walkability Ratings in Six cities. Source: Walk Score and Walkability in Indian Cities

The previous figure illustrates the low walking score in Indian cities as compared to the cities in United States. The same survey presented the travel characteristics in Indore as follows.

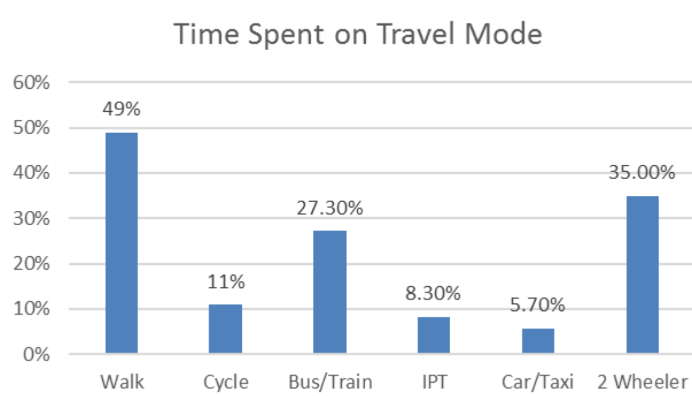


Figure 5-56. Time Spent on Travel Mode in Indore City. Source: Clean Air Asia.

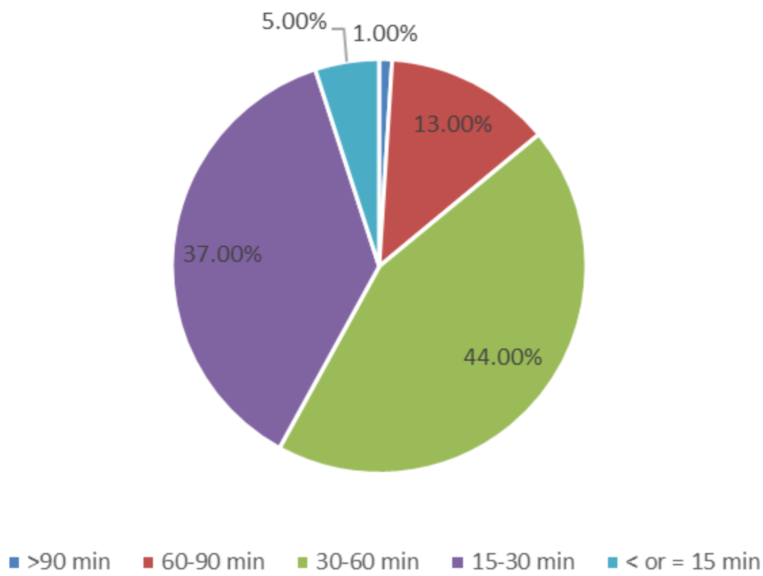


Figure 5-57. Average Time from Residence to Destination in Indore City. Source: Clean Air Asia.

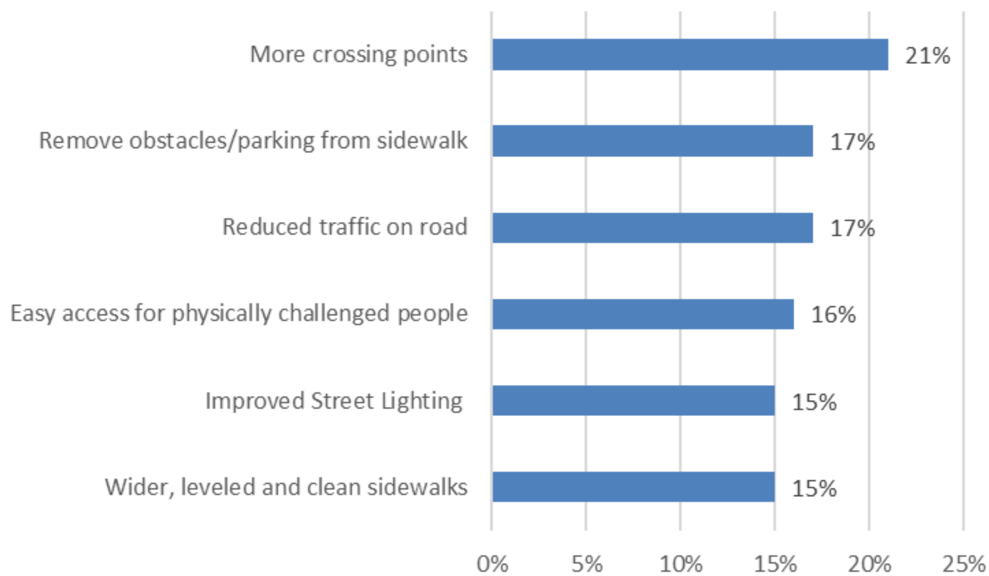


Figure 5-58. Preferred Improvement in Facilities in Indore City. Source: Clean Air Asia.

According to Times of India in 2015 the average weekly commute time has increased considerably in the last 7 years. The following figure shows the increase in New Delhi and Mumbai, from 8 hours and 46 minutes in 2008 to 12 hours and 30 minutes in 2015.

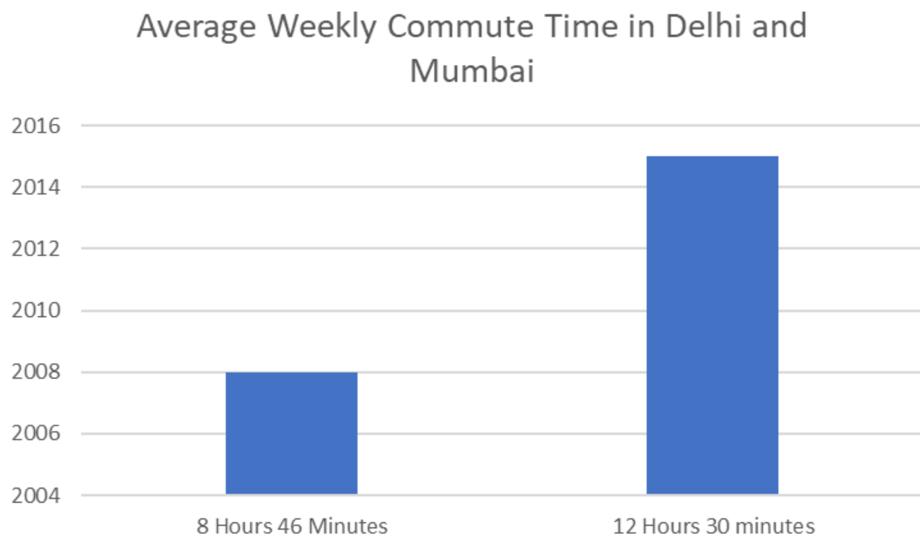


Figure 5-59. Increase in Average Weekly Commute Time. Source: The Hindu.

This increase can negatively impact social relationships and personal health of an individual. While 51% of the Indian population uses non-motorized transport, the space allotted to them on the roadway is non-existent (The Hindu, 2015). By 2040, India is expected to face an increase in cars by 775% (NDTV, 2016) which would mean 7 more cars would be fighting for the same space on the road in comparison to 2016. For years, the local and central governments have responded to these congestion and safety issues by either widening the roads or building new ones. The sales pitch for freeways is always that they solve congestion but they are only good for longer distances and result in regional growth. Building more freeways leads to a temporary solution but as time goes on, they only exacerbate the traffic congestion problem.

Apart from the negative impacts, building freeways are extremely expensive in comparison to building or improving street furniture for walking and biking. As mentioned earlier in the paper, the cost dedicated towards walking and biking in a transportation budget is 2% in even the most bike and pedestrian friendly cities. The emphasis of the investments has been on moving cars rather than moving people for the longest of times. Public transit is efficient in moving people from many places to a few places but lacks the ability to move people from few places to many places making cities and neighborhoods car dependent and increasing private vehicle ownership. Cities were originally designed to maximize exchange of goods and minimize travel, so a well-designed city would be one where there is less transportation and more accessibility by putting thing closer (Moore, 2014).

According to National Crime Records Bureau of India, every 4 minutes an Indian resident is killed on the roads and according to Stanford Law School in 2013, human error is responsible for 90% of the traffic crashes which makes it hard to ignore that eliminating vehicles from roads by promoting walking and biking would provide a socio-economic benefit to the society, especially in a India where 51% of the population uses non-motorized mode of transport exposing a large population to risk.

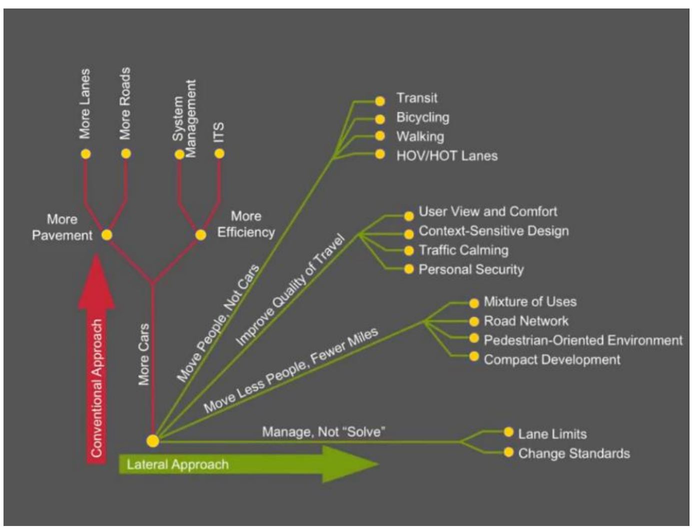


Figure 5-60. Change in Transit Planning Approach. Source: USC Price

The above diagram explains the difference between conventional transportation planning and modern-day approaches to tackle challenges with a new perspective. By focusing on a paradigm shift in planning, these strategies bring the focus of the transportation system from moving cars to moving people.

5.5. Budget Restructuring

Per Smart City Plan for Indore City, the Transportation and Walkability budget is ₹ 507.13 crores and following traditional distribution less than one percent of that budget would be allocated towards walking and biking. The following figure displays the debt repayment and collection involved in the Smart City Plan.

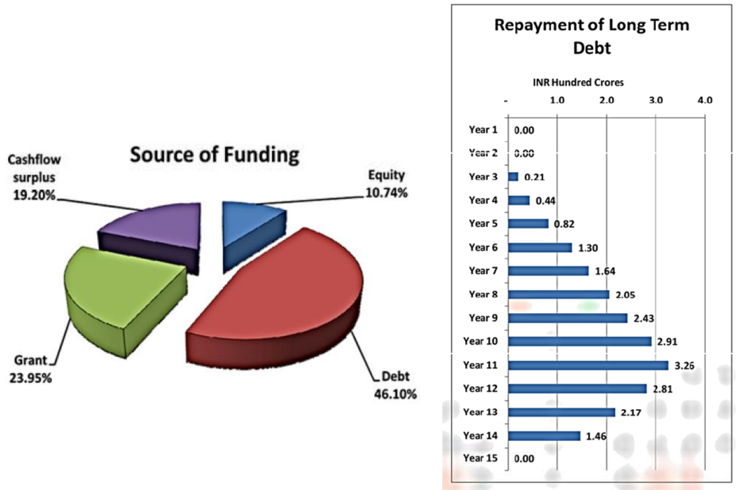


Figure 5-61. Source of Funding and Debt Repayment Structure for Smart City Plan Indore. Source. Smart City Indore

Considering a transportation budget restructuring and increasing the walking and bicycling budget even by 2% could lead to a faster debt repayment scheme while increasing the efficiency of available funds. Like most projects, Smart City Indore also suffers from deficiency of funds and by slightly altering the transportation budget, the city can benefit from the economic perks of increased walkability and bicycling. To provide high density mixed use development plans, LUCIS has been used for years and it provides a solid analytical base for the plan. By combining LUCIS and budget incentives for walking as well as bicycling, the final development plan has the potential to provide high economic and social benefits. Lack of safety is a major issue in developing countries like India right now growing congestion is only making it worse, this plan better supports safety and focuses on congestion decreasing initiatives. This form of development also favors a rise in retail and employment sector, by using suitability analysis. Apart from this people in India have had a history of walking since ancient times and so it would not be an irrational argument to propose a plan where people leap frog from using their cars on a daily basis to walking in close proximities. Apart from this a planned transit system taking people from one urban center to the other would work very well with this system, for example, an improved BRT or Metro. This could make it easier to travel regionally for people living in high density mixed use neighborhood while improving accessibility and decreasing car usage at the same time.

Table 5-6. AHP for Commercial Development

	Roads	Commercial	Bus	PSP	Residential	Airport	Rail	
Roads	1	4	3	5	4	5	6	
Commercial	0.25	1	2	3	3	4	5	
Bus	0.333333333	0.5	1	3	3	5	6	
PSP	0.2	0.33333333	0.33	1	2	4	5	
Residential	0.25	0.33	1	0.5	1	3	5	
Airport	0.2	0.25	0.2	0.25	0.33	1	3	
Rail	0.166666667	0.2	0.16	0.2	0.2	0.33	1	
SUM	2.4	6.61	7.69	12.95	13.53	22.33	31	
Standardized Matrix								
	Roads	Commercial	Bus	PSP	Residential	Airport	Rail	Weight %
Roads	0.416666667	0.60514372	0.390117	0.3861	0.295639	0.223914	0.193548	35
Commercial	0.104166667	0.15128593	0.260078	0.23166	0.221729	0.179131	0.16129	18
Bus	0.138888889	0.07564297	0.130039	0.23166	0.221729	0.223914	0.193548	17
PSP	0.138888889	0.05042864	0.042913	0.07722	0.14782	0.179131	0.16129	11
Residential	0.104166667	0.04992436	0.130039	0.03861	0.07391	0.134348	0.16129	9
Airport	0.083333333	0.03782148	0.026008	0.019305	0.02439	0.044783	0.096774	4
Rail	0.069444444	0.03025719	0.020806	0.015444	0.014782	0.014778	0.032258	6

Table 5-7. AHP for Residential Development

	PSP	Roads	Bus	Commercial	Industrial	Residential	Airport	Rail	
PSP	1	2	3	2	2	3	6	5	
Roads	0.5	1	2	3	3	4	5	5	
Bus	0.33	0.5	1	2	3	4	6	6	
Commercial	0.5	0.33	0.5	1	2	2	6	5	
Industrial	0.5	0.33	0.33	0.5	1	2	5	5	
Residential	0.33	0.25	0.25	0.5	0.5	1	4	6	
Airport	0.166667	0.2	0.16	0.16	0.2	0.25	1	3	
Rail	0.2	0.2	0.16	0.2	0.2	0.16	0.33	1	
Sum	3.52	4.81	7.4	9.36	11.9	16.41	33.33	36	Weight
Standardized Matrix									
	PSP	Roads	Bus	Commercial	Industrial	Residential	Airport	Rail	
PSP	0.284091	0.4158	0.405405	0.2136752	0.168067	0.182815	0.150015	0.138889	0.24
Roads	0.142045	0.2079	0.2079	0.3205128	0.252101	0.243754	0.180018	0.138889	0.21
Bus	0.09375	0.10395	0.135135	0.2136752	0.252101	0.243754	0.180018	0.166667	0.1725
Commercial	0.142045	0.068607	0.067568	0.1068376	0.168067	0.121877	0.150015	0.138889	0.12
Industrial	0.142045	0.068607	0.044595	0.0534188	0.084034	0.121877	0.150015	0.138889	0.1
Residential	0.09375	0.051975	0.033784	0.0534188	0.042017	0.060938	0.120012	0.166667	0.0775
Airport	0.047348	0.04158	0.021622	0.017094	0.016807	0.015235	0.030003	0.083333	0.03375
Rail	0.056818	0.04158	0.021622	0.0213675	0.016807	0.00975	0.009901	0.027778	0.02

Table 5-8. AHP for PSP Development

	Roads	Bus	PSP	Commercial	PUF	Airport	Rail
Roads	1	4	3	4	4	6	6
Bus	0.25	1	4	3	4	5	5
PSP	0.33	0.25	1	3	4	5	5
Commercial	0.25	0.25	0.25	1	3	6	5
PUF	0.25	0.25	0.25	0.33	1	6	6
Airport	0.16	0.2	0.2	0.16	0.16	1	2
Rail	0.16	0.2	0.2	0.2	0.16	0.5	1
SUM	2.4	6.15	8.9	11.69	16.32	29.5	30

	Roads	Bus	PSP	Commercial	PUF	Airport	Rail	Weight
Roads	0.416667	0.650407	0.337079	0.3421728	0.245098	0.20339	0.166667	34
Bus	0.104167	0.162602	0.449438	0.2566296	0.245098	0.169492	0.166667	22
PSP	0.1375	0.04065	0.11236	0.2566296	0.245098	0.169492	0.166667	16
Commercial	0.104167	0.04065	0.02809	0.0855432	0.1838235	0.20339	0.166667	11
PUF	0.104167	0.04065	0.02809	0.0282293	0.0612745	0.20339	0.2	10
Airport	0.066667	0.03252	0.022472	0.0136869	0.0098039	0.033898	0.066667	4
Rail	0.066667	0.03252	0.022472	0.0171086	0.0098039	0.016949	0.033333	3

CHAPTER 6
LIMITATIONS and CONCLUSION

6.1 Limitations

There were limitations with this research. The first limitation was to access the GIS data for land values in the city of Indore. Secondary data only included basic land uses divided over Khasras. To calculate the values of different land uses, approximate values were used which required filling excel tables and translating from Hindi to English as most of the government documents are still in Hindi. This lowered the accuracy of land value analysis due to which this research had to put a low weightage on Land Value Suitability while combining all suitability surfaces. Although, the data lacks a little accuracy, once better data is received it can be easily put in the system to improve overall accuracy. The second limitation for this research was the lack of communication with actual stakeholders in the city, due to a travel barrier and time difference between the countries, meetings and interviews were tough to schedule. Once there is chance for this research to be presented within the city, feedbacks can further strengthen the research. The third limitation for this research would be lack of economic data specifications in the smart city plan and lack of literature regarding economic value of walkability in India. This research wanted to establish a direct relationship between the money saved from creating a high density mixed use and walkable plan to the debt repayment structure of the Smart City Plan. The specifications for money allocated to walking and biking in the transportation budget are not present in the data and the current conversion of money saved by increased walking and bicycling initiatives in United States to money saved in rupees in India is a tough transition as it involves many externalities. With further research into making an accurate conversion between the two currencies, this research can improve. The fourth limitation was the absence of soils and flooding data for the city which could have improved the analysis. The final limitation was the limited usage of ArcGIS in India. Due to this, the data collection process was strenuous and there was an understanding barrier for the people who oversaw dispatching the required dataset.

6.2 Conclusion

The purpose of this study was to evaluate the land use development and transportation plan for City of Indore, India while suggesting alterations to its Smart City Plan. The results displayed that there is over 1000 Acres of land suitable for high density mixed use which is spread across the city with a bulk of it in the center of the city. Apart from this 11,891 Acres of land is moderately suitable mixed-use development, some of which even extends to the outskirts of the city. With massive growth and urbanization occurring in the city, the government would benefit a great deal by using their funds allocated for mixed use development in these certain locations with respect to their high suitability. The LUCIS analysis created a master plan or surface for the city pinpointing suitable land uses for land parcels. With feedback from planners in the city and stakeholders, this study would provide great potential for change. The secondary purpose of this study was to introduce a paradigm shift in traditional land development and transportation planning. The study identifies current transportation challenges and how traditional planning strategies have only turned out to be a temporary solution while exacerbating those issues in the long run. Further, it explains how the everlasting problem of funding shortage for modern transportation interventions can be minimized. This research proposes a paradigm shift in conventional planning by increasing budgets for walking and biking for infrastructural improvements to reap economic, social and health benefits induced by it. After explaining what the paradigm shift could be, it explains how to achieve it by using LUCIS and producing a high density mixed use and walkable plan for the city. By putting things closer to each other, it increases accessibility and shifts the focus from moving cars back to moving people. Especially, in a country like India where 51% of the total population still uses non-motorized form of transportation, a study putting emphasis on improved walking and biking infrastructure could be beneficial for the planning authorities (The Hindu, 2015). With cities like Indore still fighting digitization and use of ArcGIS in planning decision making and processes, this could be a great start and introduction of LUCIS as a decision-making tool could prove lucrative for departments struggling with analysis of different land uses. Although, this study cannot be defined as the one solution to planning problems in India, it does a fairly good job of managing some of the current issues and with better data, communication and feedback from stakeholders, it will only improve as we move on building up on this first initial step.

LIST OF REFERENCES

Appleyard, D. (1981), Livable Streets. University of California Press (Berkeley).

Arnold, C., & Gibbons, J. (1996). Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. American Planning Association Journal, 62(2), 243-258.

Boarnet, M. (1995). New Highways & Economic Productivity: Interpreting Recent Evidence. Journal of Planning Literature, 11(4), 476-486.

Boarnet, M.G., Greenwald, M., & McMillan, M.E. (2008). Walking, Urban Design, and Health: Toward a Cost-Benefit Analysis Framework. Journal of Planning Education and Research, 27(3), 341-358.

Brog, W., Erl, E., & James, B. (2003). Does Anybody Walk Anymore?. Sustainable Transport: Planning for Walking and Cycling In Urban Environments, 59-69.

Burchell, R. (1998). The Costs of Sprawl – Revisited. Transportation Research Board, Report 39, (www.trb.org).

Delgado, O.B, Mendoza, M., Granados, E.L., & Geneletti, D. (2008). Analysis of land suitability for the siting of inter-municipal landfills in the Cuitzeo Lake Basin, Mexico. Science Direct, 28(7), 1137-1146.

ECU (2004a). Physical Inactivity Cost Calculator (www.ecu.edu/picostcalc). College of Health & Human Performance, East Carolina University (www.ecu.edu); documentation at www.ecu.edu/picostcalc/pdf_file/Methods.pdf.

ECU (2004b). Physical Activity Facts and Figures. College of Health & Human Performance, East Carolina University (www.ecu.edu); at www.ecu.edu/picostcalc/pdf_file/FactsandFigures.pdf.

Eppli, M., & Tu, C.C. (2000). Valuing the New Urbanism; The Impact of New Urbanism on Prices of Single-Family Homes. Urban Land Institute, (www.uli.org).

Ewing, R., Pendall, R., & Chen, D. (2002). Measuring Sprawl and Its Impacts. Smart Growth America, (www.smartgrowthamerica.org).

Feizizadeh, B., & Blaschke, T. (2013). Land suitability analysis for Tabriz County, Iran: a multi-criteria evaluation approach using GIS. Journal of Environmental Planning and Management, 56(1), 1-23.

Forkenbrock, D., & Weisbrod, G. (2001). Assessing the Social and Economic Effects of Transportation Projects. NCHRP, Report 456, (www.trb.org).

Goodman, R., Tolley, R. (2003). The Decline of Everyday Walking In The UK: Explanations And Policy Implications. Sustainable Transport: Planning for Walking and Cycling In Urban Environments, 70-83.

Haze, G., (2000). Counting Pedestrians. Walk San Francisco, (www.walksf.org/essays/pedCountEssay.html).

Indore Municipal Corporation & Mehta and Associates. (2015). Smart City Indore.

Killingsworth, R. E., & Lamming, J. (2001). Development and public health. Urban Land, 12-17.

Leinberger, C.B., & Alfonzo, M., (2012). Walk this Way: The Economic Promise of Walkable Places in Metropolitan Washington, D.C. Brookings Institute (www.brookings.edu); at www.brookings.edu/research/papers/2012/05/~/media/Research/Files/Papers/2012/5/25%20walkable%20places%20leinberger/25%20walkable%20places%20leinberger.pdf.

Litman, T.A. (2002). Evaluating Transportation Land Use Impacts. VTPI, (www.vtpi.org/landuse.pdf).

Litman, T.A. (2003). Measuring Transportation Traffic, Mobility and Accessibility. ITE Journal (www.ite.org), 73(10), 28-32.

Litman, T.A. (2009), Transportation Cost and Benefit Analysis. VTPI, (www.vtpi.org).

Litman, T.A. (2011), Evaluating Transportation Economic Development Impacts. VTPI, (www.vtpi.org).

Litman, T.A. (2017). Economic Value of Walkability. Journal of the Transportation Research Board, 1828. doi: 10.3141/1828-01

Litman, T.A., & Fitzroy, S. (2005). Safe Travels: Evaluating Mobility Management Traffic Safety Impacts. VTPI (www.vtpi.org); at www.vtpi.org/safetrav.pdf.

LTNZ (2010). Economic Evaluation Manual (EEM) – Volumes 1 & 2. Land Transport New Zealand (www.landtransport.govt.nz); at www.landtransport.govt.nz/funding/manuals.html (Active transportation health benefits data, 2 (3.8), 3-22.

McCann, B., (2000). Driven to Spend; The Impact of Sprawl on Household Transportation Expenses. Surface Transportation Policy Project, (www.transact.org)

Mehra, S., & Verma, S. (2016). Smart Transportation- transforming Indian cities. Grant Thornton India.

Murphy, J., & Delucchi, M. (1998). A Review of the Literature on the Social Cost of Motor Vehicle Use. Journal of Transportation And Statistics, 1(1), 15-42.

NBPC (1995), The Economic and Social Benefits of Off-Road Bicycle and Pedestrian Facilities. National Bicycle and Pedestrian Clearinghouse, (2), (www.bikefed.org).

Pucher, J., & Dijkstra, L., (2000). Making Walking and Cycling Safer: Lessons from Europe. Transportation Quarterly, 54(3), at www.vtpi.org/puchertq.pdf.

Rietveld, P., (2000). Nonmotorized Modes in Transport Systems: A Multimodal Chain Perspective for The Netherlands. Transportation Research D, 5(1), 31-36

Sallis, J.F., Frank, L.D., Saelens, B.E., & Kraft, M.K. (2004). Active Transportation and Physical Activity. Transportation and Physical Activity, 38(4), 249-268.

Stokes, R.J., MacDonald, J., & Ridgeway, G. (2008). Estimating The Effects Of Light Rail Transit On Health Care Costs. Health & Place, 14(1), 45-58.

Sztabinski, F., (2009). Bike Lanes, On-Street Parking and Business A Study of Bloor Street in Toronto's Annex Neighbourhood. The Clean Air Partnership (www.cleanairpartnership.org); at www.cleanairpartnership.org/pdf/bike-lanes-parking.pdf.

Tomalty, R., & Haider, M., (2009). Walkability and Health; BC Sprawl Report 2009. Smart Growth BC (www.smartgrowth.bc.ca); at www.smartgrowth.bc.ca/Portals/0/Downloads/sgbc-sprawlreport-2009.pdf.

VTPI (2008). Evaluating Nonmotorized Transportation. Online TDM Encyclopedia, (www.vtpi.org).

Weissman, S., & Corbett, J. (1992). Land Use Strategies for More Livable Places. Local Government Commission, (www.lgc.org).

Yeh, G.A. (2007). The development and applications of geographic information systems for urban and regional planning in the developing countries. International Journal of Geographical Information Systems, 5(1), 5-27.

Zwick, P., & Carr, M.H. (2007). Smart Land-Use Analysis: The LUCIS Model: Land-Use Conflict Identification Strategy. Journal of American Planning Association, 75(1).

BIOGRAPHICAL SKETCH

Yash Nagal completed his Bachelor in Civil Engineering in 2015 from Oriental Institute of Science and Technology. From there after gaining work experience for 7 months he started school at University of Florida for Master of Urban and Regional Planning. He is expected to graduate in December 2017. Following his interdisciplinary education background, he specializes in Transportation Planning with a goal to bridge the gap between the fields of Planning and Engineering.