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Reviewing the First Settlements

Nagarlo
55(3), 1-16
July-September, 2023
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DOI: <https://doi.org/10.32381/NL.2023.55.03.1>

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Abstract

The first humans appeared about 300,000 years ago and were called *homo sapiens*. As these appeared on the earth, requirement of food and shelter grew and thus the requirement of first settlement. This research paper tries to explore the various concepts given by a number of authors in different areas across the globe that contributed to the development of first settlements. The authors have tried to cover through some notable settlements in Middle East like Catal Huyuk in Southern Turkey, Nabta Playa in Egypt and Jericho in West Bank region of Middle East. The research type is exploratory with focus on literature from well-known authors like Smith (2009), and anthropologists like Mellaart (1967), Kenyon (1956), Wendorf and Schild (1998, 2001). The settlements have been studied in terms of various parameters like population, housing, religion, occupation, art and pottery, etc. In the discussion, some similarities or common features and differences among the settlements have been noted by the researchers.

Keywords

Settlements, Housing, Religion, Time period, Economy, Occupation.

Introduction

According to Smith (2009), during the last few millennia, human social orders have experienced significant changes in their social requests. 10,000 years back, all people lived in little mobile groups or clusters that survived on wild plants and creatures. In a few regions of earth, early hunting groups domesticated plant and animal species to create a cultivating lifestyle (Smith, 2009). Agriculture was joined by more noteworthy sedentism and populace development, and its appropriation was regularly

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trailed by the extension of cultivating (Neolithic) lifestyle into new regions through a mix of relocation and exchange (Smith, 2009, p. 4). Later, people started settling in the places where food was surplus, they started making permanent settlements where they could reside leaving behind the nomadic culture. In this context, the authors chose few settlements and tried to study their evolution, occupation, population, housing, religion and the time period in which they existed. The major settlements selected were from Middle East which are believed to be the oldest of their times. All these civilisations arose near a river or a water body like the first civilisation rose in Indus valley in India along river Indus, Yellow River near China, Nile Valley in Egypt and Tigris and Euphrates in Mesopotamia and so on.

The present paper is based on exploratory research by the authors and aims to review the various researches done by various eminent scholars like, Childe (1950), Tilly (2010), (2018) as well as anthropologists like Mellaart (1967), Kenyon (1956), Wendorf and Schild (1998, 2001). The cases taken for reviewing are Jericho in Palestine, Catal Huyuk in Southern Turkey, and Nabta Playa in Egypt.

Research Methodology

The descriptive research methodologies are applied. The data is gathered from secondary sources such as Google scholar, Scopus, and Web of Science, mostly papers by well-known historians and archive records. The researchers have reviewed secondary databases available in terms of literature through university databases, the best available resources have been referred like books, journals, research articles etc. The research bent towards description tries to decipher certain questions:

1. Which were the first settlements in the global scenario?
2. How these settlements developed across various parts of the globe?
3. What was the location, housing, religion, economy and art work of these settlements?
4. How different timelines were covered?

Jordan Hericho/ Jericho

Location

Jericho, also known as *Arabic Ariha*, is situated on the West Bank region of Middle East (Encyclopaedia Britannica, n.d). It is now known as Palestinian City in Jordan (Wikipedia, n.d.). It is one of the world's first continuously occupied communities, as stated in the Holy Bible. It gives evidence of the first development of permanent settlements and in this manner of the initial move towards development of civilisation.

Date and Time Period

There are various views by different authors on the date and time of origin of Jericho. The authors have tried to classify these time periods according to various sources. Britannica Encyclopaedia states that Mesolithic hunters from about 9000 BC resided here.

Similar finding has been done by a researcher (Bar-Yosef, 1986) who states that the oldest remains of Jericho are from around 9000 B.C. when the *Natufian* culture has been found. Later, subsequently after a break of approximately a millennium or epoch (9200-8350 B.C.), the place was settled as well as occupied by one of the initial farming and agricultural societies (Bar-Yosef, 1986). Another researcher Wright (1985) in his book writes that by around 10,000 B.C a “Mediterranean Type” of man was existing and residing in the area, more in the practice as well as tradition of constructing his own permanent abodes than to sheltering caves. It was the Natufian culture of Mesolithic man. By 7500 B.C, the oasis site of Jericho in north of Jordan valley was built (Wright, 1985). Wright further states that Pre-Pottery Neolithic Age (PPNA) 8000 BC (precisely 8300-7300 BC) invention of mud brick was here and PPNB (7000 BC) diversified building angular plan with load-bearing walls was found in Jericho. Kenyon, (1954) states that Jericho was dated back sometime between 1400 and 1250 BC and may be considered as the oldest town in the world (Kenyon 1954). Tilly, (2010, p. 269) states that Jericho had an intense settlement, substantial walls, and at least a thousand residents towards 7000 BCE.

There are different time periods given by different authors in various research papers and books indicating that it started in Mesolithic time with hunters and pre-agriculture and PPNA and PPNB (Pre-pottery Neolithic A and B) time period were part of it. It also extended up to (Pre-pottery Neolithic B) PPNB time period where the walls and tower of Jericho were established.

Population

Kramer (1982) cited by Bar-Yosef (1986) states that population of Jericho was estimated to be 400-900. The scope of the settlement population is crudely between 2000-3000 people according to Britannica.

Bar-Yosef (1986) cites Kenyon stating that her population approximation was 3000-4000 while Wright (1985) states that Jericho had a population of 7000.

Therefore, according to the researchers, these populations would also vary according to various time periods. In the initial stage, the community staying would be ranging between 400-900 as stated by Kramer and later with PPNA and PPNB they were increased to several thousand as stated above.

Occupation

The occupation as stated by (Bar-Yosef, 1986) and Wright (1985) is “*Natufian Culture*”.

The authors explored about the Natufian culture and occupation which mainly consisted of hunters and gatherers. According to Britannica, these people gathered and collected wild grains and they were not doing cultivation. They had sickles of flint blades (Britannica Encyclopaedia).

The Natufian family occupation as well as economy was completely dependent upon gathering (for which the sign and records is relatively light due to meagre conservation in Mediterranean soils), hunting (mainly gazelle, fallow deer, roe deer, wild boar, ibex, etc.), and fishing, mainly in inland lakes such as Hula Lake, on the shores of which the site of Eynan was established (Bar-Yosef 1983, 1986). Vernon (1964) states that there are extraordinary remnants of Nabatean civilisation grew by an Arabic language people who had accepted a combination of Egyptian and Hellenistic culture and philosophy. They were also possibly domesticating sheep during PPNB (Wikipedia, nd). According to (Bar-Yosef, 1986), the first transformation took place when slight movable clusters of hunter gatherers became partly or completely sedentary, long-term occupied sites housed larger (perhaps 50-80 persons).

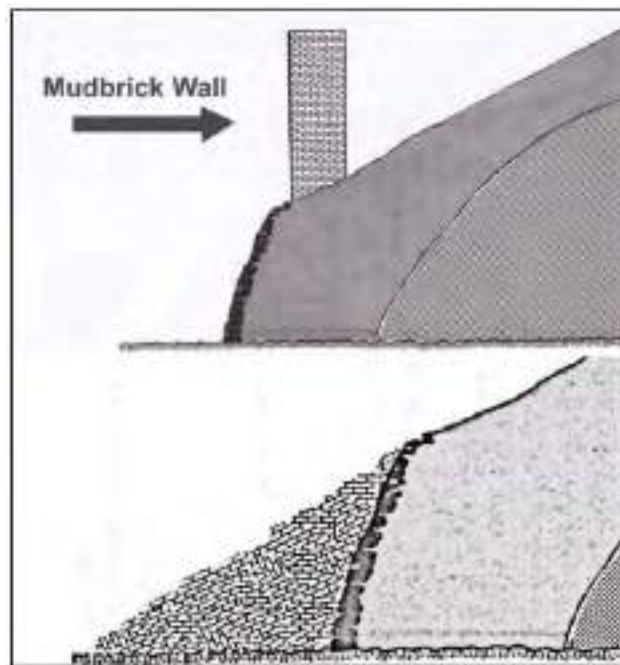


Figure 1: Mud Brick wall in Jericho

Source: <https://www.youtube.com/watch?v=C27CmsSGx5Y&t=488s> (Drawn by authors)

Wall, Stairs, and Tower

Bar-Yosef (1986) states that Jericho had a wall and tower (Refer figure 1). The first perimeter wall 3.6 m in height was 1.8 m thick at its base and only 1.1 m at its conserved top (Bar-Yosef, 1986). The tower, located inside the perimeter of the settlement was 8.3 m in height and built of undressed stones (Bar-Yosef, 1986). It had a stairway going to the topmost with 22 steps built of dressed slabs (Bar-Yosef, 1986). There were no rooms inside the tower (Bar-Yosef, 1986). The obtainable dates show that the construction took place between 8300 BC and 7800 BC which may mean around 8000 BC as estimated by Kenyon. Kenyon concluded that the oval mound of Jericho was encircled by a defensive wall enclosing an area of 2.4 hectares (Bar-Yosef, 1986). Additional walls, also interpreted by Kenyon as "town walls" were uncovered in the western trench and dated to the following period, the Pre-pottery Neolithic B (7300-6000 BC) (Bar-Yosef, 1986). These were slanting built of undressed stones, retaining the earlier levels (Bar-Yosef, 1986). The existence of a thick, free-standing wall and a tower specify a collective public effort to fortify the settlement. Bar-Yosef, (1986, p. 158) states that the effort required to build the perimeter wall was later calculated by Dorrell (1978) as about a week's worth for 200 men; a recalculation based on a more realistic estimate of 0.5 m³ per man per day yields a figure of 10,400 work days or about 104 work days for 100 men (Bar-Yosef, 1986 p. 158). As a walled site, Jericho deserves to be called a "town" and is therefore equivalent to the later Near Eastern fortified towns (Bar, 1986, p 158).

There are certain different views of settlements as suggested by Tilly (2010) that Jericho's early walls could have served predominantly to guard or shield stored crops from minor group of hunter gatherers or merely to keep out invading water (Tilly, 2010, p 269 cites Gat 2006, pp 170 -172, Smith 1995, p. 3). Bar-Yosef (1986) states that Neolithic walls of Jericho are that they were built in stages as a defence system against flood sand mudflows. The PPNA residents of Jericho selected to reside near an inexhaustible spring on a slanting plain which was liable to mud streams and sheet wash. Their reaction was to construct a wall, and then when required, excavate a ditch. The necessity for better construction on the western side would clarify the changing thickness of the wall (Bar-Yosef, 1986). The walled settlement of Jericho was to the extent of 4 hectares (Wright, 1985 p. 23).

House Form

Wright (1985) states that Jericho seems to be a considerable settlement of around 7000 residents living in enormous and strong rectangular houses. Pre-pottery Neolithic fortifications (strongholds), tower as well as rounded and rectangular houses were present in Jericho. Wright (1985, p. 23) states that beginnings of man's first building construction and structure custom in later Palaeolithic was with the use of sticks and

stones and it was considered as first house built of these materials in Mesolithic times (10000 BC). During Natufian Period (10000-8000 BC), minor clusters of type of round house pit abode were present. During PPNA (8000 BC) creation of mud brick came. New structure traditions in PPNB (7000 BC) demonstrating diversified angular plans with load bearing walls took place (Wright, 1985, p. 23). The sunken round dwelling was there with walls were made of hand shaped mud bricks called as “hog baked” imitating some natural material like field stone, etc. (Wright, 1985, p. 25). The materials used were stone, clay and wood in the houses and it was a semi-sunken house.

Religion/Cult Places

Cult places have been recognised in Neolithic Jericho but nowhere was the excavated area extensive enough to demonstrate the relationship of the temple building to its environs (Wright, 1985). Kenyon (1956) states that it is clear from the finds that the people believed and had developed a concept of an “impersonal force”. There are traces in which one can see a small room at one end of which is a niche with rough stone pedestal set at its base. There are figurines of goddesses as well as animals (Kenyon, 1956, p. 184).

Pottery

Kenyon (1956) states that the Neolithic settlements were categorised by the first use of pottery, the first of the new local expression of arts and crafts, which were of clear convenience to the housewives, however, a burden to the nomad (Kenyon, 1956, p 184). Dishes and bowls were made of a fine limestone, attempted to an excellent completion; these no doubt were accompanied as vessels by others in perishable materials such as wood and skin (Kenyon, 1956). There was assortment of mortars and grinding bowls in harder stone, and a large number of highly individual querns, not resembled elsewhere, with a trough running out at one end of a sub-rectangular block, and a flat rim round the other three sides; these with the accompanying grinding stones were extremely well made (Kenyon, 1956). Hammer stones, pestles, coarse grinding stones and a great present variety of polishing stones, some with an almost mirror-like surface, were other items in the household equipment and utensils. (Kenyon, 1956, p. 184).

Catal Huyuk Turkey

Location

Catal Huyuk is considered as a primary Neolithic site in Middle East, situated in south central Turkey, close to Konya (Refer Figure 2). Catal Huyuk is surrounded by the ancient sites of central Anatolia for its existence and is distinguished among them

(Camurcuoglu, 2015). Mallart, (1967) states that it is positioned on a fertile and lush plain in Southern Turkey. Catal Huyuk precede the well-known acclaimed urban areas of Mesopotamia by 3000 years. Mellaart (1967) states that Catal Huyuk, lies on a reachable or accessible and fertile as well as productive landscape at the elevation of 3000 feet above sea level and 32 miles south east of Kenya. It comprises two riverside mounds or hills, the bigger for which was 32 acres of land in extent. The diggings of this archaeological site were done in 1961-1965 by British archaeologist James Mellaart who revealed that Anatolia in Neolithic times was the hub of a progressive culture (Encyclopaedia Britannica, n.d).

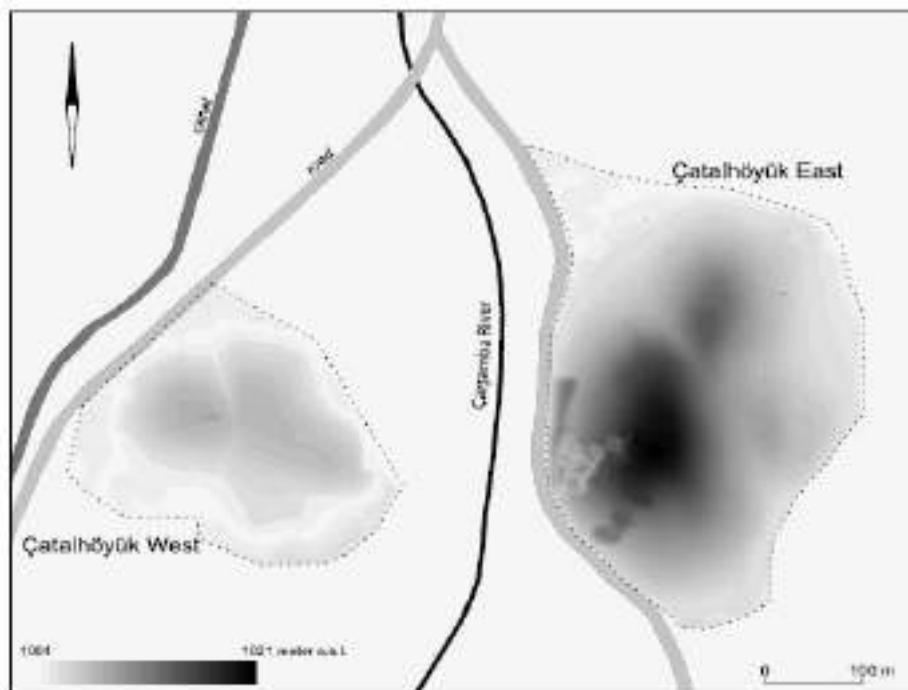


Figure 2: Location of Catal HUyuk

Source: During, 2006.

Time Period

Daly (n.d) states that Catal Huyuk is the oldest one established and the biggest Neolithic city found, up until this point. It dates to 8,000 years BCE and was engaged and occupied uninterruptedly for 376 generations (Daly, n.d). Mellaart (1967) writes that most well-known and settled ideas and notions about Neolithic life were broken by the detection and revelation of Catal Huyuk, which had a fairly considerable size in 7000 B.C. Mellaart, further expresses that Catal Huyuk grew extensively by seventh millennium as compared to third or fourth millennium settlements of Mesopotamia (Mellaart, 1967, p. 9). Catal Huyuk has ended up being not just a significant Neolithic

site, that thrived on Antolian Plateau in the seventh and early sixth millennium BC yet in addition it was a focal point of art and workmanship during that period. Britannica states that the initial building period at Catal Huyuk is approximately dated back to 6700 B.C. and the latest to about 5650 B.C.

Population

The inhabitants of the eastern mound are assessed and predicted to have been up to 10,000 persons but the average populace is supposed to have been between 5,000 and 8,000 people (Daly, n.d). Life expectancy was very brief by contemporary standards, with men living to 34 and women living to around 28 years (Daly, n.d).

Housing

Catal Huyuk had densely packed buildings without doorways or entry ways demonstrating that the inhabitants entered by ladder (Mellaart, 1967), the odd and abnormal character of its thoroughly stuffed dense structures, into which the guest apparently rose or went down by ladder. The fundamental cause would have been infighting among competing cults, as well as a protective strategy that depicted it as an earthen mound or succession of earthen mounds rather than inhabited places. The homes resembled burrows, with a little entrance in the roof top. Though the obstacles of draining the water over the top would have existed, the fundamental goal of security took precedence. There were traces of mud brick buildings burned red in conflagration contrasting with patches of grey ash, broken bones, potsherds and obsidian tools and weapons (Dally, n.d). In addition to hearth and oven, houses had platforms for sleeping, sitting or working.



Figure 2: Housing Typology in Catal Huyuk

Source: (Mellaart, 1967)

Religion

The numerous amazing outfitted holy places or shrines and ghastly (macabre) creativity or artistry reflect the passionately innovative religion (Mellaart, 1967). There is indication and proof for Neolithic religion in the arrangement and form of abundant shrines, imaginatively ornamented with reliefs in plaster, as demonstrated on the walls or cut into plaster when in site, or with wall paintings in unique colours, and casing a period firmly between 6500 and 5700 B.C. The cult statues of male and female divinities, engraved in assortment of stones or demonstrated in clay and occasionally painted were found in shrines (Mellaart, 1967).

Neolithic Graves

As the deceased or dead were buried in the settlements, hundreds of Neolithic religions and various places of worship in the form of shrines, were creatively, aesthetically ornamented with reliefs in plaster or with works of art. The inhabitants buried their forefathers beneath their homes (Hodder, 2008). The site evolved throughout time as a result of years of use by people living in a home filling it and building another house on top, resulting in a 21-meter-high mound (Hodder, 2008).

Economy

Mellaart, (1967) opines that hints of prospering economy appear and vouch for cutting edge and advanced rehearses as well as practice in agriculture and stockbreeding and remain of non-local merchandise show a cultured complex exchange of trade in raw or crude materials. Catal Huyuk could pay for and bear the cost of luxuries and extravagances like obsidian mirrors, ritual knives and Knick knacks and jeweleries of metal outside the grasp of its most of the known counterparts. Its stone industry in local obsidian and imported flint rock was the most sophisticated of the dated period. Its wooden vessels were diverse and classy, its woollen textile industry fully advanced and established. At Catal Huyuk, the study of conversion from an aceramic Neolithic baskets and wooden vessels to a ceramic Neolithic with its first pottery. Plentiful food deposits found the range of crop grown, collected or imported from the hills (Mellaart, 1967, p. 22). It primarily shows the growth of peas and collection of almonds, Pistachio, etc. from the hills (Haddow, 2017).

Art and Pottery

Mellart (1967) states that Catal Huyuk is acknowledged for its extraordinary and amazing wall paintings and plaster reliefs, its statues in stone and clay as well as its progressive skill and technology in the crafts of weaving, woodwork, metallurgy and obsidian working. Copper and lead were melted and operated into beads, tubes, small tools thus taking the beginnings of metallurgy back into the seventh millennium (Mellaart 1967, p. 22). While studying the textiles and fabrics, Burnham (1965),

observes that there could have been the fire that destroyed all the housings and due to smaller vents and suffocation, the people would have died in a large number.

Nabta Playa, Egypt

Location

Haynie (2014) states that site is located about 100 km west of Abu Simbel on Lake Nasser and about 100 km north of the Egypt–Sudan border.

Wendorf and Schild. (2001) state that Nabta Playa is not only the largest internally drained basin in the Nubia–Sheb Pediplain, and its catchment area, as estimated on the basis of Landsat imagery, it covers about 1500 km² (Schild, 2001, p. 11). According to Wendorf and Schild (1998), numerous archaeological sites occur here, often imbedded within sediments of the ephemeral ponds and lakes (playas) that filled the basin (p. 99). Nabta was the name given by Bedouin workers to a nearby prominent inselberg or gebel. It means “little bushes” and was suggested because of three small clumps of now dead tamarisk growing in a sub-basin at the foot of Gebel Nabta (Wendorf, Schild, 2001, p. 1).

Time period

According to Wendorf and Schild (1998), from around 65,000 years back until around 12,000 years prior to the Western Desert was hyper-arid, as dry as today and maybe drier. This started to alter and change following 12,000 years prior when the downpours or rains of summer of tropical Africa started to move northward, bringing adequate dampness as well as moisture for a wide assortment of sahelian grasses, trees and hedges to develop, and for a couple of little creatures to exist, generally rabbits and little gazelle, yet additionally including a couple of little carnivores (Wendorf and Schild, 1998). Indeed, even with the downpours it was still extremely dry; the yearly precipitation was close to 100 - 150 mm for each year, and it was erratic and interrupted with various dry spells or droughts, some of which made the desert abandoned and left neglected for long periods (Wendorf and Schild, 1998).

Housing

Wendorf and Schild (1998) state that during these 9000 years (8000 bp, uncalibrated), the settlements were a lot bigger, and their occupants had the option to live in the desert all year, burrowing huge, profound wells and living in sorted out villages which were organised and comprised little huts organised in straight lines. No images and visual of the same could be traced by the authors as well.

Religion/Nabta Playa as a regional ceremonial centre

Wendorf and Schild, (1998) observed that a significant change happened in the character of the Neolithic culture at Nabta at around 7500 years ago. The gatherings

that came back to the desert had a perplexing social framework that communicated a level of association and control not recently found in Egypt. Wendorf and Schild, (1998) states that they relinquished and sacrificed youthful cows and covered them in mud lined and roofed chambers secured by unpleasant stone tumuli, they raised arrangements of enormous, unshaped stones, they assembled Egypt's earliest cosmic estimating gadget (astronomical measuring device - a "schedule circle" or a calendar circle which seems to have been utilised to check the mid-year solstice), and they developed 30 complex structures having both surface and underground highlights. A moulded stone from one of these buildings might be the most established known model in Egypt (Wendorf and Schild, 1998). These structures are significant in light of the fact that they demonstrate the manner in which the individuals had the option to arrange work, their way of life, and maybe express their strict convictions. Moreover, they disclose to us that the Saharan individuals may have been more exceptionally composed than their peers in the Nile Valley (Wendorf and Schild, 1998). There are four types of structure under this category: the stone circle, the tumuli, the so-called complex structures and the megalithic alignments, all constructed from Nubian Formation sandstone that was quarried locally (Byrnes, 2019).

The researchers also discussed about a territorial formal community where isolated gatherings were held occasionally to direct services and to reaffirm their social and political solidarity.

The ceremonial features indicate that Neolithic cattle pastoralists of the Sahara can no longer be viewed as simple bands (Wendorf, Schild, 2001). Instead, there must have been religious or political authority at Nabta with control over human resources for extended period of time. Only this kind of authority could organise and support such elaborate ceremonial complex involving burial of cattle, the use of astronomical observations, the transport and working of lay stones and the construction of enigmatic structures (Wendorf, Schild, 2001).

Occupation

According to Wendorf and Schild (1998), the plants at these locations reveal that they were harvesting vast quantities of consumable wild plants, such as sorghum, millets, vegetables, tubers, and organic goods. They began making pottery locally around 8800 years ago (7800 BP, uncalibrated), possibly the first stoneware in Egypt. Sheep and goats appeared two or three hundred years later, about 8100 years ago (7100 BP, uncalibrated), since they were most likely brought from Southwest Asia, where domestic caproids had been known for more than 2000 years. There have most certainly been multiple changes to the settlement framework to accommodate these new species; the towns are incredibly large and feature various hearths, but there is no

confirmation or proof of existing cottages (Wendorf and Schild, 1998). Also, while researching no images and visuals of the housing was available.

Art and Pottery

The pottery was extremely rare in these sites, but distinguishing. It is ornamented over the whole exterior with complex patterns of imitations applied with a rocking motion (Wendorf and Schild, 1998). The basis of this ceramic has not been known, but it is among the oldest known in Africa, and older than pottery in Southwest Asia (Wendorf and Schild, 1998). These early individuals presumably came into the desert after the late spring downpours from either farther south or the neighbouring Nile Valley, in either case checking out pastures for their dairy cattle. Each fall, when the surface water in the playas evaporated and there was no water for them or their steers, they needed to come back to the Nile, or maybe to the better watered regions toward the south (Wendorf and Schild, 1998).

The other kind of art and pottery is one pot sherd, ostrich eggshell, beads in early Neolithic, other worked eggshells, red and yellow ochre and faunal remains of gazelle (Wendorf, Schild, 2001, p. 68). (Wendorf, Schild, 2001, p. 71) states that fine beadlets, backed beadlets are also found and perhaps used for jewellery.

Conclusion

Jericho

It can be concluded that Jericho was a settlement with *Natufian* culture which later became permanent and where people were residing in pit dwelling and sunken houses believing in impersonal forces and had cult places. There was a wall, stairs and tower in the settlement of Jericho.

Catal Huyuk

The digging levels of Turkey's Catal Huyuk site (Between 6859 and 6300 BCE) comprise astoundingly beautifully ornamented rooms proposing religious shrines as well as the remnants of adequate houses to house 5000 people (Tilly, 2010, p. 269). In the absence of streets, as no doors were present to enter inside the house or an individual living unit, the additive forms extruding out and connected simultaneously from the entire whole of the settlement. Until now the site does not yield enough other proof of focal central authority, differentiation, disparity or nodal location to succeed Catal Huyuk, unmistakably as a full-fledged undeniable city (Tilly, 2010, p. 269, Roaf, 1990, No specific reasons for its abandonment have been found but it may have just gotten too high for comfortable living on top of the mound (Mellaart, 1967).

Nabta Playa

Nabta Playa served as the main regional ritual centre and it had houses, hearth, storage pits as well as seasonal floods (Wendorf, Schild, 2001, p. 6). Remnants of goat and sheep were also found, alongside huge hearths (Ching et al, 2011). By 3500 BCE, though Nabta Playa turned out to be continuously and gradually dry, the lake dried up and the villages had to be uninhabited and abandoned (Ching et al, 2011).

Discussion and Way Forward

The paper discussed in detail the three notable settlements of Middle East namely Jericho, Catal Huyuk and Nabta Playa. Jericho was the first settlement with time period ranging from Mesolithic to Neolithic Period (PPNB). It had a Natufian culture which later changed to agriculture. Catal Huyuk had little advanced practice of agriculture, stock breeding and trading of merchandise while as Nabta Playa is again seen as gathering of wild plants and domestication of animals. The authors have derived common parameters from the history which is explained in Table 1.

Jericho had wall, stair and tower while there was no mention of wall around the Catal Huyuk and Nabta Playa settlements.

All the three settlements had a very strong belief in religion or cult forces or “impersonal force” All three believed in varied rituals, sacrifices with elaborate practices as mentioned above and Nabta Playa became the Regional Ceremonial Centre with some very advanced astronomical measurement device or calendar circle.

Little is known about housing of Nabta Playa while Jericho had sunken dwellings and Catal Huyuk had compact houses with entrance through ladder in absence of doorways. Art and pottery of all these settlements show that they had imaginative creativity thereby showing permanent and storage wares.

In today’s context, all the three settlements have great relevance as it shows how the settlements grew into permanent abode and made use of native resources available to them. The fall of each settlement is not proven, but one thing is certain: the religion demonstrates a strong backbone in order to safeguard and maintain its connection to the locations. Even if the connections could not be bridged, there is a sequence of solid arguments that attempt to justify each viewpoint. Settlements across geopolitical borders tend to draw a line, despite the fact that they should have been the common link with the human race and its progress for centuries. History bears the burden of uniting many cultures, and it is vital to discover those threads so that the future might be sewn well in harmony.

Table 1: Common Parameters derived for the settlements

S. No.	Parameter	Name of the settlement		
		Jordan Hericho / Jericho	Catal Huyuk, Turkey	Nabta Playa, Egypt
1.	Location	Palestine	Turkey	Egypt
2.	Date and Time period	8500 BCE	8000 BCE	7500BCE
3.	Population	10000<, 5000<	5000<	
4.	Occupation	Agriculture, Weaving Cloth	Pastoral	Agriculture
5.	Wall, Stairs and Tower	Tower is present with 8 m height and 9m base dimensions. Walls were of mud with terrazzo flooring in line	The walls were primarily in mud and wood. The stairs were of wooden ladder used to climb down from roof.	Monolithic structures as more of Ritual or ceremonial grounds.
6.	House Site and structure	Circular and rectilinear shaped houses, easy to infiltrate, for which they built 2m thick wall and a tower to secure the settlement from infiltration and floods, the houses were circular or oval, 4-5 m (13-16 feet) across	Rectilinear shaped houses, approached from the roof. No doors, Absence of roads	
7.	Religion/Cult. Places	Town said to be raised by Joshua as per biblical records	Ceremonial Spaces were carved as per within the houses.	Ceremonial Spaces were carved as per celestial movements.
8.	Pottery	Stoneware pottery	Stoneware and beautifully carved wooden pottery found with intricate designs and ochre	No major Pottery found in excavations. Some ceramic relief was found, yet not sure if it belonged to the same period

Sources: Compiled by Authors.

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Spatial Aspects of a Secondary City: Change Detection and Index-based Built-up Assessment for Jorhat

Nagarloket
55(3), 33-53
July-September, 2023
© 2023 IIPA
DOI:
<https://doi.org/10.32381/NL.2023.55.03.3>

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Abstract

Land use planning has emerged as a cornerstone of modernism and the application of geospatial technologies has laid the groundwork for the rejuvenation of the decision-making process. The present research aims to evaluate the changes in the spatial patterns of landscape mosaics, with a primary focus on the built-up environs in Jorhat, an upcoming secondary city of Assam. The study also highlights one of the most conspicuous challenges of secondary cities, i.e., the proliferation of slums. LANDSAT 7 (2002) and 9 (2022) satellite data were used for Land Use Land Cover (LULC) and change detection which was obtained from the United States Geological Survey (USGS) earth explorer. The Index-based Builtup Index (IBI) has been used for urban extraction. The accuracy assessment results of LULC classes were discovered to be extremely good for both years (i.e. Kappa coefficient >80%). Over the past two decades, paddy cultivation has registered a decline from 701.12 sq. km. in 2002 to 438 sq. km. in 2022. On the other hand, the built-up area has registered an increase from 77.84 sq. km. in 2002 to 168.29 sq. km. in 2022. Moreover, this study has shown that the IBI has a strong negative correlation with water and vegetation. The slum pockets were identified and growth was traced. Such findings on the built-up area holds tremendous implications for the future of urban planning exercises.

Keywords

LULC, IBI, Change detection, Jorhat, Slums.

Introduction

Much of the existing research on urbanization trends in North-East India focuses on primate cities, ignoring the capacity and functionalities of secondary cities in the urban environment. Secondary cities are an indispensable part of the urban system. This new

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phenomenon has the potential to herald a brand-new era of occupational and intellectual liberty for its residents (Ammann et al., 2021). A secondary city, alternatively called a second-tier city, is an urban area that is smaller in scale and economically less important as compared to a nation's primary city. Secondary cities are critical for balanced regional development because they ameliorate the concentration of resources and population in the primary city and contribute to a country's overall growth and well-being. Secondary city studies have risen to prominence as a result of spatial divisions, particularly in developing countries. Secondary cities serve as the urban market for rural hinterland products, as well as off-farm employment and a variety of services and facilities for rural residents. Several factors such as a suitable geographic location, an advantage in administration and politics, and an abundance of natural resources, trade and services shaped and continue to mould these urbanizing economies. For their sustained growth, the cities must possess urban resilience to respond to socio-economic and political upheavals, both internal and external. Functional linkages with smaller and larger urban nodes, the ability for economic diversification, and the creation of comparative advantages are crucial in maintaining the stability of these cities (Rondinelli, 1983). Secondary cities act as nodes to absorb such repercussions and pressures on the primates of a region (Nel and Donaldson, 2016). The study of secondary cities is typically approached through the lens of its population base (Zimmer et al., 2020; Roberts and Hohmann, 2014), which, no doubt, is an important criterion for its conceptualisation. The study area as a secondary city plays a significant role in regional trade, and cultural activities, serves as a hub for the surrounding rural areas and provides essential services to the native citizens.

The terms “Land Use” and “Land Cover” (LULC) refer to different ideas. “Land cover” refers to the physical cover that is visible on the Earth's surface (Naikoo et al., 2020), whereas “land use” focuses on the human activities and purposes for which the land is utilized (Chen et al., 2014). But these ideas are used together as “LULC” to refer the both land patterns. LULC and change detection studies of cities and their hinterland are important as they provide useful insights into the temporal and spatial aspects of the drivers of change. The structural integrity of resources is largely determined by a location's demography, and as the population has grown, there has been an enormous demand for land availability. This competition between occupants and land has resulted in many habitual repercussions. Shifts in LULC are one serious environmental matter (Patley et al., 2018). The global process of urbanisation is a driving force behind LULC evolution (Yousif et al., 2015). Estimating the LULC changes is necessary for prevailing natural resource planning and monitoring (Kiran, 2013). The Neolithic revolution marked a major milestone in the modification of the natural landscape through anthropogenic actions, and this change has gained pace with

the emergence of urbanised societies (Stephens et al., 2019). LULC assessment has emerged as a cornerstone of modernism and the application of geospatial techniques for city mapping has laid the groundwork for the rejuvenation of the urban planning process.

Valuable information about the LULC can be extracted from remote sensing products coupled with classification techniques. LULC analysis by using geospatial technology makes it easier to understand the current distribution of urban infrastructure, residential neighbourhoods, business areas, industrial sites, open spaces, and vegetation cover. Remote sensing plays a crucial role in understanding urban dynamics and conducting urban studies. It assists in spatial analysis, monitoring changes, addressing environmental challenges, and supporting decision-making processes for sustainable urban development and resilience. Prakasam et al., (2018) used supervised classification, and accuracy assessment, for depicting and analysing the LULC and urban sprawl in Himachal Pradesh. Change detection is one of the popular techniques for monitoring landscape change. Remotely sensed data has been widely applied for change detection in recent generations (Lu et al., 2004). Digital change detection methods based on multi-temporal imageries demonstrate a greater potential to uncover landscape evolution (Acharjee et al., 2012). Gogoi and Chetry (2016) have enumerated the trend and growth pattern of Jorhat city, whereas, Acharjee et al., (2012) carried out a forest cover change detection in Jorhat district. However, there is a lack of comprehensive LULC study of the district in these studies. A remotely sensed index that can be utilised to extract the built-up and urbanization growth from satellite images is known as the Index-based built-up index (IBI). IBI differs from conventional indexes as instead of using the original wavelength bands it uses three thematic layers, i.e., Soil Adjusted Vegetation Index (SAVI), Modified Normalized Difference Water Index MNDWI and Normalized Difference Built-up Index (NDBI) (Xu, 2008). These three satellite-based indices have their application to evaluate the earth's surface features. SAVI has been utilised for vegetation monitoring; MNDWI for waterbody and NDBI for built-up area monitoring. IBI is one such technique that was proposed as an improvement to the NDBI. The details extracted using the IBI can take both plus and minus values, which correspond to built-up and non-built-up areas (Valdiviezo-N et al., 2017). Unplanned growth of secondary cities can plague their sustainable development by having to confront challenges such as the growth of slums (Basu and Das, 2022). Identification of such pockets is important because, as Lebas et al., (1978) put it, the state can intervene to control such phenomenon which is not profitable, yet vital for the operation of the economy. Right to social justice is another facet that calls for the identification of such depressed areas. Jorhat district has been considered an area of interest to explore its spatio-temporal aspects and slum growth within the city.

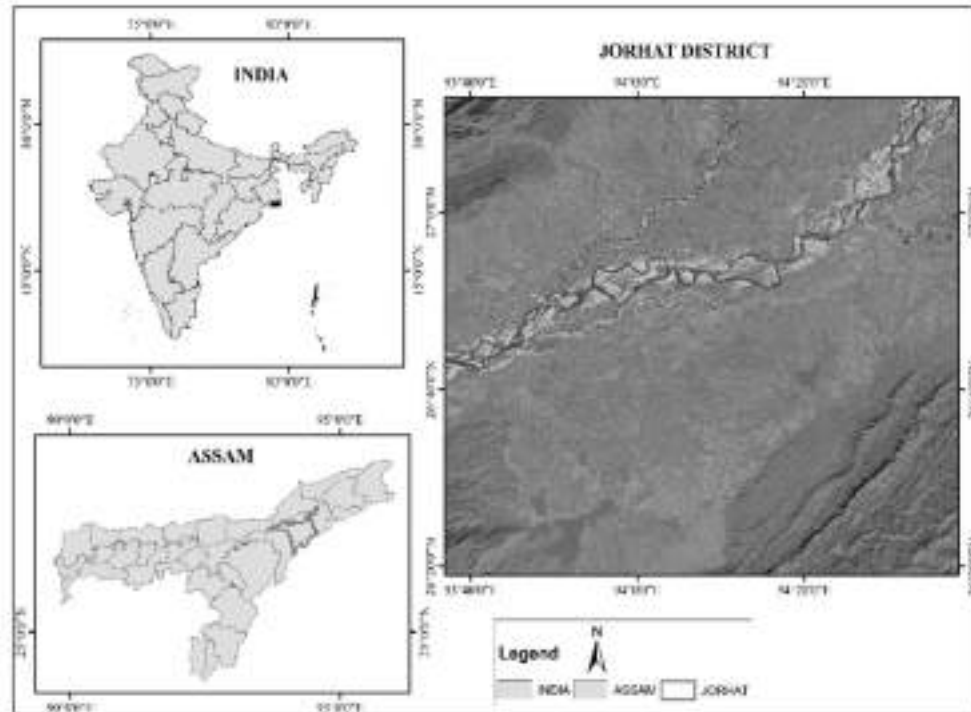


Figure 1: Location of the study area

Source: www.diva.gis.com, satellite image: Landsat 7 ETM+, 2002

Study Area

The present study relates to the Jorhat district, which is nestled in the Brahmaputra valley, Assam. To its north is the district of Majuli, the Indian state of Nagaland to its south, and is bounded by Charaideo district in the east and the district of Golaghat to its west. The total geographical area of the district is 2852 sq. km. and it came into existence in 1983. The geographic location of the urban centre of Jorhat is $26^{\circ} 40' 00''$ N, $94^{\circ} 20' 00''$ E (Figure 1). The Municipality area covers 9.20 sq. km. and is made up of 19 wards. The river Bhogdoi runs through the heart of the city, and there are other smaller streams such as the Toklai and the Tarajan crisscrossing Jorhat. The town has witnessed a rise in its population from 1.12 lakhs in 1991 to 1.53 lakhs in 2011. The urban area recorded an increase of 4.95 sq. km. in 1961 to 72.58 sq. km. in 2001 (Gogoi and Chetry, 2016; Census 2011, GOI).

Objectives

The paper's major concern is to detect the LULC change for the Jorhat district within 20 years, changes in built-up areas and growth of slums within the Jorhat city. The research intends to achieve the following goals:

1. To evaluate the change in LULC for 2002 and 2022 for the Jorhat district.
2. To assess the built-up area using the IBI and quantify the change for Jorhat city.
3. Identify the growth of slum pockets in the Jorhat city.

Database and Methodology

Table 1: Details of satellite imageries used in the study

Satellite	Year	Date	Path/Row	Spatial resolution	Source
Landsat 7 ETM+	2002	2002-01-02	135/041	30	USGS Earth explorer
		2002-01-02	135/042	30	
Landsat 9 OLI	2022	2022-03-14	135/041	30	USGS Earth Explorer
		2022-03-14	135/042	30	

The downloaded satellite imageries are layer-stacked, mosaicked, and clipped as per the study area. SAGA Geographic Information System (GIS) and Arc GIS 10.2 Software has been used to perform data processing and analysis. Landsat series of satellite datasets with 30 m spatial resolution is used for the analysis (Table 1). SAGA GIS software has been used for change detection and supervised classification. The classified imagery has been verified from high-resolution Google Earth images and sentinel 10 m images and also checked with Google Maps. Using the raster calculator in Arc GIS 10.2, the urban expansion was extracted with the IBI band ratio. The final results of IBI are a conglomerate of three indices viz., NDBI, SAVI, and MNDWI.

The Indices were calculated using the following formulae:

1. $SAVI = ((NIR - R) / (NIR + R + 1)) * (1 + L)$
 $ETM = ((B4 - B3) / (B4 + B3 + 0.5)) * (1 + 0.5)$
 $L09(OLI) = ((B5 - B4) / (B5 + B4 + 0.5)) * (1 + 0.5)$

L is a factor that completely depends on the vegetation cover of an area that varies from 0-1, as the study area the focus is to extract urban pixels for the city region '0.5' will be the L value due to moderate vegetation cover within the city. For a highly dense vegetation cover area, the L factor must be set to 1.

2. $MNDWI = (GREEN - MIR) / (GREEN + MIR)$
 $ETM = (B2 - B5) / (B2 + B5)$
 $L09(OLI) = (B3 - B6) / (B3 + B6)$
3. $NDBI = (SWIR - NIR) / (SWIR + NIR)$
 $ETM = (B5 - B4) / (B5 + B4)$
 $L09(OLI) = (B5 - B6) / (B5 + B6)$

$$4. \quad IBI = [(NDBI-(SAVI+MNDWI))/2] \\ /[(NDBI+(SAVI+MNDWI))/2]$$

Where, B = band of wavelengths,

NIR = near infrared,

SWIR = shortwave infrared,

MIR = middle infrared,

RED = is red band and GREEN is green band of the wavelength.

In the present study, the above-mentioned thematic layers have been used to calculate the IBI for the study area. After calculating all the indices for both years, a correlation matrix was calculated, and the correlation graph for SAVI, MNDWI, and IBI using Microsoft Excel. In Figure 2a, the steps of the entire methodology have been shown in the form of a flowchart. Results are shown in the form of a table, figure, and bar diagram. Figure 2b shows the workflow for slum identification.

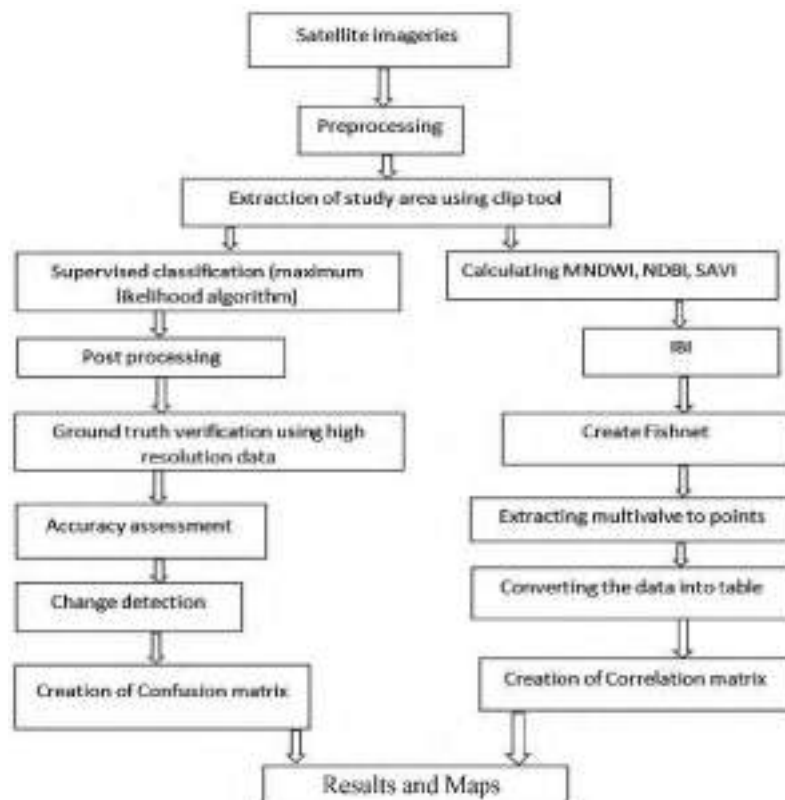


Figure 2a: Research Methodology Flowchart

Source: Done by the researcher

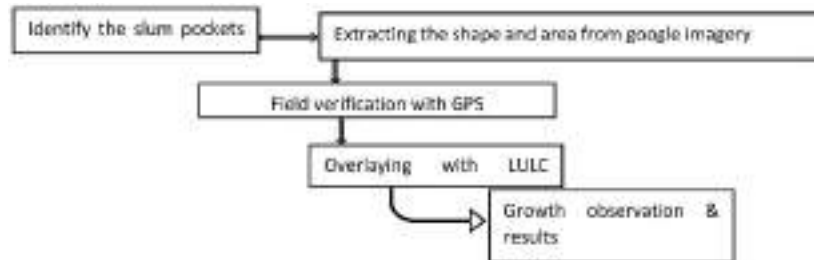


Figure 2b: Workflow for Slum identification

Source: Done by the researcher

Results and Discussion

Image classification is a part of the post-processing of imagery. Based on the digital number (DN) the pixels are sorted into a finite number of individual classes. The present study opts for supervised classification that requires the collection of training samples based on the analyst's experience and familiarity with land use-land cover of a specific area. Figure 3 and 4, represent the LULC classes processed by applying the maximum likelihood parametric rule using the created training samples for each class. Maximum likelihood uses the probability theory and is considered the most powerful parametric rule for classification. A total of eight (8) land use land cover class has been generated.

1. Supervised image classification

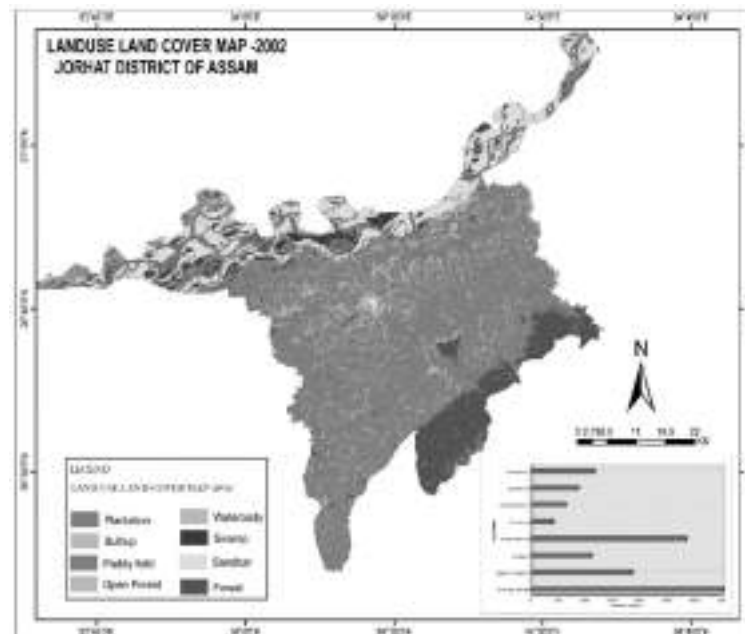


Figure 3: Supervised classification of LULC class, 2002

Source: Landsat 7 ETM+ (www.usgs.com)

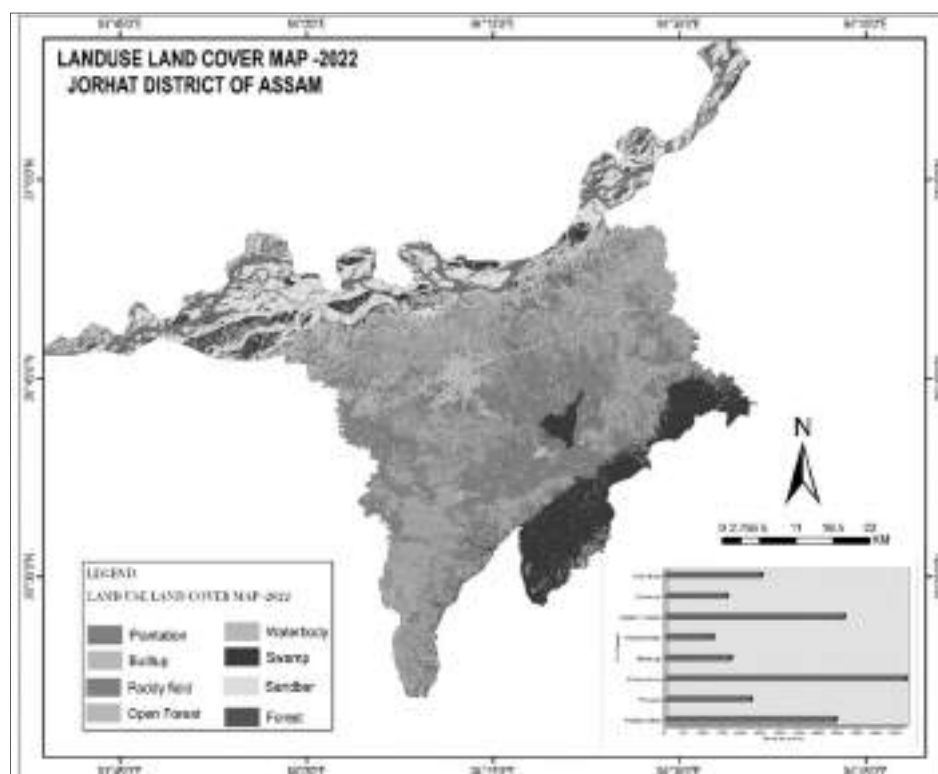


Figure 4: Supervised classification of LULC class, 2022

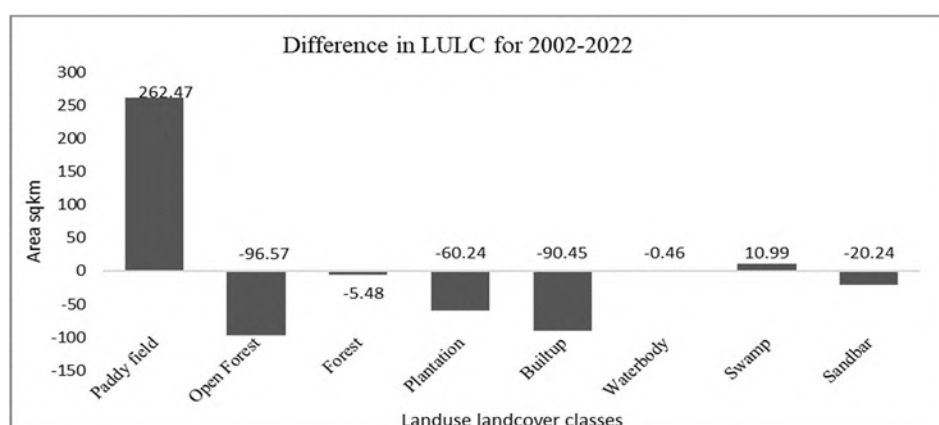
Source: Landsat 9 OLI, 2022 (<http://www.usgs.com>)

The results show that in the year 2002, out of a total area of 2440 sq. km, paddy fields occupied 27.8 per cent of the total area, the percentage share for the open forest was 15 per cent forest 9 per cent the plantation 23 per cent, built-up accounted for 3 per cent, waterbody 5 per cent the swamps 7 per cent, and the sandbar 9 per cent. For 2022, the paddy field is 18 per cent the open forest is 19 per cent the forest is per cent the plantation is 26 per cent, built-up is 7 per cent, waterbody is 5 per cent, swamp is 6 per cent, and sandbar is 10 per cent out of the total study area. The classes belonging to forest and waterbody are similar in percentage for both years. The LULC class corresponding to the paddy field has decreased from 701.12 sq. km to 438.65 sq. km from 2002 to 2022. Swamp also decreased by 10.99 sq. km from 2002-2022 (Table 2). The other classes such as open forest, plantation, and built-up have increased in quite a noticeable way, i.e., 96.57 sq. km, 60.24 sq. km, and 168.29 sq. km respectively. Figure 5 represents the bar diagram of area-wise differences in each class for the study period.

Table 2: The difference in the area of LULC in 2002 Vs. 2021

Class Name	Area sq. km (2002)	Area in (%)	Area sq. km (2022)	Area in (%)	Difference (2002 VS 2022)
Paddy field	701.12	28.7	438.65	18	+262.47
Open Forest	365.71	15	462.28	19	-96.57
Forest	215.24	9	220.72	9	-5.48
Plantation	563.15	23	623.40	26	-60.24
Built-up	77.84	3	168.29	7	-90.45
Waterbody	121.87	5	122.34	5	-0.46
Swamp	167.36	7	156.37	6	+10.99
Sandbar	227.52	9	247.76	10	-20.24
Total	2440	100	2440	100	

Source: Calculated from LULC results obtained from satellite images

**Figure 5:** The area-wise difference in each land-use class

Source: Table 2

2. Accuracy assessment

Accuracy assessment is an integral part of image classification to verify the correctness of a pixel whether it has been classified correctly or not to its corresponding class. The process uses some ground reference points to compare the classified data. After calculating the producer's accuracy and user's accuracy for the LULC classes, overall accuracy for 2002 is 94.31 per cent and for 2022 is 89.64 per cent and the kappa coefficient is 93 per cent and 87 per cent for 2002 and 2022 respectively. The Kappa coefficient, often known as Cohen's kappa, is a statistical measure of categorical data

reliability. It is used to evaluate the agreement of two or more observers when classifying items into a set of mutually exclusive categories. Values above 80 per cent are considered extremely good agreement, values between 60 and 80 per cent are considered significant, values between 40 and 60 per cent are considered moderate, and values below 40 per cent are considered poor.

3. Change detection

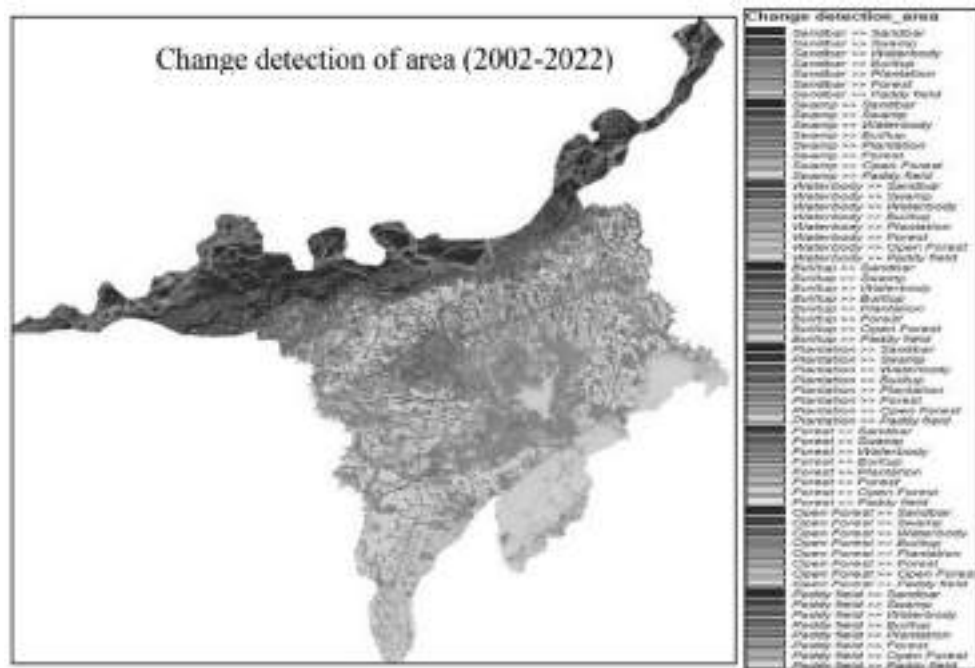


Figure 6: Change detection map using area of LULC classes

Source: LULC of 2002 and 2022

The classified images of 2002 and 2022 are used for change detection to observe and evaluate the changes occurring in land cover classes within 20 years for the district of Jorhat. The change detection map (Figure 6) shows the area of LULC classes that have been created in the SAGA GIS. One advantage of using a System for Automated Geoscientific Analyses Geographic Information System (SAGA GIS) software is that it generates a change detection map considering the area as well as to and from transformation. It shows how every class has been changed from one to another and the classes which are unchanged within 20 years. For example, Figure 6 shows the transformation of classes such as sandbar to sandbar, sandbar to swamp, sandbar to a waterbody, sandbar to built-up, sandbar to plantation, sandbar to forest, sandbar to paddy field accordingly.

Table 3: Change detection confusion matrix 2002-2022

The sum of all classes (area in sq. km)								
Name	Paddy field	Forest	Plantation	Built-up	Water-body	Open forest	Swamp	Sand bar
Paddy field	400.0	1.06	154.83	34.18	1.34	91.00	16.55	2.66
Forest	0.28	185.9	17.12	2.85	0.42	6.50	2.08	0.02
Plantation	23.39	19.0	325.85	29.79	7.99	112.0	25.34	19.66
Built-up	1.05	0.01	1.90	14.00	12.08	13.56	11.37	23.61
Waterbody	0.06	0.002	0.33	10.47	30.73	7.03	15.77	57.46
Open Forest	6.56	13.13	104.24	36.77	3.52	185.02	10.58	5.55
Swamp	6.79	0.98	19.09	18.17	14.45	33.20	35.78	38.82
Sandbar	0.06	0.00	0.02	22.02	51.78	13.93	38.83	99.86

Source: Calculating from the change detection map using SAGA GIS software

A change detection confusion matrix has been created to see how much area has been converted from one class to another and how much area has remained unchanged during the study period. The conversion from paddy field to forest in the year 2022 is 1.06 sq. km and a total of 400.08 km² has remained unchanged (Table 3). The built-up area which was common for both the year is 14.00 sq. km. The built-up class of 2022 has been transformed from the other land use classes of 2002 such as paddy fields, forest, plantation, waterbody, open forest, swamp, and sandbar, with the converted area being 34.18 sq. km, 2.85 sq. km, 29.79 sq. km, 10.47 sq. km, 36.77 sq. km, 18.17 sq. km, and 22.02 sq. km respectively. Likewise, to-and-fro conversion and changes within each LULC class between 2002-2022 have been estimated.

4. Calculation of indices

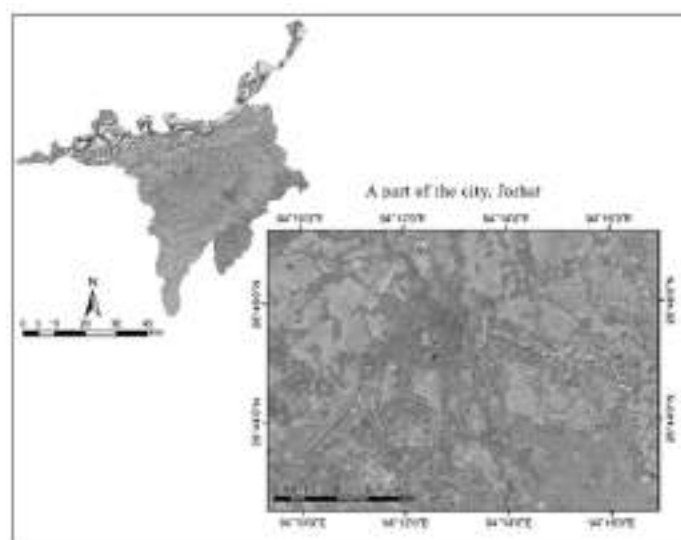


Figure 7: The map of Jorhat City

Source: Landsat 7 ETM+, 2002 (www.usgs.com)

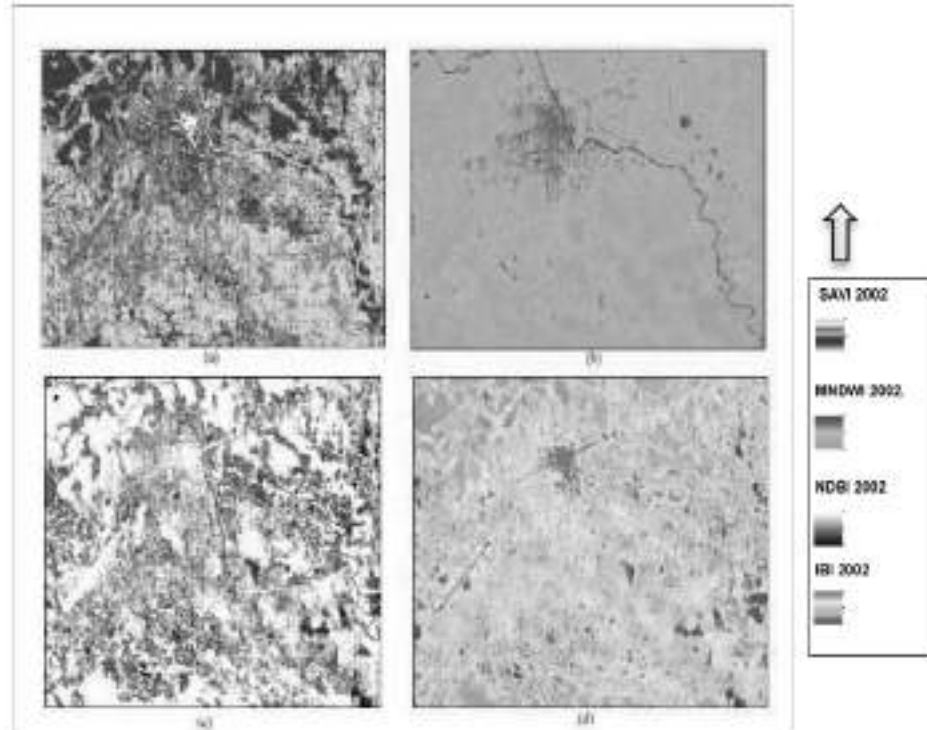


Figure 8: (a) SAVI, (b) MNDWI, (c) NDBI and (d) IBI of 2002.

Source: Landsat 7 ETM+, (www.usgs.com)

Band ratio using indices is an image enhancement technique, resulting from the division of DN values in one spectral band by the corresponding values in another band. Calculation of indices is the most common arithmetic operation in GIS to visualize an earth's object in a precise way using the corresponding band of the wavelength. The range of the indices varies between +1 to -1. Figure 7 shows the location map of Jorhat city. SAVI, MNDWI, NDBI, and IBI these four indices have been calculated for both years to acquire the necessary information. SAVI is a modified form of the Normalized Difference Vegetation Index (NDVI) index used to minimize soil brightness using the red and NIR wavelength of the spectrum (Huete, 1988). L as a correction factor of the intensity of vegetation cover ranges from 0 as high to 1 as low, 0.5 (moderate) was used for the present study. Jorhat city area has less vegetation cover compared to the other parts of the district. Figure 8(a) and 9(a) both show this hybrid vegetation index, where the lowest value is found in the waterbody and settlement area. The highest value is pre-dominated by the plantation, forest, and paddy field land use classes for the area. The highest value for the year 2002 was 0.73 and in 2022 it is 0.74 and the lowest value was -0.36, and -0.07 respectively. SAVI uses NIR and red band and in the NIR band soil pixels get absorbed

hence low reflectance can be observed in the NIR band and reflect higher in the red band. As shown in Figure 8(b) MNDWI is 0.63 to -0.417, and NDBI is 0.34 to -0.49 (Figure 8c). Figure 9(b) shows the MNDWI value ranges between 0.34 to -0.7, and NDBI is 0.25 to -0.52 (Figure 9c) identifying a clear change in vegetation, waterbody, and built-up area from 2002 to 2022. The MNDWI is an upgraded version of the Normalised Difference Water Index (NDWI) index. It is used to improve the water pixel concerning brightness and value. From figures 8(b) and 9(b), it can be elucidated that the highest value is found in the water bodies such as rivers, and ponds, and the lowest values are found in the built-up, paddy field, and forested land.

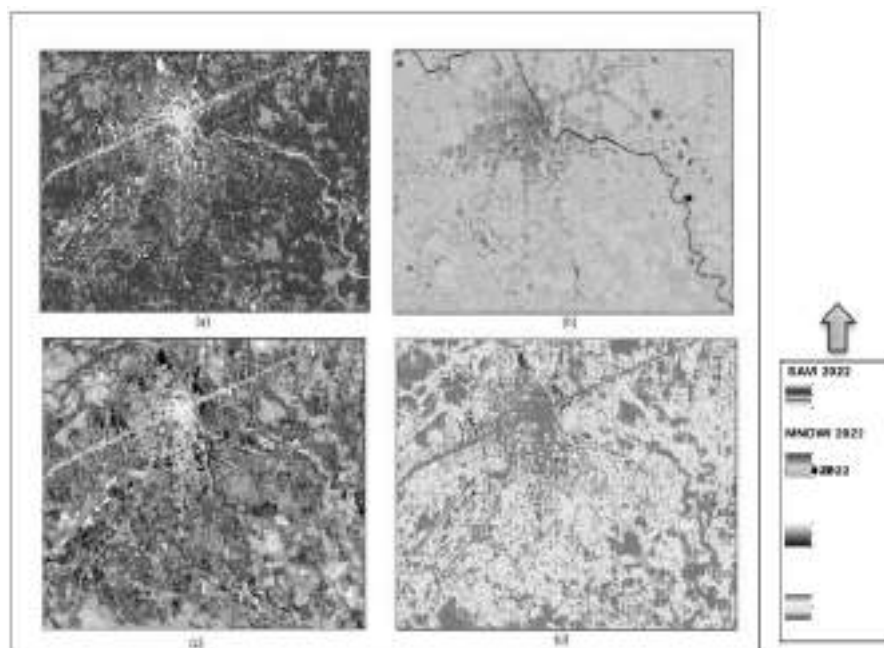


Figure 9: (a) SAVI (b) MNDWI (c) NDBI and (d) IBI of 2022.

Source: Landsat 9OLI (www.usgs.com)

However, seasonal or non-perennial surface water can make a different visual effect while using the MNDWI index. The reflection curve of MNDWI depends on the monsoon and post-monsoon seasons. MNDWI can extract the water surface from satellite imagery. The results show that MNDWI values are very low in 2022 than in 2002. The area under the paddy field has been decreasing since 2002 around the city area of Jorhat and the change can be estimated with a visual interpretation of the MNDWI results. The paddy fields are shown as light green colour in the images.

To monitor the changes due to urbanisation in and around a city NDBI is most commonly used. The highest value of NDBI is in the built-up areas. The roads, as well as the airport of the district, can be easily located from the NDBI image. IBI which is

generated by unifying the three indices can be addressed as the advanced form of the NDBI. IBI dealt with MIR, NIR, and red and green bands of the electromagnetic spectrum. The index is a comparatively modern technique to plan the city model, urban sprawl, and network transportation facilities. The index is used to extract the building footprints to analyze the urban change. Since only pixels on built-up land will have positive values after subtracting the SAVI and MNDWI bands from the NDBI band, the index can significantly boost the built-up land feature (Xu, 2008). The highest value of IBI i.e., 0.15 (Figure 8d) for 2002 and 2022, 0.24 (Figure 9d) are found in the built-up areas including urban settlements, roads, and commercial buildings such as an aerodrome, and marketplace. The lowest value can be identified from the water bodies, vegetated areas, swamps, etc. The moderate value can be found in the paddy fields or the barren soils. Although built-up areas have higher thermal ductility than exposed soil areas, the wavelength properties of urban built-up and bare soil are identical. The difference in the lowest value of IBI from 2002 to 2022 has been found as 0.29. As the urban settlement has increased since 2002 the highest value of IBI has also increased.

5. Analysis of the association of IBI with SAVI and MNDWI

Correlation is a quantitative technique for determining the degree of relationship between two, or sometimes more, sets of variables. In the present study, the correlation graphs have been established between SAVI /IBI and MNDWI/IBI. For both years, SAVI and MNDWI were used as independent variables, and IBI was used as the dependent variable. The association between IBI and SAVI was negative but very strong i.e. -0.939 in 2002 while it is highly negative in 2022 i.e. -0.84 (Table 4). On the other hand, the association between IBI and MNDWI was negative and moderate in 2002 i.e., -0.39, while it was strong and negative in 2022 i.e., -0.80. This reveals that an increase in built-up has led to a decrease in both water and vegetation covers.

Table 4: Correlation of matrix indices from 2002-2022

2002	SAVI	MNDWI	IBI
SAVI	1	0.104	-0.939
MNDWI	0.104	1	-0.39
IBI	-0.939	-0.39	1
2022	SAVI	MNDWI	IBI
SAVI	1	0.425	-0.840
MNDWI	0.425	1	-0.800
IBI	-0.8400	-0.800	1

Source: Done by the researcher in Microsoft Excel

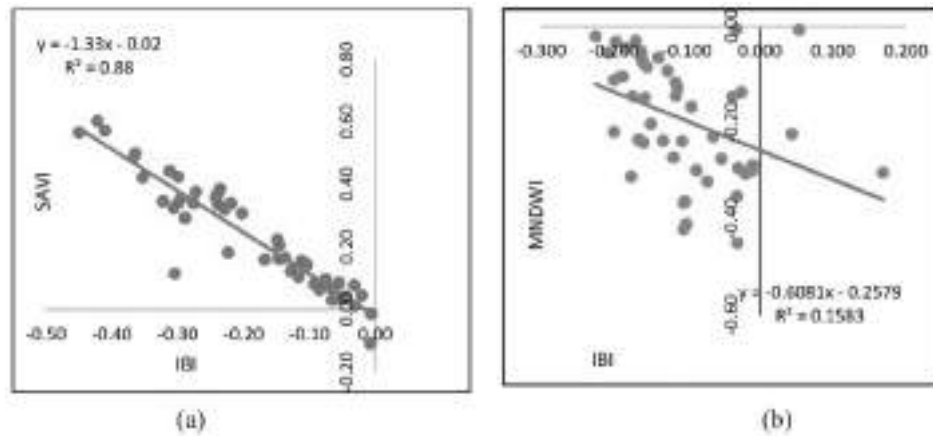


Figure 10: (a) Correlation between SAVI and IBI, (b) Correlation between MNDWI and IBI -2002
Source: Table 4

The coefficient of determination (R^2) between IBI and SAVI was 0.88 in 2002 (figure 10a) and 0.70 in 2022 (figure 11a), whereas the R^2 value of association between IBI and MNDWI was 0.15 in 2002 (figure 10b), which increased to 0.65 in 2022 (figure 11b). Therefore, it is clear that the association between built-up and the vegetation index has slightly decreased during 2002-2022 as revealed by the coefficient of determination, but has increased between built-up and the water index.

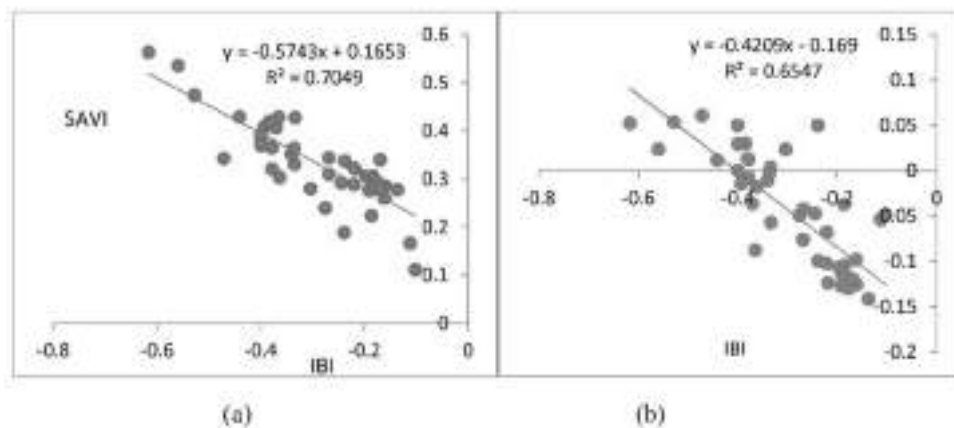


Figure 11: (a) Correlation between SAVI and IBI, (b) Correlation between MNDWI and IBI -2022
Source: Table 4

6. Growth of slums

Slums are densely populated, low-income neighbourhoods with substandard housing and insufficient access to basic services. Slums can occur as a result of several reasons, including informal land occupation, overpopulation, poor housing quality, and inadequate access to necessities such as clean water, sanitation, healthcare, and

education. The growth of slums in Jorhat is over three decades old, and New colony slum is the oldest. Slums have cropped up in the region as a result of streams of migration in successive years, mostly after the 1970s. Jorhat town has experienced unprecedented growth in its size, without any perceptible thought of planning and the slums have grown, scattered in small pockets all over the city. The overall trend of the emergence of slums is conditioned by factors such as proximity to the Central Business District (CBD), along transport arteries, and river banks. It must be recognized, however, that in addition to the latter factors of slum growth, landlordism has played an important role in the emergence of slums. The Fancy Ali slum and parts of Rajamaidam New Colony have cropped up because some landowners have entered the renting business, and have built hutments and shacks to house the floating population of the city. The slum pockets are mostly concentrated in the northeastern part of the city, with the pattern being compact and nucleated. Pujadubi, Harijan colony, and New colony have emerged along the Bhogdoi river, and its tributary, Toklai. Fancy Ali, on the other hand, is located near Babupatty, Gar-Ali, and Chowk bazaar, the major commercial hubs of the city. An on-field survey of the slums brought to notice the degradation of the surrounding environment mainly due to improper waste disposal methods. The new colony slum, which has cropped up along the Toklai River, is hurting the waters of the Toklai; the river is choked by pollutants from bathing or washing utensils in the river, or by open defecation. Another negative impact on surrounding areas is the degradation of land due to improper disposal of wastes. These dumpsites in turn become the breeding grounds of the vectors of various diseases, and sites of obnoxious smell. Moreover, with the ever-growing slums, all the accompanying vices—gambling, theft, etc. have risen in the area. The petty crimes have increased due to the emergence of the floating population in the city that normally finds sanctuary in the slums. There has been an instance of drug dealers being arrested from the Fancy Ali. The boundary of the slum pocket has been delineated using Google imagery and overlaid with the LULC map of both years. Identification of the slum pocket has been done based on a Global Positioning System (GPS) survey and its association with other land cover and structures, which are characterised by more congestion. The slum areas of Jorhat city are likely to be found in and around river Toklai (Figure 12). Although the boundary of slums is recent (2022), a comparison with the LULC of 2002 and 2022 has been tried to be depicted in this paper. The growth of the slums area is quite visible from 2002 to 2022 in the New colony area (Figure 13d). The overlay image of LULC and slum pockets shows the expansion of slums from other land-use classes to built-up classes (Figure 13).

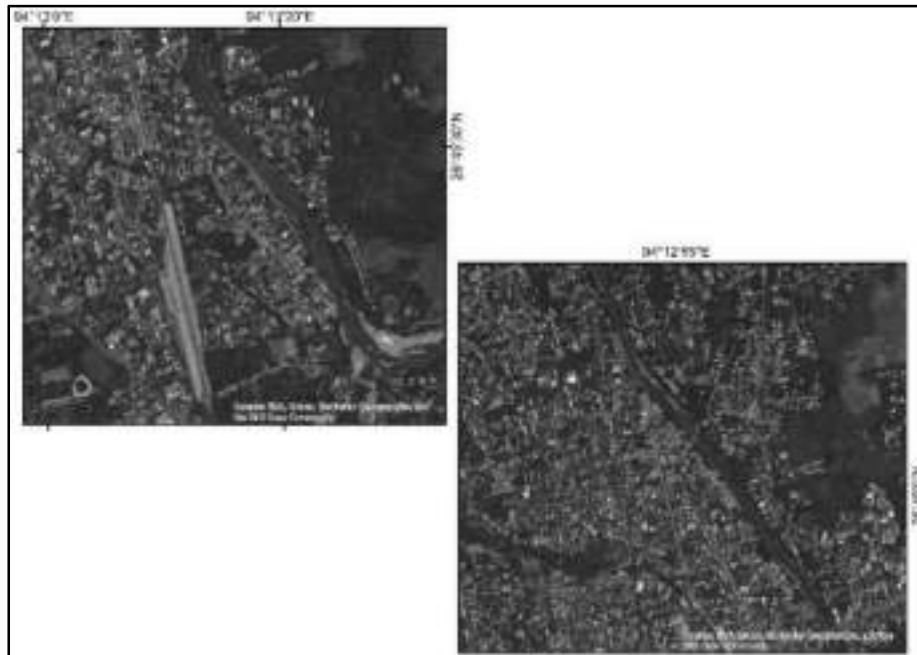


Figure 12: Example of identification of slum pockets boundary from Google imagery

Source: ESRI, MAXAR, Earthstar Geographics and the GIS User Community

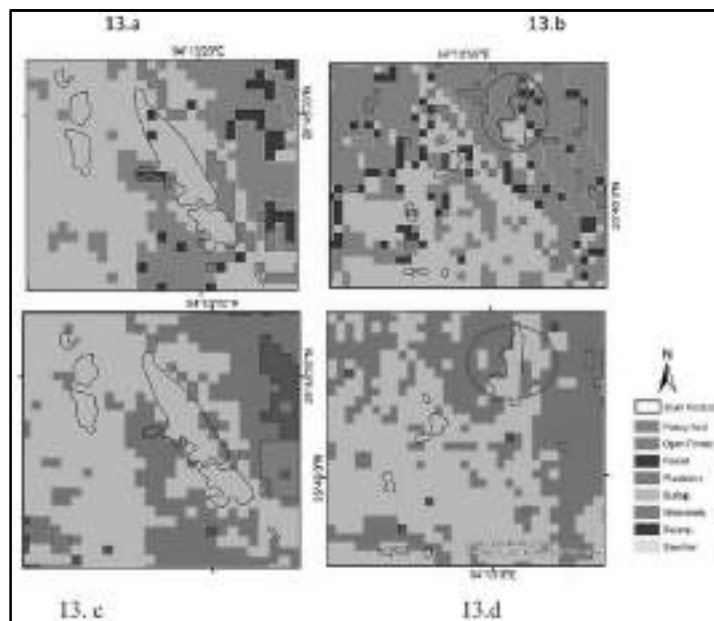


Figure 13: The expansion and changes of slum pocket within the city with its associated land cover (a) Pujadubi and Fancy ali, 2002, (b) New colony and Harijan colony, 2002, (c) Pujadubi and Fancy ali, 2022 and (d) New colony and Harijan colony, 2022.

Source: LULC, 2002 and 2022

In 2002, the land cover was found to be plantation and open forest in Fancy ali and Pujadubi area (Figure 13a), while in 2022 all the area converted into built-up shows an expansion of slum area in those pockets (Figure 13c). Table 5 shows the name and area of slums in 2022. The highest area is found in Fancy ali, i.e., 0.046 sq. km (46275.08 sq. m), contributing more than 55% area to the slum population. A pie diagram has been prepared for a visual understanding of the percentage of slum pockets. The lowest is the Harijan colony and the area is only 2.73 per cent (Figure 14).

Table 5: Name and area of slum pockets of Jorhat, 2022

Slum pockets	Area in sq. m	Area in sq. km	Area in %
Area of New colony	18354.99	0.018	21.97
Area of Fancy ali	46275.08	0.046	55.39
Area of Rajamadam colony	4171.93	0.004	4.99
Area Harijan colony	2279.73	0.002	2.73
Area of Pujadubi	12466.92	0.012	14.92
Total area of all slums	83548.65	0.084	100.00

Source: Calculated from the slum pocket boundary using ArcGIS 10.2.2 software

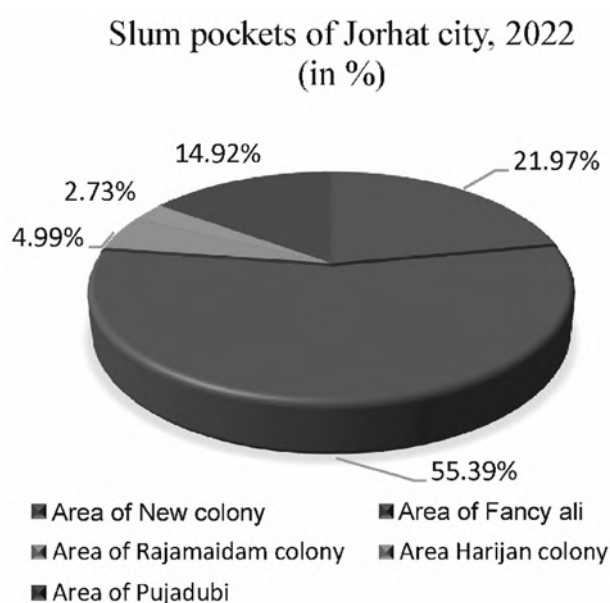


Figure 14: Pie chart representation of slum areas of Jorhat city

Source: Table 5

Conclusion

Asia and Africa house the maximum number of secondary cities and according to the UN Habitat's World City Report (2016), a steady increase in the number of secondary

cities has been witnessed. Secondary cities play a significant role in the organisation of the global economic landscape (Roberts and Hohmann, 2014). The growing importance of these cities in the reconstruction of the urban hierarchy reveals the need for studies on their sustainable growth and management. Land use is an integral element of man-environment relationships and its assessment, therefore, gains paramount importance in understanding landscape dynamics. Therefore, the present paper has aspired to depict a secondary city with the help of geospatial technologies to highlight its spatial and temporal aspects in a detailed way. The paper concludes that between 2002 and 2022, major changes in LULC had taken place in Jorhat district. The region is predominantly covered with agricultural lands and plantations. However, there has been a steady increase in built-up areas at the expense of forest and paddy fields. According to the study, over the last two decades, paddy fields have decreased by 262.47 sq. km while built-up areas have increased by 90.45 sq. km. The overall accuracy of the classified images has been found as 94.31 per cent and 89.64 per cent for 2002 and 2022 respectively. Using the Saga software package of GIS, which is open-source may give us the desired result that enables us to explain every change in detail. The use of the IBI has demonstrated that ambient noise in Landsat imageries can be effectively reduced while preserving built-up land features, with the highlight being the reduction in confusion between LULC classes. However, the results of the IBI are dependent on seasons, marked by an inability to differentiate bare soil from urban surfaces in the dry season, especially in places with low plant density (Shao et al., 2014). The results can be potentially useful for urban planning in Jorhat City as the use of the IBI demonstrated an enhanced built-up land class, which can be effectively used to gauge the direction of urban sprawl, urban growth, and agglomeration in the region. Moreover, this opens up avenues for slum detection, which is a pressing problem of contemporary times. Slum identification helps urban planners and policymakers understand the quantity, location, and characteristics of slums in a city. This information is essential for creating effective urban planning strategies such as slum upgrading campaigns, affordable housing initiatives, and infrastructure development projects. It allows for targeted interventions and resource allocation to improve living conditions and foster long-term urban growth. It promotes social inclusion and works towards sustainable and inclusive urban development.

Acknowledgement

The author would like to express gratitude to the editor of the journal *Nagarlok* for allowing us to submit our article. The author would like to thank the Department of Geography, Gauhati University for allowing us to access the lab.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article only.

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Adapting Remote Sensing Technique to Study the Changes in the Spatial Cover and the Urban Temperatures – A Case Study of Indore City, Madhya Pradesh

Nagarlok
55(3), 54-64
July-September, 2023
© 2023 IIPA

DOI: <https://doi.org/10.32381/NL.2023.55.03.4>

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Abstract

The urban areas are over-expanding to their permissible spatial limits to accommodate the increasing population. This has also brought about an increase in the allied sectors of grey infrastructure along with the massive modifications in the current land uses. The rapid conversion of the green and agricultural land into built-up areas is an observation due to these changes. The consequent effects of such changes and haphazard growth have led to changes in the climatic conditions, such as an increase in the urban temperature levels, unforeseen weather switches, and unpredictable seasonal changes, etc. The paper attempts to study the changing trends in the land use-land cover (LULC) sectors and its relative inter-relationship with the surface temperatures, for the Indore city of Madhya Pradesh (M.P.), India. The remote sensing technology is used to generate the land cover and the thermal maps and a comparative decadal analysis is done for the years 1996 and 2019. An approximate 3 to 5°C increase in the surface temperature is observed from the analysis and the increase in the human-generated anthropogenic activities prevalent in those specific areas could be concluded as one of the major reasons of the expansion in the city's heat island effect.

Keywords

Built-up, Greenery, Landsat, Land Use Land Cover, surface temperatures, Urban Heat Island.

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Introduction

Today's world is rapidly growing and developing from rural settlements to urban hubs. Urban centres which may be described as large regional Central Business Districts (CBDs) or the metro centres are characterised by human settlements with high population density and high built-up areas. This together constitutes our existing surrounding - a concrete environment. This is a result of the industrialisation, along with innovations and technology, further leading to the emission of a tremendous amount of anthropogenic heat. This heat is also emitted through factories, industries, service centres, automobiles, air conditioners, etc. Such urban anthropogenic heat, so generated, remains trapped in the atmosphere for longer durations, due to the decreased rate of humidity and precipitation; further warming up the area both during the course of the day as well as at night. This kind of occurrence is due to Urban Heat Island Effect (UHIE) and is currently one of the major issues to be dealt with in developing as well as developed countries of the world.

With the demands of the ever-growing population increasing exponentially, and the supply from the environment taking place at a normal rate; the impacts of such situation is visible by reduced green areas and an increase of built-up areas, a rise in temperatures and heat strokes, etc. The built areas and impervious areas reduce the surface runoff capacity and affect the evapotranspiration rate of the surrounding soil; thus, creating unfavourable changes in microclimatic as well as the weather conditions of any place.

The paper along with studying the changes, attempts to identify the possible situation of the existence of the UHIE for Indore City. The state is well-established and known for its highest number of forests in the country; covers 94,689 square kilometres of forest territory make up 30.72% of the state's overall geographical span. Despite of this green cover, the cities of MP are reportedly climate-vulnerable (Figure 1); also the agricultural lands are getting converted into built-up areas and the allied man-made activities are one of the reasons responsible for generating the anthropogenic heat. Thus, the cities face urban issues of rise in temperatures, heat strokes, water scarcity, and increase in pollution levels further degrading the qualities of air, water, and land. The detailed causes of this formation of UHIE can be further explored and identified by comparing the land use/ land cover, temperature differences, difference between built up and green spaces, etc. over the decades; as these factors are some of the reasons causing the UHI effect in cities. And hence, to repair and improve the effects and impacts, resilient adaptation and mitigation strategies should be initiated and implemented at the neighbourhood and local levels.

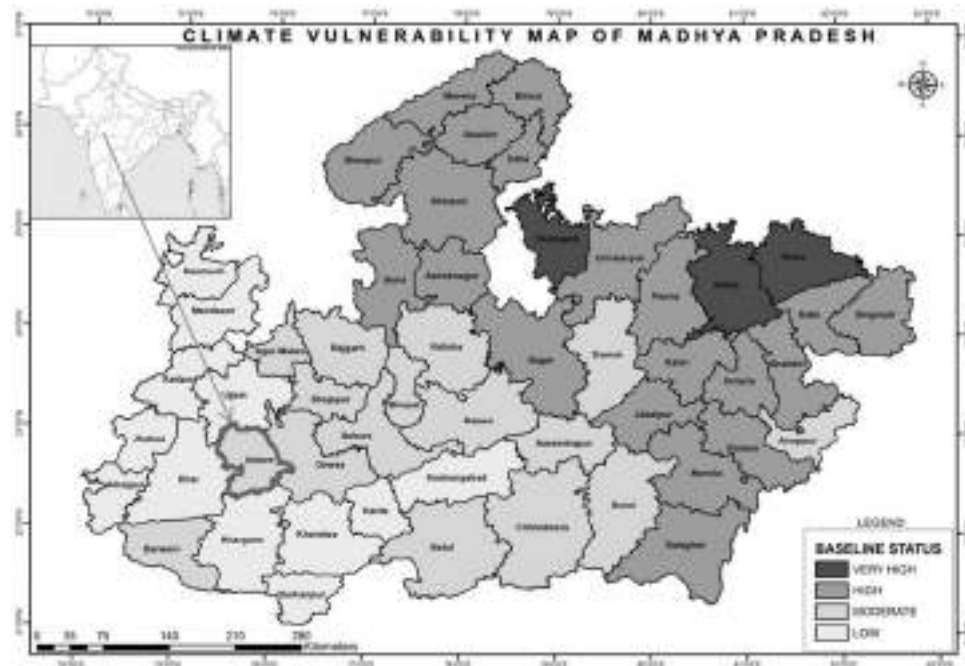


Figure 1: Climate Vulnerability Map of Madhya Pradesh

Source: Climate Vulnerability Map of Madhya Pradesh (2014); edited by Author

Study Area

Indore, also known as the commercial capital is the most populous city with regard to the area in the state of Madhya Pradesh, India and falls at 22°43'N and 75°50'50"E on the southern end of the Malwa plateau. It is spread over an area of 504.87 sq. km. with a population of 19,64,086, as per the Census 2011. The city receives an average moderate rainfall of 700 to 800 mm with major soil type as Medium black. The city is located in the composite-climatic zone of India (Subarao, Mukherjee, and Shankar, 2015) and exhibits a hot summer and an equally chilly winter.

For this research, the entire stretch of land of Indore city was studied extensively through the available secondary sources. The initial observation indicated the city growth which took place from the city centre core area, known as the Rajwada, towards the Eastern, Northern and Southern peripheries. All this growth was owing to the extensive demand and rise of trade and development activities. This city, which initially exhibited low-rise building typology, is now under dense and high-rise construction till date. Figure 2 elaborates the spatial evolution of the city from the year 1800's till the year 2005 and onwards.

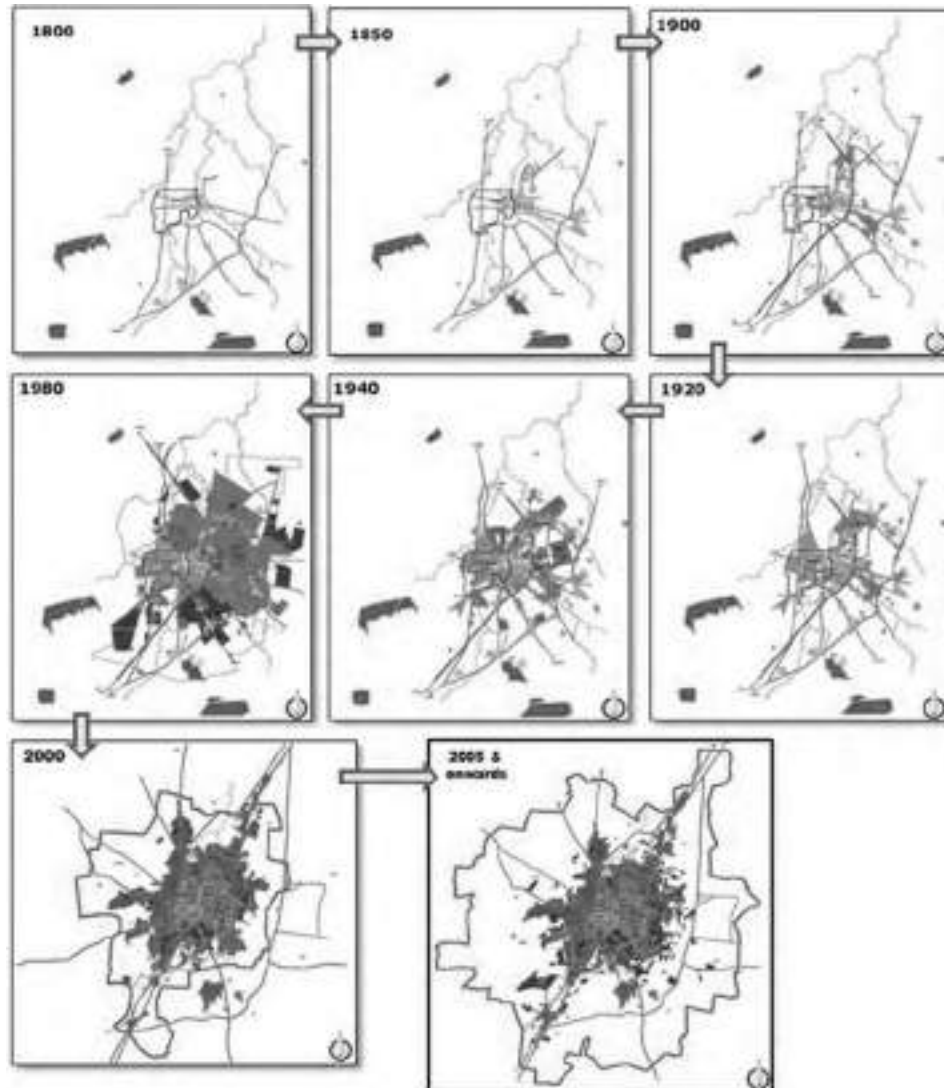


Figure 2: Spatial Evolution and City Growth of Indore, Madhya Pradesh

Source: Indore Smart City- ABD Master Plan, edited by Author

It was also observed that competing equally in terms of industrialisation and urban growth, Indore reflects an equal development and has maintained the vibrancy in its rich history and heritage, while continuously providing the basic amenities to the extending population, above and over its threshold limits. The decadal population growth rate is registered at about 40%, putting a tremendous pressure over the available amenities (TARU, 2012), such that a shortage in the infrastructural activities is already observed. This has resulted in a growth in the populated areas and modifications to the land cover categories, expanding the city limits vastly.

Methodology

The paper addresses the importance and advantages of adapting the remote sensing techniques in analysing the land cover and land surface temperature aspects for any urban area. In this case, the Indian city of Indore is studied to explore the changes in the land cover and the changing trend in the surface temperatures prevailing in the city. The methodology adopted for this study includes the generation of land use land cover (LULC) maps and the land surface temperature (LST) maps, done in the analysis and data processing software, ArcGIS (version 10.4). The United States Geological Survey (USGS) Earth Explorer website offers downloads of the necessary Landsat imageries, which include satellite bands for the investigation area. The satellite data for the typical summer month of May was acquired and further processed for the study with an extra condition for 0 to >10% cloud cover in the original settings. Before analysis, all data is pre-processed and projected to the WGS84 Datum and Universal Transverse Mercator (UTM) projection system. The satellites Landsat05 and Landsat08 ETM+ have been used for the map generations of the years 1996 and 2019 respectively.

Land Use Land Cover of Indore

The LULC regarding a place defines its spatial characteristics or the spread of the built and un-built spaces in any geographical location. The concept of LULC categorizes the land/place/area or city under various categories such as residential areas, transportation, industries, water bodies and green areas. This categorisation done by the development authorities plays an essential role while logically planning and designing a new urban growth. The changes in these land uses in terms of conversion of land use categories or modifications are the results of the modern age industrialisation and urbanisation. These types of changes affect the land quality and its productivity due to land degradation, changes in environmental conditions and biodiversity, impacting the runoff, etc. (Falcucci, Maiorano, and Boitani, 2007; Mallupattu and Sreenivasula Reddy, 2013; Ganasri and Dwarakish, 2015; Hassan et al., 2016; Liping, Yujun, and Saeed, 2018; Chang, Hou, Li, Zhang, and Chen, 2018; Parveen, Basheer, and Praveen, 2018; Yohannes, Cotter, Kelboro, and Dessalegn, 2018; Mishra, Rai, and Rai, 2019). The urbanisation has adversely affected the environment by altering the land uses. A decrease in the vegetative areas and a simultaneous rise in the number of constructed neighbourhoods has brought about modifications in our surroundings and atmosphere. A similar situation of altered LULC of urban form and fabric is observed in Indore, the trading capital of the state of Madhya Pradesh. Figure 3 details the steps for generating the LULC maps:

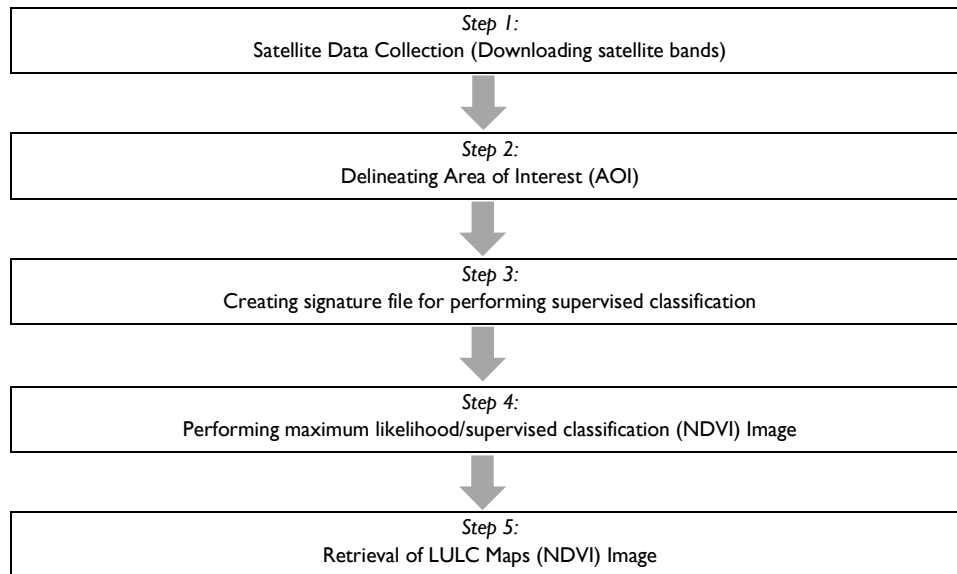


Figure 3: Methodology adopted for creation of Land Surface Temperature (LST) maps

Source: Author



Figure 4: Land Use Land Cover (LULC) Maps of Indore; (a) LULC of Indore, May 1996, (b) LULC of Indore, May 2019

Source: Author

In this study, the maps of land use and cover (Figure 4) have been generated by performing the supervised classification in the ArcGIS software. The maps have been generated for two years, namely 1996 and 2019, with a decadal gap of around 20 years.

The maps have been generated with the major objectives of identifying the nature of the land covers; their spatial extent and the alterations occurred in the numerical area classification of LULC. The initial observation shows a growth in the developed areas.

A drastic difference in the LULC categories was observed in the comparative analysis between May 1996 and May 2019. A significant rise witnessed was 12.22% in the build areas with a decrease of 14.75% and 5.64% in the other land use categories of agricultural and vacant land respectively. An increase in the spatial extent among the constructed sections in the city's core was observed. Its growth was observed to be spread in the North, South and the East directions in the LULC map of 2019. The peri-urban locations of the city in the 1900's was surrounded with a dense agricultural land, which in recent decade has been converted to build areas under categories of residence, commercial and industrial. The changes observed in the categories of the land uses are also mentioned in Table 1.

Table 1: Areas under different Land Use categories for May 1996 and May 2019

	Built-Up	Vegetation	Agricultural	Water	Vacant	Total
May 1996 (Area in sq. km)	70.32	38.11	298.02	4.39	94.00	504.87
(Area in %)	13.93	7.55	59.03	0.87	18.62	100
May 2019 (Area in sq. km)	132.02	46.95	225.42	32.76	67.70	504.87
(Area in %)	26.15	9.3	44.65	6.49	13.41	100

The increase in the rate of population and the relative need to cope up with their demands can be inferred to be one of the major causes of the altered land uses land covers (LULC). These changes could also be responsible for bringing meteorological changes, in the city.

Land Surface Temperature (LST) Maps of Indore

To study the changing trends in temperatures and to identify the existence of the UHI in the city, the LST maps were created for the month of May for the years 1996 and 2019 (Figure 4). The methodology adopted for the derivation of Land Surface Temperature maps is a four-step procedure that involves (i) collecting satellite data, which includes downloading appropriate Landsat bands for additional analyses, (ii) creating NDVI (Normalized Difference Vegetation Index) maps, (iii) determining maps for assessing emissivity at the surface maps and (iv) extracting land surface temperature maps. Figure 5 details the steps for generating the LST maps.

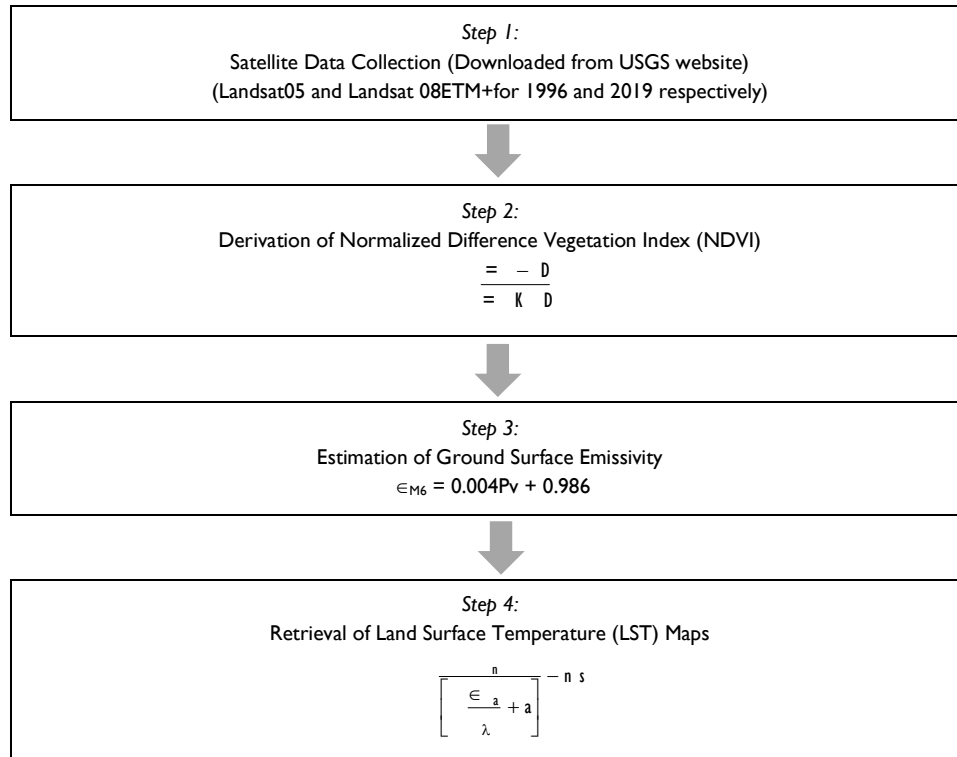


Figure 5: Methodology adopted for creation of Land Surface Temperature (LST) maps

Source: Author

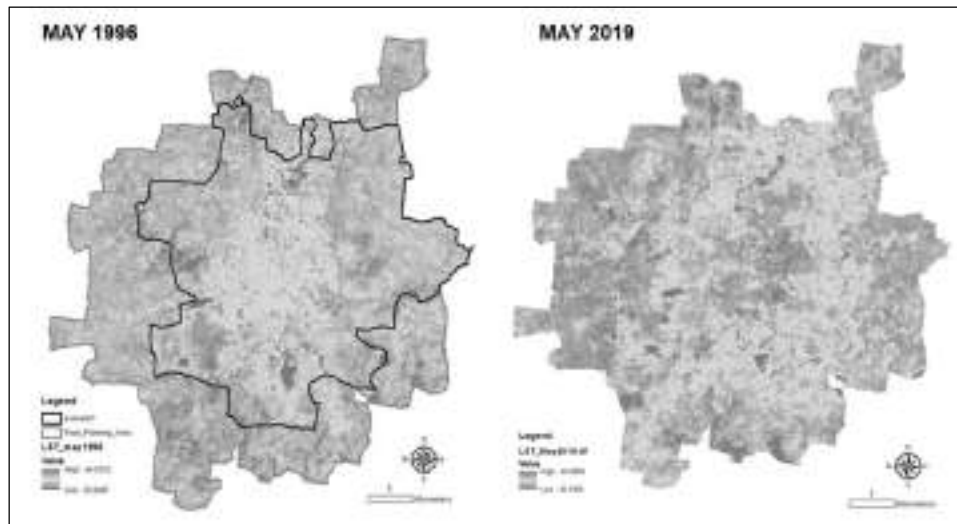


Figure 6: Land Surface Temperature (LST) Maps of Indore; (a) LST of Indore, May 1996, (b) LST of May, 2019

Source: Satellite data downloaded from USGS website, thermal maps generated by Author in ArcGIS software

In the LST images (Figure 6), the black line denotes the Indore Municipal Boundary and outer orange boundary is the Planning Area Boundary for Indore. The higher temperature values were observed to be 44.07°C and 49.88°C, for the years 1996 and 2019 respectively; whereas the lower temperature values were 23.24°C and 30.19°C respectively. An observed temperature difference of 3 to 4°C was observed in the minimum range of temperature, suggesting that the heat trapped by the surfaces during daytime couldn't escape in the night-time. These keep the surfaces of the cities warmer, demonstrating the occurrence of UHIE. This may be due to the various man-made reasons such as increased impervious surfaces and built up, reduced green areas, increase in automobiles and their vehicular emissions and GHG emissions, etc. which remain in the atmosphere throughout the day.

Discussion and Conclusion

With the advancement of science and technology, adapting analysis techniques such as GIS and Remote Sensing have enabled obtaining any required quality and quantity of secondary data, for any spatial area, even though being located at any remote location. Such type of satellite-based data is widely used these days to sense and map the existing land cover, over the surface of the Earth. The processing of these satellite bands also helps to identify the prevailing surface temperatures on the land surfaces, for any month of the year. The figures thus obtained are primarily used for initial levels of primary analysis and trend analysis for land classifications and meteorological studies.

On the similar lines, this study conducted a survey of Indore, the most populous city of Madhya Pradesh. The city highlighted an eventual increase in the built-up areas which was a result of the growth and development occurring in the city. The study of the decadal spatial evolution of the city suggested tremendous growth and new developments rising on the Western, Northern and Southern peripheries of the city. To further clarify the existing scenario of the land cover in the city, the Landsat 05 and Landsat 08 ETM+ satellite bands were adopted and processed using the ArcGIS software. A comparative analysis of the two decadal land cover maps was done for the years 1996 and 2019. The analysis suggested a decline in the percentage of the share in the land used for agriculture and an increase in the percentage share of densely constructed and populated regions. These changes are also responsible in the decreased air-flow, and increased polluted air in the city. In the second part of the study, the land surface temperatures were observed explore the connection between the two concepts. For this analysis, the same satellite bands were used to create the Land Surface Temperature maps. The outcome showed that initially, the overall temperature of the city was in a range of 0 to 40°C (in 1996), which increased to a range of 0 to 50°C (in

2019). The maps identified the hot and cool temperature pockets in the city. It was observed that the areas with dense construction are the ones with higher temperatures, thus validating the fact that there exists a direct relationship between built-up, land cover and surface temperatures. Also, the approximate temperature difference of around 4°C, observed in the lower limits of surface temperatures denote the observation of the UHI effect. The presence of such situation in the decadal years proves the consistency in rising temperatures along with the rise in the built-up areas. As a result of which, both the human and environmental health of the city may suffer to a larger extent.

If the effects are not promptly mitigated and controlled, the climate would continue to deteriorate, which would lessen and weaken these cities' ability for resilience. In order to create a sustainable and healthy environment, it is urgently necessary to mitigate the sources of urban heat islands as well as to develop and incorporate adaptation plans for climate change resiliency. The scope of this study includes the adaptation of the methodology and its process for conducting other similar studies. Thus, due to its promising outcomes and ease of applicability, it could also be concluded that the adaptation of the remote sensing technique and Landsat imageries are proven to be an essential strategy to study or compare the spatial and temporal scenarios for any urban area. This study can be further extended as a detailed investigation can be further explored so as to reduce the possible negative impacts and build a climate change resiliency for Indore and other cities of Madhya Pradesh.

Acknowledgments

We would like to thank the State Knowledge Management Centre on Climate Change (SKMCCC), Environmental Planning and Coordination Organisation (EPCO), for funding the research work and providing the climate data required for the study; and to the institute of conducting this research, School of Planning and Architecture Bhopal for providing ample resources, libraries and software-based laboratories.

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Mobility App Usage and Transportation Preferences: A Latent Class Cluster Analysis of Smartphone Users of Bhopal, India

Nagarloket
55(3), 65-82
July-September, 2023
© 2023 IIPA
DOI: <https://doi.org/10.32381/NL.2023.55.03.5>

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Abstract

With the rapid rise of information and communication technology (ICT), various smartphone-based transportation platforms in the form of apps have emerged, with the potential to totally revolutionise mobility through more advanced multimodal platforms like, for example, Mobility as a Service. However, in order to incorporate these new mobility services in a systematic manner, it is essential to investigate the characteristics of current smartphone users as well as their transportation preferences. Against this background, this research paper utilised latent class cluster analysis to empirically investigate the characteristics of current smartphone users in the city of Bhopal and their transport usage patterns by categorising them into three latent clusters based on a comprehensive set of variables like socio-economic characteristics, smartphone app usage, transportation usage, and attitudes and preferences. Cluster 1 consists of users with low app usage and higher usage of public transport and intermediate public transport; Cluster 2 consists of multimodal users with high app usage; and Cluster 3 consists of users with moderate app usage and heavy reliance on private vehicles.

Keywords

App usage, Transport mode usage, Latent class cluster analysis, Multimodality.

Introduction

India's urbanisation and rapid economic expansion have significantly increased the demand for mobility services (Juyal et al., 2018). However, as passenger traffic increased significantly, the number of private cars rather than the use of public

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transport increased (Gupta and Garg, 2020). Policymakers are considering comprehensive measures, including technological advances and policy measures, as efforts to achieve low-carbon transport and mobility. Technology plays a key role in encouraging a shift from private vehicles to mass transit and shared mobility, primarily through advances in Information and Communication Technology (ICT) and its applications in transport sector (ESCAP, 2019). In the last decade, ICT has become much more available, especially in the form of mobile phones. According to the latest figures, the use of mobile phones has grown exponentially, and India has 85 mobile phone connections for every 100 individuals (TRAI, 2022).

These mobile phones have also evolved from an essential communication tool to a trusted information, communication, search, and entertainment device known as a smartphone. Smartphone applications or “apps” can provide quick access to previously unavailable transport-related information, including real-time data, in some cases, to enable users to make informed mobility decisions. The way people use smartphone apps for travel is constantly evolving. Smartphone users are increasingly using apps for various transportation applications. More and more people use their smartphones to start a trip, direct a trip, check the departure time of the next bus, train, or subway, hail a taxi, or use the services of an app-based taxi aggregator. In developed countries, this has created a smartphone-enabled ecosystem of mobility services called Mobility-as-a-Service (MaaS) — a platform that combines different transportation modes and services into a single app and is capable of shifting users towards sustainable mobility patterns (Hartikainen et al., 2019). Such platforms have either already been deployed or are under trial in many cities across the world.

Work on smartphone-enabled connected mobility platforms has also started in India, and the Ministry of Housing and Urban Affairs (MoHUA) of Government of India, in collaboration with industry partners are working to establish a framework to introduce smartphone-enabled connected mobility platforms in Indian cities for integrating all forms of shared transportation through a single app with multiple functions, including route/mode choices and payment gateways (Cities Forum, 2021). Owing to rapidly increasing internet and smartphone penetration in all the regions of the country as a result of lowering the costs of data and handsets, along with other flagship government projects like ‘Smart Cities Mission’ (MoHUA, 2015), which aims to develop 100 prominent Indian cities that are meant to procure and integrate the most advanced technologies that the industry can provide to create a highly connected and technology-friendly infrastructure (Deokar, 2020) and ‘Digital India’ (MeitY, 2019) for improving access to the internet in all urban and rural areas, it is not going to be long when use cases based on these platforms start emerging in Indian cities.

However, the market for smartphones and their applications is still developing, and it is unclear how they will affect everyday mobility patterns of users in the future

with these continuous changes and improvements (Brazil and Caulfield, 2013). Therefore, examining the relationship between the usage of smartphone-based transport apps and transport system usage may provide insights into the potential impact of smartphone app usage on people's transport preferences. Such research could aid in policy development measures for smartphone-related travel enhancements and alternatives, such as carpooling, shared mobility, etc. (Khan, et al., 2020), further contributing towards a low-carbon future of urban transport. Modern literature has shown that the use of ICT devices has changed daily activities and travel decisions, such as time of activity, start time, destination selection, selection of transportation mode, selection of route, etc. (Mokhtarian and Tal, 2013; Kaplan, et al., 2017; and Windmiller, et al., 2014). The versatility of smartphone apps is changing the way people travel everyday. People can use various smartphone apps for work, shopping, banking, etc., instead of physically travelling. Smartphone apps can also become a popular source of information about various places and attractions, local festivals, and community events, leading to trips to new places and attending social gatherings. Smartphone users can use reviews and ratings for new places to decide whether to visit them. Users may even get encouraged to participate in community events due to readily available information about local activities (Khan et al., 2020). With the advent of smartphone-based shared mobility solutions, users now also have various transport options to cater to these new mobility requirements.

In this context, the objectives of this study are two-fold. First, it attempts to probabilistically classify smartphone users with similar transport usage patterns using a rich set of covariates, including socio-economic characteristics, smartphone app usage patterns and attitudes/preferences, while maximizing the diversity of these patterns between groups. Second, it also seeks to analyse these covariates as factors that affect individuals' probabilities of belonging to these clusters.

Materials and Methods

Study Area

The city of Bhopal has been taken up as the case study for this research. It serves as the capital of the State (Province) of Madhya Pradesh in Central India. The city has compelling reasons to be considered as a Case Study. Out of the 100 cities selected for the Smart Cities Mission (MoHUA, 2015), it was chosen as one of the first round's 20 lighthouse cities, with the goal of transforming the city into a smart, sustainable, and liveable city that is ready for the future. A 186-kilometre Bus Rapid Transit System (BRTS) is operational in the city and is integrated with an app called 'Chalo', which provides real-time information about the bus service. App-based shared mobility platforms are already providing their services. Construction work on Phase-1 of the

Metro commenced in January 2019 and is expected to be completed by 2026. As the city grows in size and complexities, trip planning will become a critical part of everyday lives of the residents. Many mobility apps offering such services are already available in the city which include Map and Navigation Apps (Google Maps and Apple Maps), Public Transport Apps (Chalo App), Shared Mobility Apps (Uber, Ola, Rapido, Chartered Bikes, etc.), Information Apps for Recreation (BookMyShow, Zomato, etc.), Ticketing and Payment Apps (PayTM, PhonePay, GPay, etc.) and Social Network Apps (Facebook, WhatsApp, Twitter, etc.). So, with almost all the modern forms of mobility systems (both existing and committed) and increasing smartphone penetration, the city already has the ingredients for deploying higher-order app-based mobility systems and their deployment requires a comprehensive assessment of current app users in the city and their transport usage patterns.

Data and Variables

An online survey of smartphone users was used to acquire the main data for this study. A sample of 548 people for Bhopal was obtained through an online questionnaire survey between September 2021 and December 2021 using a snowball sampling technique, out of which, 475 were randomly selected based on proportion of users belonging to various age groups in Bhopal as per the Census of India (2011). The study considered four main types of systems: private cars (including two- and four-wheeled motor vehicles), public transportation (such as bus and metro services), intermediate public transportation, or “IPT” services (such as autorickshaws and battery-powered rickshaws), and app-based shared mobility services. On a Likert scale with the following options, respondents were questioned about their propensity to use the aforementioned forms of transportation: Never, Rarely, Sometimes, Often, and Always. Gender, age group (users under 18 have not been taken into consideration in this study), education level, and years of smartphone use were recorded at the personal level. Household level information included household composition (with or without children under 18), monthly household income, four-wheeler ownership, and two-wheeler ownership. The socio-economic data at the individual and household levels has been categorised. Responses were also gathered from smartphone users regarding how frequently they used the apps for tasks related to trip planning, such as selecting a mode of transportation, choosing a destination, deciding on a departure time, communicating, and coordinating, and other travel-related activities like navigation, looking up the schedule of public transportation, online shopping, etc. Information was collected on a Likert Scale, with responses: Never, Rarely, Sometimes, Often and Always. The dataset for app users' attitudes and perceptions comprise respondents' levels of agreement with 12 statements concerning attitudes and preferences, with responses: Strongly disagree, slightly disagree, neutral, slightly agree, and strongly agree.

Methods

First, *Chi-Square Test of Association* has been performed between socio-economic parameters and usage frequency of the transport modes for testing association between them. SPSS software package has been used to perform this analysis and apart from gender and household composition, all the personal and household level variables have shown a strong association with frequency of use of transport modes, i.e., $p < 0.05$. Table 1 shows the results of Chi-Square test between gender (Household Composition) and frequency of use of various modes of transport.

Table 1. Chi-Square test for Gender (Household Composition) and Frequency of Transport Usage

Socio – economic variable	Statistic	Frequency of use of:			App – based Cab Services
		Private Vehicle	Public Transport	IPT	
Gender	Asymptotic Significance	Less than	0.874	Less than	Less than
	(2 sided)	0.01		0.01	0.05
	Cramer's V	0.234	0.134	0.232	0.165
Household Composition	Asymptotic Significance	0.29	Less than	Less than	
	(2 sided)		0.05	0.05	0.65
	Cramer's V		0.16	0.155	0.072

Source: Authors

It has been found that apart from the frequency of use of public transport, gender has a significant relationship with frequency of use of all other modes. But for these significant relationships, the value of Cramer's V, which is a measure of the effect size for the chi-square test (Liebetrau, 1983), is close to 0.2 which means that although the results are statistically significant, Gender has a weak or moderately weak relationship with the frequency of use of Private Vehicles, IPT and App-based Cab Services (Cohen, 1988). Similarly, household composition has significant relationship with the frequency of use of public transport and IPT, but Cramer's V is less than 0.2 and so, there is a weak relationship.

Exploratory Factor Analysis (or EFA) has been used as a variable reduction technique for the statements recording attitudes and preferences and accounts for the common variance among them (Williams, et al., 2010). The SPSS software package has been used to perform this analysis. Statement having low factor loading (less than 0.4 in this study) should be considered (Field, 2013). Table 2 shows the statements along with the estimated factor loadings.

Table 2: Statements assessing Attitudes and Preferences of Users towards Choice of Transport

Statements		Factor Loadings
1.	Any form of transportation will suffice as long as it meets my needs for travel.	0.4
2.	Before beginning a trip, I often compare travel alternatives and means of transportation.	0.5
3.	The ability to integrate various means of transportation, such as buses, cars, bicycles, or vehicle sharing, with ease is crucial for improving transportation.	0.6
4.	I'm willing to try various new travel options.	0.6
5.	Riding public transportation with strangers is uncomfortable.	0.6
6.	There is lack of cleanliness in public transportation.	0.4
7.	It's crucial to use public transportation to protect the environment.	0.6
8.	To cut cost of transportation, I like to use the bus or carpooling.	0.6
9.	I would rather benefit from a car's convenience without owning one myself.	0.6
10.	I enjoy the privacy a private vehicle or bike provides.	0.7
11.	People like me only use privately owned cars and/or bikes.	0.5
12.	If there was a less expensive option, I would use my private vehicle less.	0.6

Source: Authors

It can be observed that none of the statements have factor loading less than 0.4 and can be considered for further analysis. Data suitability for EFA was investigated using Kaiser-Meyer-Olkin (KMO) model fit measures, along with Bartlett's test of sphericity (Field, 2013). A KMO of 0.934 has been obtained, showing good sample adequacy (Hutcheson and Sofroniou, 1999), and Bartlett's test is less than 0.001 indicating good relationships between indicators for the EFA.

Latent Class Cluster Analysis (or LCCA) has been used to probabilistically classify smartphone app users into traveller groups, each characterised by somewhat similar patterns of mode use while also maximising their heterogeneity across groups. The model classifies individuals in different clusters based on unobserved (latent) variables that describe their responses for a set of observed indicators (Molin et al., 2016). Compared to more simple techniques, this analytical approach has several advantages for identifying multimodal travel behaviours. As travel multimodality cannot be simply reduced to a one-dimensional measure like HHI or Shannon's Entropy, LCCA aims to quantify multimodality as a whole rather than creating a single (composite) index. Instead, it classifies individuals into latent classes on the basis of multiple indicators that reflect each class's unique mode usage patterns. Second, this method evaluates individual's probability of being classified to various latent classes,

in contrast to deterministic classification approaches. Each of these classes displays a unique profile that includes the average frequency of use for the various modes. In particular, this is the mean of a set of sample-wide probability-weighted indicator variables (Lee et al., 2020).

The model includes two sub-models which are simultaneously estimated. A multinomial logit model is used in one sub-model to estimate the probability that the individual ‘i’ (with the covariates ‘ x_i ’) belongs to the latent class ‘c’. The other sub-model estimates specific means and standard deviations for ‘J’ indicators for each class, ‘ y_{ij} ’ ($j=1, 2, 3, \dots, J$) or arrayed into the vector ‘ y_i ’ that is the monthly frequencies of transport mode usage, and also assumes that the indicators will have a normal distribution. Equation below represents the entire model (Vermunt and Magidson, 2002).

$$P(y_i | x_i) = \sum_{c=1}^C P(c | x_i) \prod_{j=1}^J P(y_{ij} | c) \quad (1)$$

The results include two sets of estimations for parameter: the active covariate coefficients specific to the class, as well as averages and standard deviations of the indicators specific to the class. The statistical significance of a given covariate in a multinomial logit model setting determines whether it accounts for the probability of a commuter’s membership in a particular class. Due to weak relationship between gender (household composition) and frequency of use of some transport systems, gender and household composition have been considered as inactive covariates in LCCA model and do not affect the classification. Similarly, the statements one and six have been considered inactive.

Results

The model has been run in the Latent Gold software with a variety of defined numbers of latent classes (clusters), and the best model has been chosen out of those runs using information criteria such as the Akaike Information Criterion (or AIC) and the Bayesian Information Criterion (or BIC). A higher model fit is associated with low values for these criteria and based on lower AIC and BIC values, the three-cluster model has been selected.

Cluster-wise transport mode usage

The frequency profiles for the study’s respondents, who were grouped into three latent class clusters based on higher response probabilities, are shown in Figure 1. The darker shades represent higher usage of transport modes.

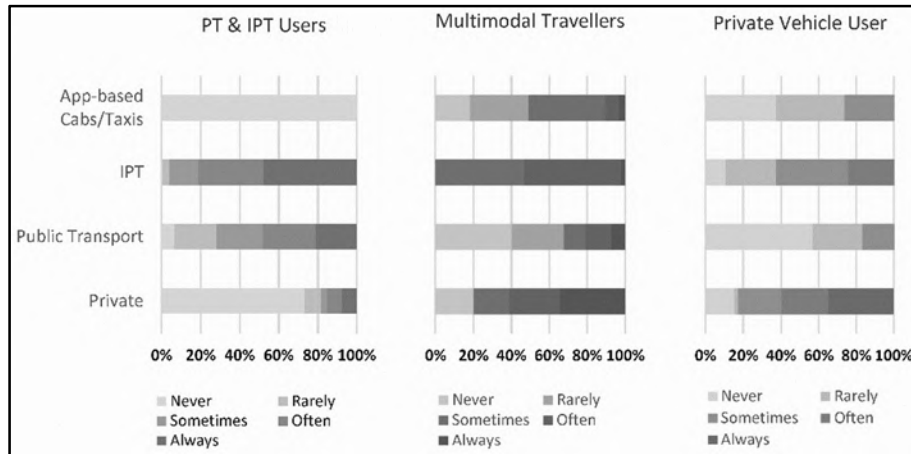


Figure 1: Cluster-wise Transport Mode Usage Pattern

It has been observed that the respondents classified in cluster 1 show very high reliance on public and intermediate public transport, less dependence on private vehicles and no usage of app-based cabs/taxis. In contrast, the ones classified in Cluster 2 show a significant dependence on all modes of transport. Finally, respondents in Cluster 3 show higher reliance on private vehicles. Thus, the three latent classes can be named as – *Cluster 1: PT and IPT Users*, *Cluster 2: Multimodal Travellers* and *Cluster 3: Private Vehicle Users*. All the active and inactive covariates can now be classified under these latent classes as per the LCCA model. Cluster Profile for App Usage.

Reference depicts the profile of respondents clustered into the three latent clusters in terms of how frequently they use smartphone apps for trip planning activities.

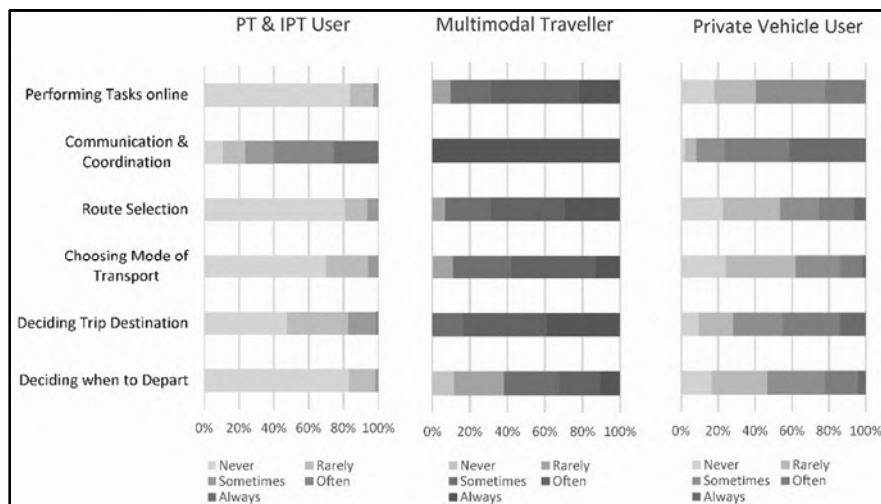


Figure 2: Cluster probabilities of respondents based on Usage of Trip Planning Activities

Even though the majority of respondents stated that they rely heavily on apps for communication and coordination, those who stated they never (or occasionally) use them for all other trip planning activities are far more likely to be clustered as PT and IPT users. On the other hand, respondents who stated “Often” to “Always” for all purposes are more likely to be categorised as multimodal travellers. The respondents, who were clustered as private vehicle users, gave a range of responses between “Rarely” and “Often”. Further, source depicts the profile for respondents clustered into the three latent clusters in terms of how frequently they use smartphone apps for other travel-impacting purposes.

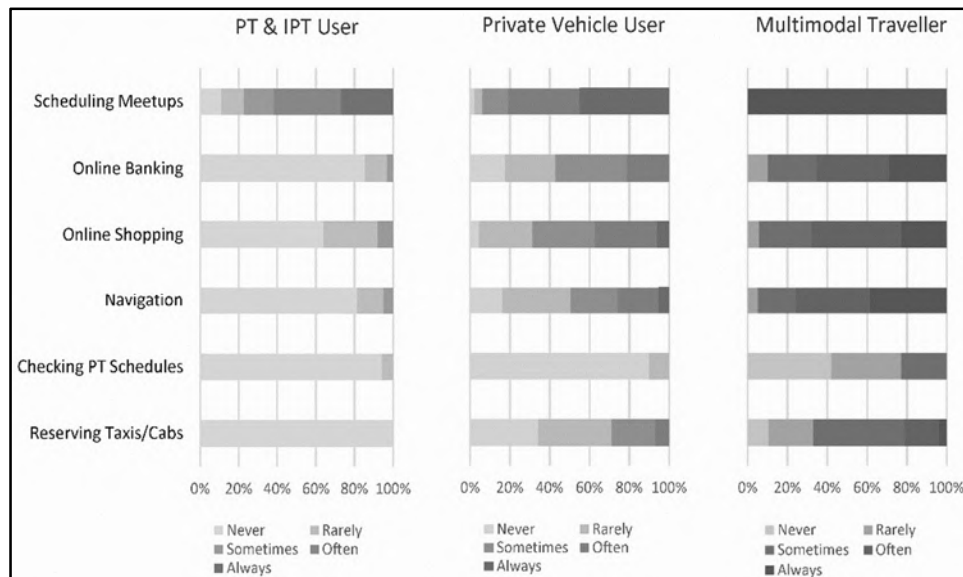


Figure 3: Cluster probabilities of respondents based on Usage of other Travel Impacting Purposes

Source: Even though the majority of respondents claimed to rely heavily on apps to schedule meets using social networking applications, those who answered “Never” to “Sometimes” had a higher likelihood of being clustered as PT and IPT users for all purposes of trip planning. However, there is a strong likelihood that respondents who answered “Often” to “Always” will be clustered as multimodal travellers. The responses from the respondents with a high probability of being clustered as private vehicle users ranged from “Rarely” to “Often”.

Class memberships

In addition to depicting the three latent class clusters of travellers, an attempt has been made to analyse the mentioned covariates as factors which affect the probabilities of individuals to belong to these clusters. Table 3 shows the probabilities of respondents to be classified in a cluster depending upon their socio-economic characteristics.

Table 3. Cluster probabilities of respondents based on socio-economic characteristics

Socio-economic Characteristics	Latent Classes (Clusters)		
	Cluster 1: PT and IPT User	Cluster 2: Multimodal Traveller	Cluster 3: Private Vehicle User
Gender <Inactive>			
Male	42.9%	29.8%	27.3%
Female	42.6%	28.7%	28.7%
Age Group			
18 to 24 Years	40.0%	60.0%	0.0%
25 to 34 Years	40.0%	60.0%	0.0%
35 to 44 Years	40.0%	1.0%	59.0%
45 to 54 Years	40.0%	0.0%	60.0%
55 to 64 Years	52.5%	0.0%	47.5%
65 Years and above	40.0%	60.0%	0.0%
Educational Qualification			
High (undergraduate degree or more)	4.7%	68.8%	26.5%
Medium (high school education)	32.4%	19.8%	47.7%
Low (less than high school education)	82.0%	0.0%	18.0%
Experience with Smartphone Use			
Less than 1 Year	100.0%	0.0%	0.0%
1 to 3 Years	100.0%	0.0%	0.0%
3 to 5 Years	88.2%	11.8%	0.0%
More than 5 Years	19.4%	39.7%	40.9%
Household Composition			
With Children below 18 Years	40.4%	32.2%	27.5%
Without Children below 18 Years	45.5%	25.9%	28.6%
Monthly Household Income			
Less than INR 5,000	100.0%	0.0%	0.0%
INR 5,000 to 20,000	100.0%	0.0%	0.0%
INR 20,000 to 50,000	13.7%	48.4%	37.9%
INR 50,000 to 100,000	0.0%	48.4%	51.6%
More than INR 100,000	0.0%	49.5%	50.5%

Socio-economic Characteristics	Latent Classes (Clusters)		
	Cluster 1: PT and IPT User	Cluster 2: Multimodal Traveller	Cluster 3: Private Vehicle User
Four-Wheeler Ownership			
None	95.0%	5.0%	0.0%
One	8.1%	44.7%	47.2%
Two	0.0%	50.6%	49.4%
Three or More	0.0%	48.5%	51.5%
Two-Wheeler Ownership			
None	92.1%	7.9%	0.0%
One	41.8%	26.8%	31.4%
Two or More	4.8%	48.4%	46.8%
The bold values represent the highest value for each row			

Source: Authors.

The following are the socio-economic characteristic-wise cluster probabilities –

- **Gender <Inactive>:** Does not contribute to the model for latent cluster formulation. It can be observed that for both male and female respondents, the probability of getting classified as a PT and IPT user (42.9% and 42.6% respectively) is slightly higher than a multimodal traveller and significantly higher than a private vehicle user.
- **Age Group:** Younger Users (18 to 34 years) have a higher probability (60%) of getting classified as a multimodal traveller and no probability of getting classified as private vehicle users. Respondents of middle age groups of 35 to 44 years and 45 to 54 years have a higher probability (59% and 60% respectively) of getting classified as private vehicle users. Respondents of age group 55 to 64 are mostly still working and have a 52.5% probability of being classified as PT and IPT users and 47.5% probability of being classified as Private Vehicle Users depending on the household income. However, the respondents above 65 years of age mostly become dependent on others for their mobility requirements and have a 60 per cent chance of being classified as Multimodal travellers.
- **Educational Qualification:** Respondents with higher education (undergraduate or more) have a high probability (68.8%) of getting classified as a multimodal traveller, and conversely, those with lesser education (less than high school) have a high probability (82%) of getting

classified as PT and IPT users. Users with medium education (high school) have a 47.7 per cent probability of becoming private vehicle users and a 32.4 per cent probability of becoming PT and IPT users.

- **Number of Years of Smartphone Use:** Experience with smartphone usage is a major contributor to app usage, and all users with less than three years of experience are PT and IPT users. Although users with three to five years of experience with smartphone use also have a high probability (88.2%) of getting classified as PT and IPT users, there is also some probability (11.8%) of getting classified as a multimodal traveller. Users with more than five years of smartphone use experience have a 40.9 per cent probability of getting classified as private vehicle users, 39.7 per cent probability of getting classified as multimodal travellers and only 19.4 per cent probability of getting classified as PT and IPT users.
- **Household Composition <Inactive>:** Does not contribute to the model for latent cluster formulation. Although respondents with or without the presence of children below 18 years in the household have a higher probability (40.4% and 45.5% respectively) of getting classified as PT and IPT users, respondents with children in the house also have a high probability (32.2%) of being a multimodal traveller and ones without children have a high probability (28.6%) of being a private vehicle user.
- **Monthly Household Income:** All respondents with a monthly income of less than INR 20,000 have been classified as PT and IPT users. Those earning INR 20,000 to 50,000 are highly likely (48.4%) to be classified as multimodal travellers. Among the high-income households, those belonging to ones with income INR 50,000 to 100,000 has a slightly higher probability of being classified as private vehicle user (51.6%) than multimodal traveller (48.4%). Similarly, those belonging to the group with more than INR 100,000 monthly income has a slightly higher probability of being classified as private vehicle user (50.5%) than multimodal traveller (49.5%).
- **Four-Wheeler Ownership:** Respondents belonging to households with no four-wheeler have a 95 per cent probability of being a PT and IPT user. However, the ownership of even a single four-wheeler by the household ensures that they almost completely shift away from public transport but not completely in favour of private vehicles. Households with one vehicle have a slightly higher probability of being classified as private vehicle users (47.2%) than multimodal travellers (44.7%). Similar is the case with very high-income groups with three or more vehicles, where users have a slightly higher probability of being classified as private vehicle users (51.5%) than

multimodal travellers (48.5%). Interestingly, in the case of households with two vehicles, users have a slightly higher probability of being classified as multimodal travellers (50.6%) than private vehicle users (49.4%).

- Two-Wheeler Ownership:** Respondents belonging to households with no two-wheeler have a 92.1 per cent probability of being a PT and IPT user. However, the ownership of even a single two-wheeler by the household ensures that they significantly shift away from public transport but not completely in favour of private vehicles. Although in households with one vehicle, 41.8 per cent of respondents still have a high probability of being PT and IPT users, there is also 31.4% that they get classified as private vehicle users. In the case of households with two vehicles, users have a slightly higher probability of being classified as multimodal travellers (48.4%) than private vehicle users (46.8%).

Attitudes and preferences

Associations of respondents' attitudes and preferences with class membership have also been studied separately. Figure 4 shows latent class cluster-wise weighted mean exploratory factor analysis scores for statements relating to the choice of travel. Statement excluded from the LCCA is also included in the radar graphs for a more comprehensive overview of all studied aspects.

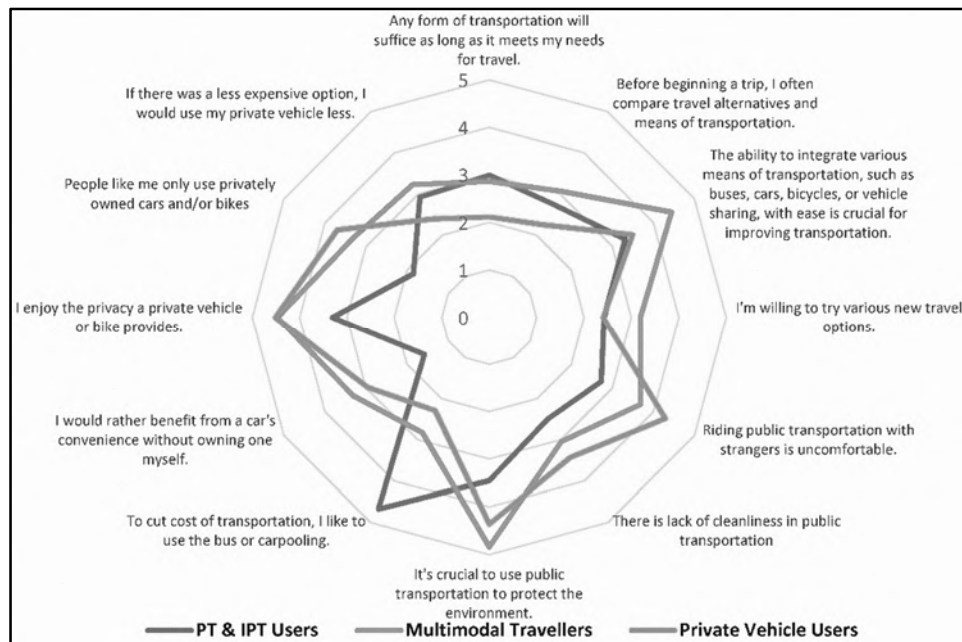


Figure 4: Weighted mean EFA scores for choice of travel

The Following are the cluster-wise observations associated with Attitudes:

- **PT and IPT Users** are captive to their mode of transportation because of their susceptibility to the cost of travel, and they are unwilling to switch to another mobility option unless it is more affordable than their current system and is technologically accessible to them. Thus, additional considerations like comfort, cleanliness, privacy, or environmental friendliness are not taken into account while making decisions.
- The **Multimodal Travellers** frequently compare the various travel options at their disposal, including the mode combinations for their trips, and they are even open to experimenting with new mobility options. They are sensitive to environmental concerns and acknowledge the importance of using public transportation and are open to the idea of shared mobility, which would allow them to enjoy the convenience of a private vehicle without having to own one, despite their slight discomfort at the thought of riding with strangers and their concern for the cleanliness of public transportation.
- Although some of the **Private Vehicle Users** see the value of public transportation for protecting the environment, they are less likely than multimodal users to experiment with new modes of transportation since they find it so uncomfortable to ride with strangers. In contrast to using public transportation or even shared mobility services, they are more likely to own a car and are only moderately open to trying new services.

Discussion

In this section, the key findings of the study have been discussed. Public Transport and Intermediate Public Transport Users comprise either younger or very old users with lower educational qualification and belonging to low-income households. They have less experience using smartphones and show less dependence on app usage for transport needs. These users are susceptible to the cost of travel which makes them captive to their choice of transport, and they are not willing to make different mobility choices unless they are technologically accessible to them and are cheaper than the existing system of their choice. Thus, their choices are not based on other concerns like comfort, cleanliness, privacy, or environmental friendliness. The *Multimodal Traveller* cluster includes respondents who choose to travel with various transport modes depending upon their requirements. It primarily comprises highly educated younger users belonging to medium and high-income households. They have extensive experience with the use of smartphones and show very high dependence on app usage for their transport needs. They often compare different travel options

available to them, including the combination of modes for their trips and are even willing to try new mobility choices. Even though they are slightly uncomfortable with the prospect of riding with strangers and the cleanliness of public transport is a concern to them, they acknowledge that the use of public transport is essential for preserving the environment and are very open to the idea of shared mobility where they can get the convenience of a private vehicle without the need to own them. For users in this group, the cost is also not a big issue. The *Private Vehicle User* cluster includes respondents dependent on private modes of transport. It comprises medium- to old-age users primarily belonging to medium- and high-income households. They have moderate experience with using smartphones and show medium dependence on app usage depending on specific purposes. Although, the users in this group somewhat acknowledge the importance of public transport for improving the environment, they are less inclined to try new mobility options compared to multimodal users due to their high degree of discomfort in riding with strangers. Instead, they are more inclined towards owning a vehicle and moderately willing to try new services compared to public transport.

Conclusion

The transport sector is primarily fossil fuel-driven and responsible for environmental externalities, including greenhouse gases. Policymakers are considering a wide range of measures, including technological developments and policy measures, low-carbon mobility, and technologies that play an essential role in this process, mainly through the application of ICT in the sector. Smartphone applications or “apps” represent such innovation and have helped create an ecosystem of smartphone-based mobility services. However, the market for smartphones and their applications is still developing, and it is unclear how they will affect everyday mobility patterns of users in the future with these continuous changes and improvements. Examining the relationship between smartphone app usage and frequency of use of transport systems can thus provide insight into the potential impact of smartphone app usage on people's mobility preferences.

In this context, latent class analysis has been used to probabilistically classify smartphone users into three traveller groups (or clusters) in the National Capital Territory of Delhi, each characterised by similar usage whilst maximising heterogeneity between groups. It has been observed that respondents categorised in cluster 1 show a very high reliance on public transport and intermediate public transport, very low reliance on private vehicles, and no use of taxis/app-based taxis. On the other hand, those classified in cluster 2 show a significant dependence on all modes of transport. Finally, cluster 3 respondents show a greater reliance on private vehicles. From the analysis of app usage patterns for trip planning activities and other

travel-impacting purposes, it can be concluded that users with lower app dependency have high probability of getting classified in cluster 1 as PT and IPT users. Users with higher app dependency have high probability of getting classified in cluster 2 as multimodal travellers, and those with moderate app dependency are most likely to be classified in cluster 3 as private vehicle users.

In addition to depicting the three latent class clusters of travellers, an attempt has been made to analyse the mentioned covariates as factors which affect the probabilities of individuals to belong to these clusters, especially for the multimodal users with high app usage. It can be observed that male and female respondents are relatively less likely to be classified as multimodal travellers than PT and IPT users. Younger respondents are more likely to be classified as multimodal travellers and less likely to be classified as private vehicle users. In addition, respondents with higher education are highly likely to be classified as multimodal travellers. Smartphone usage experience is a major contributor to app usage, and users with more than five years of smartphone usage experience are very likely to be classified as multimodal users. Respondents who belong to households with children under 18 are slightly more likely to be classified as multimodal travellers. The respondents who earn INR 20,000 to INR 50,000 have a great chance of being classified as multimodal travellers. Among the families with a high income, those who belong to households with income between INR 50,000 and INR 100,000 have a slightly higher possibility of being classified as a user of private vehicles than the multimodal traveller. It is interesting, however, that there is a considerably high possibility that the respondents belonging to households who earn more than INR 100,000 monthly to be classified as multimodal travellers. The ownership of four-wheeled or two-wheeled vehicles ensures that they have a high possibility of being classified as a user of private vehicles and a strong possibility of being classified as a multimodal user too. Multimodal travellers compare travel options, choose the mode of transport per their travel needs and are willing to try new travel methods. As per the responses, these users are pro-environment, feel a little uncomfortable riding with strangers and are most likely to reduce car dependence if a cheaper alternative is provided, preferably something that can provide the convenience of a private transport modes like cars and bikes without owning one.

For PT and IPT Users, it becomes imperative for policymakers to ensure that the traditional forms of public transport and IPT are not compromised while introducing a smartphone-oriented mobility ecosystem, and the new systems must be integrated around the existing transit options as an additional choice for the users. Given incentives, coupled with increasing familiarity with smartphones and cost-saving alternatives, these users may even be willing to shift to the newer travel platforms. The multimodal users can become early adopters and significant users of the new smartphone-based mobility platform while reducing the private vehicle use for other

modes. Also, given their attitudes towards traditional transport, we can expect them to (slightly) reduce the usage of public transport by shifting to app-based on-demand services. Focusing on practical benefits which services similar to MaaS offer, awareness campaigns can help this group shift away from private transport while also avoiding substantial departures from the usage of public transport based on the environmental sensitivity. Inducing a behavioural shift is very difficult with Private vehicle Users. Previous research suggests that new mobility options for these users should be promoted as an alternative only in the absence of a private transport rather than a complete replacement of vehicles (Paundra et al., 2017).

These innovative transportation platforms and policies are also important because they link into Goal 11 for Sustainable Development Goals - “*Make cities inclusive, safe, resilient and sustainable*”, as decrease in air pollution from transport sector allows for a better quality of life along with sustainable growth of the urban centres and its residents. Also, in accordance with the Paris Agreement’s objective of limiting the rise of average global temperature to well below two degrees Celsius from 2005 levels, the intended decrease in emission from transport sector as a result of implementing the app-based mobility platforms also contribute towards the Goal 13 of Sustainable Development Goals - “*Climate Action*”, which encourages limiting the impacts of climate change by decreasing greenhouse gas emissions.

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Parking Spaces viz-a-viz Healthcare Facilities in Jalandhar City

Nagarlok
55(3), 83-103
July-September, 2023
@ 2023 IIPA

DOI: <https://doi.org/10.32381/NL.2023.55.03.6>

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Abstract

The purpose of this article is to study and analyse the problems caused by excessive number of healthcare facilities in Jalandhar City. Jalandhar City is the city with maximum number of healthcare facilities in Asia. A sample is selected from the large set of hospitals in the city with the help of stratified random sampling technique. The field surveys are undertaken around the sample set of hospitals to understand the ground situation. Optimum number of parking spaces are not provided for the visitors by the hospital authorities and it has also been observed that a significant number of healthcare facilities do not have adequate parking spaces as per the parking norms mentioned in respective guidelines and bylaws. Encroachments by vehicles of visitors are visible on roads and also on the private properties of residents around the healthcare facilities.

Keywords

Healthcare facilities, Clustering of facilities, Parking facility, Encroachment.

Background

Healthcare facilities are constituents of social infrastructure which is necessary for cities to enhance social well-being. Availability and accessibility to quality social infrastructure determine the standard of living in a city. Healthcare facilities in a city can be classified into two broad categories, i.e. Public healthcare and Private healthcare facilities. Public healthcare facilities depict the accessibility of healthcare facilities by all in the city including the non-privileged and below poverty line section of society (Anchour and Price, 2010). The neo-liberal policy introduced in the year 1991 in India made a very significant change in the healthcare system of the country

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on account of their emphasis on free-market rather than the right to health. People are disadvantaged by such reforms, due to their increased healthcare needs and lower socio-economic status (Sakellariou and Rotarou, 2017). The free-market capitalism impacted healthcare in the purview of the sudden increase in the number of healthcare facilities in the urban areas.

Introduction to Jalandhar City

Jalandhar is a city in the state of Punjab and is well-connected to the rest of the parts of the country through railways, airways and roadways as it lies along the Grand Trunk Road. Its name was translated as Jullundur during British Raj in India. In 1852, the municipal committee was founded for the city which is considered as one of the oldest municipal committees in the state of Punjab. In the year 1870, the first rail link was established for the city connecting it to Beas. Later in the year 1947, after the partition of the country, Jalandhar city was made the temporary capital of the united Punjab. The Municipal Committee of the city was raised to Class I in the year 1950. In the year 1952, first civil hospital in the city was established for the betterment of the increased population because of the influx of migrants. The population of the city increased and hence in the year 1977, the municipal committee of the city was elevated to Municipal Corporation (Singh, 1986).

Between the 1980s and 1990s the population of the city further grew due to industrialisation and liberalisation. The city provided more employment opportunities due to growth of sports and pharmaceutical industry. This further led to migration of rural people into the city and hence the population of city grew exponentially. The inflow of rural population into the city also became one of the causes for the urban sprawl around the city. Due to increasing urban sprawl around the city, the Local Planning Area, Jalandhar was constituted in the year 2007 to achieve integrated development. In the same year, work under various sub-schemes such as Integrated Housing and Slum Development Programme (IHSDP) and Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) of Jawaharlal Nehru National Urban Renewal Mission (JNNURM) initiated for better development of the city (Jalandhar Master Plan Report, 2009). In the year 2009, Master Plan was prepared and for increasing issues related to traffic and transportation in the city comprehensive mobility plan for the city was prepared in the year 2012. Later in 2015, Jalandhar city was identified for AMRUT Scheme and Smart Cities Mission.

Scenario of Healthcare Facilities in the City

Punjab is a state in northern India and covers an area of 503 square kilometres. Jalandhar is the third most populated city in the state of Punjab. It is spread over an area of 100.6 square kilometers with a population of 8.62 lakhs as per the Census 2011.

With a total of 534 private healthcare facilities in the city, Jalandhar is the city with the highest number of healthcare facilities in Asia. Jalandhar City is located in the centre of the state as per its physical layout. The regional setting of the city enhances its ability to serve adjoining rural areas and other two-tier and three-tier cities that fall behind in the provision of healthcare facilities to their residents. People from the servable area tend to take a round trip of the city in a day for availing healthcare facilities (Detailed Project Report, 2018). Excellent connectivity of Jalandhar to all other parts of the state of Punjab through roads and railways also acts as a boon for the users to access the city.

According to the Master Plans reports of various cities of Punjab such as Ludhiana, Amritsar, Patiala, Bathinda, and Jalandhar, a maximum number of healthcare facilities are available in Jalandhar City. Jalandhar City had 396 healthcare facilities in the year 2010. The city has 234 hospitals, 29 dispensaries, 12 veterinary hospitals, 38 nursing homes, and 231 clinics (Figure 1). The maximum number of healthcare facilities such as hospitals, clinics, and nursing homes are privately owned (Jalandhar Master Plan Report, 2009). The purpose of this research is to study and analyse the problems created by the excessive number of healthcare facilities in the City.

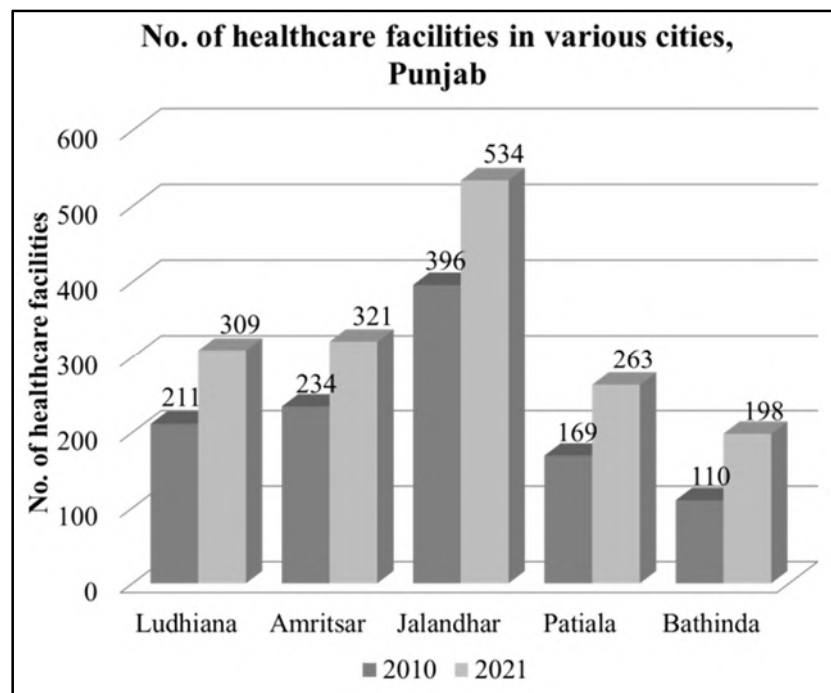


Figure 1: Healthcare facilities in cities of Punjab

Source: Master Plan Ludhiana, Amritsar, Jalandhar, Patiala, Bathinda

Sampling

Sampling is the process of selecting a few objects from a larger number of objects, i.e. a sample is capable of becoming a basis for prediction for an unknown piece of information regarding the study to be undertaken. A sample is a subgroup of the population that has to be considered for the research (Lissack, 1998). Sampling enables making estimation about the real situation regarding the collective group. The accuracy of the results depends on the selection of samples from the total population which has to be studied.

There are 224 hospitals in Jalandhar. Hence, a sample of 24 hospitals is selected to carry out the study in an unbiased manner. The sample size is 10 per cent of the total number of hospitals in the city. Ten per cent condition expresses that sample sizes ought to be close to 10 per cent of the populace in consideration to the research constraints (Glen, 2013). There are certain parameters used for the sampling mentioned below:

- (a) *Number of beds in the hospital*: Number of beds in the hospital will be directly proportional to the area of the hospital plot and also will determine the hierarchy of the hospital. Out of the total 224 hospitals in the city, 122 hospitals are up to 80 beds, 97 hospitals are between 80 to 200 beds and five hospitals are 200 to 500 beds (Table 1).
- (b) *Hierarchy of roads*: As any built-up impacts the surrounding areas, hence this parameter has been selected which is related to the location of the hospital (Table 1).

Table 1: Number of existing and sample set of hospitals

	Existing Hospitals			Hospitals selected as a sample for study		
	Sub-arterial road	Arterial road	Highway	Sub-arterial road	Arterial road	Highway
Upto 80 beds	53 hospitals	42 hospitals	27 hospitals	5 hospitals	4 hospitals	3 hospitals
80-200 beds	24 hospitals	39 hospitals	34 hospitals	2 hospitals	4 hospitals	3 hospitals
200-500 beds	1 hospital	1 hospital	3 hospitals	1 hospital	1 hospital	1 hospital

Source: Field Survey.

The sample size has been finalised and several hospitals have undertaken a sample concerning the two parameters which are the “number of beds in the hospitals” and the “hierarchy of road on which the hospital lies” has been identified by proportionate stratified sampling technique (Table 2). The following sample has been selected for the study:

Table 2: Sample set for the study

Sr. No.	Name of the Hospital	Number of Beds	Hierarchy of Road	Area of Plot (sq.yd.)	Year of Establishment
Hospitals with up to 80 beds					
1.	<i>Sikka Hospital</i>	80 beds	<i>Sub-arterial</i>	900	1984
2.	<i>Sachar Hospital</i>	50 beds	<i>Sub-arterial</i>	1680	1990
3.	<i>Orthonova Hospital</i>	60 beds	<i>Sub-arterial</i>	500	1997
4.	<i>DMC Hospital</i>	70 beds	<i>Sub-arterial</i>	500	2000
5.	<i>Bowry Hospital</i>	50 beds	<i>Sub-arterial</i>	400	2001
6.	<i>Satyam Hospital</i>	80 beds	<i>Arterial</i>	1000	2000
7.	<i>Apex Hospital</i>	50 beds	<i>Arterial</i>	1800	1967
8.	<i>Mannat IVF Hospital</i>	40 beds	<i>Arterial</i>	950	2009
9.	<i>Vedanta Hospital</i>	80 beds	<i>Arterial</i>	650	2014
10.	<i>Jammu Hospital</i>	80 beds	<i>Highway</i>	1200	2004
11.	<i>Sigma Hospital</i>	60 beds	<i>Highway</i>	630	2005
12.	<i>Dada Hospital</i>	80 beds	<i>Highway</i>	2200	2012
Hospitals with 80-200 beds					
13.	<i>Doaba Hospital</i>	110 beds	<i>Sub-arterial</i>	1600	1988
14.	<i>Joshi Hospital</i>	120 beds	<i>Sub-arterial</i>	1800	1991
15.	<i>Tagore Hospital</i>	140 beds	<i>Arterial</i>	4000	1979
16.	<i>SGL Hospital</i>	190 beds	<i>Arterial</i>	4000	1995
17.	<i>Genesis Hospital</i>	200 beds	<i>Arterial</i>	2600	2012
18.	<i>Cardionova Hospital</i>	90 beds	<i>Arterial</i>	1200	2015
19.	<i>NHS Hospital</i>	125 beds	<i>Arterial</i>	4500	2017
20.	<i>Sacred Heart Hospital</i>	90 beds	<i>Highway</i>	4000	1985
21.	<i>Johal Hospital</i>	150 beds	<i>Highway</i>	3500	1999
Hospitals with 200-500 beds					
22.	<i>Patel Hospital</i>	250 beds	<i>Sub-arterial</i>	20000	1976
23.	<i>Guru Nanak Mission Hospital</i>	275 beds	<i>Arterial</i>	50000	1981
24.	<i>Capitol Hospital</i>	300 beds	<i>Highway</i>	28000	2016

Source: Field Survey.

Analysis of Data Collected

Parking is a phenomenon which becomes a serious issue if its on the street, as it hampers the smooth operation of the street. It is an effect of transport advancement. The accessibility of less space in metropolitan areas has given rise to the demand of parking spots. Parking has some evil impacts like clogs, mishaps, contamination, checks for putting out fires tasks, and so forth. Parking consumes the road space and hence limits the speed of traffic (Vianna, Silva, and Balassiano, 2004). The vehicles not only cause contamination to the climate while halting and but also influence the tasteful magnificence of the structures. Parked vehicles may hinder the movement of fire-fighting vehicles. Now and then they block admittance to hydrants and admittance to structures (Simićević, Vukanović, and Milosavljević, 2013).

Table 3: Evaluation of parking facilities in peak hours

Sr. No.	Name of Hospital	Area (sq.yd.)	Built up area (sq.yd.)	Required parking ECS	No. of Bays	Gap in parking ECS	Time Interval (min)	Initial Count	In	Out	Accumulation	Parking Index (%)	Parking load (vehicle minutes)
1	Sikka Hospital	900	1430	18	6	12	30	10	8	9	9	150.0	270
2	Sachar Hospital	1680	2910	37	40	Surplus by 3	30	43	9	31	21	52.5	630
3	Orthanova Hospital	500	1440	18	7	11	30	12	4	5	11	157.1	330
4	DMC Hospital	500	760	10	4	6	30	7	4	5	6	150.0	180
5	Bowry Hospital	400	870	11	4	7	30	9	7	6	10	250.0	300
6	Satyam Hospital	1000	3150	40	9	31	30	16	6	8	14	155.6	420
7	Apex Hospital	1800	4860	61	12	49	30	18	7	4	29	241.7	870
8	Mannat IVF Hospital	950	2190	28	37	Surplus by 9	30	48	15	39	24	64.9	720
9	Vedanta Hospital	650	2040	27	20	7	30	24	17	15	28	140.0	840
10	Jainnu Hospital	1200	4000	50	56	Surplus by 6	30	62	12	41	33	58.9	990
11	Sigma Hospital	1000	2160	27	14	13	30	21	9	11	19	135.7	570
12	Dada Hospital	1800	4200	53	9	44	30	12	4	5	11	122.2	330
13	Dojba Hospital	1600	4590	57	7	50	30	11	5	5	11	157.1	330
14	Joshi Hospital	1800	8600	108	120	Surplus by 12	30	149	13	28	134	111.7	4020
15	Tagore Hospital	4000	13080	163	175	Surplus by 12	30	201	19	69	151	86.3	4530
16	SGL Hospital	4000	13600	170	195	Surplus by 15	30	213	21	30	-	104.6	6120
17	Genesis Hospital	2600	3800	47	60	Surplus by 13	30	72	16	50	38	63.3	1140
18	Cardionova Hospital	1200	3800	48	55	Surplus by 7	30	69	8	48	29	52.7	870
19	NHS Hospital	4500	9750	121	130	Surplus by 9	30	158	12	68	102	78.5	3060
20	Sacred Heart Hospital	4000	10350	129	75	54	30	89	9	40	58	77.3	1740
21	Johal Hospital	3500	10640	133	59	74	30	71	17	33	55	93.2	1650
22	Patel Hospital	20000	29400	367	375	Surplus by 8	30	416	36	44	381	101.6	11430
23	GNM Hospital	50000	20930	261	18	243	30	23	11	7	35	194.4	1050
24	Capitol Hospital	28000	24040	300	318	Surplus by 18	30	337	28	63	302	95.0	9060

Source: Field Survey.

Table 4: Evaluation of parking facilities in Non-peak hours

Sr. No.	Name of Hospital	Area (sq. yd.)	Built up area (sq. yd.)	Required parking (E.C.S.)	No. of Bays	Gap in parking (E.C.S.)	Time Interval (min)	Initial Count	In	Out	Accumulation	Parking index (%)	Parking load (vehicle minutes)
1	Sikka Hospital	900	1430	18	6	12	30	6	2	6	2	33.3	60
2	Sachar Hospital	1680	2910	37	40	Surplus by 3	30	13	5	10	8	20.0	240
3	Orthonova Hospital	500	1440	18	7	11	30	7	2	4	5	71.4	150
4	DMC Hospital	500	760	10	4	6	30	3	1	2	2	50.0	60
5	Bowry Hospital	400	870	11	4	7	30	4	3	4	3	75.0	90
6	Satyam Hospital	1000	3150	40	9	31	30	8	5	6	7	77.8	210
7	Apex Hospital	1800	4860	61	12	49	30	6	4	4	6	50.0	180
8	Mannat IVF Hospital	950	2190	28	37	Surplus by 9	30	12	8	11	9	24.3	270
9	Vedanta Hospital	650	2040	27	20	7	30	10	15	18	7	35.0	210
10	Jammu Hospital	1200	4000	50	56	Surplus by 6	30	22	9	20	11	19.6	330
11	Sigma Hospital	1000	2160	27	14	13	30	9	7	11	5	35.7	150
12	Dada Hospital	1800	4200	53	9	44	30	5	3	4	4	44.4	120
13	Doaba Hospital	1600	4590	57	7	50	30	3	3	1	5	71.4	150
14	Joishi Hospital	1800	8600	108	120	Surplus by 12	30	42	14	5	51	42.5	1530
15	Tagore Hospital	4000	13080	163	175	Surplus by 12	30	49	21	27	43	24.6	1290
16	SGL Hospital	4000	13600	170	195	Surplus by 15	30	71	18	28	61	31.3	1830
17	Genesis Hospital	2600	3800	47	60	Surplus by 13	30	27	7	23	11	18.3	330
18	Cardionova Hospital	1200	3800	48	55	Surplus by 7	30	18	5	17	6	10.9	180
19	NHS Hospital	4500	9750	121	130	Surplus by 9	30	27	6	1	32	24.6	960
20	Sacred Heart Hospital	4000	10350	129	75	54	30	37	9	27	19	25.3	570
21	Johal Hospital	3500	10640	133	59	74	30	29	11	23	17	28.8	510
22	Patel Hospital	20000	29400	367	375	Surplus by 8	30	103	18	13	108	28.8	3240
23	GNM Hospital	50000	20930	261	18	243	30	7	5	5	7	38.9	210
24	Capitol Hospital	28000	24040	300	318	Surplus by 18	30	81	18	21	78	24.5	2340

Source: Field Survey.

In order to understand the ground situation related to parking, evaluation of the parking facilities made available by the private hospitals has been selected as a sample for the present study during peak and non-peak hours (Tables 3 and 4). Field survey has also been carried out through the in-out survey technique to collect the relevant data. Also, the evaluation is conducted on the basis of parking norms mentioned in the Punjab building bylaws 2018. As per the Punjab building bylaws 2018, parking area has to be provided @ 1.00 Equivalent Car Space (ECS) for every 80 sq. yds. of built up/covered area on all floors.

Out of total 24 hospitals, 11 hospitals, i.e. Sachar hospital, Mannat IVF hospital, Jammu hospital, Joshi hospital, Tagore hospital, SGL hospital, Civil hospital, Cardionova hospital, NHS hospital, Patel hospital and Capitol hospital have surplus parking facility when compared with the norms. Thirteen hospitals, i.e. Sikka hospital, Cardionova hospital, DMC hospital, Bowry hospital, Satyam hospital, Apex hospital, Vedanta hospital, Sigma hospital, Dada hospital, Doaba hospital, Sacred Heart hospital, Johal hospital and Guru Nanak Mission hospital have deficient parking facility. From the above information, it can be concluded that 54 per cent of the total hospitals have deficient parking facility and 46 per cent of the hospitals have sufficient parking facility available. Parking index of the hospital parkings has been worked out on the basis of field survey. As per the survey for peak hours, 58 per cent of the total hospitals have over-utilized parking facility, i.e. the parking index is more than 100 per cent and 42 per cent of the total hospitals have under-utilised parking facility.

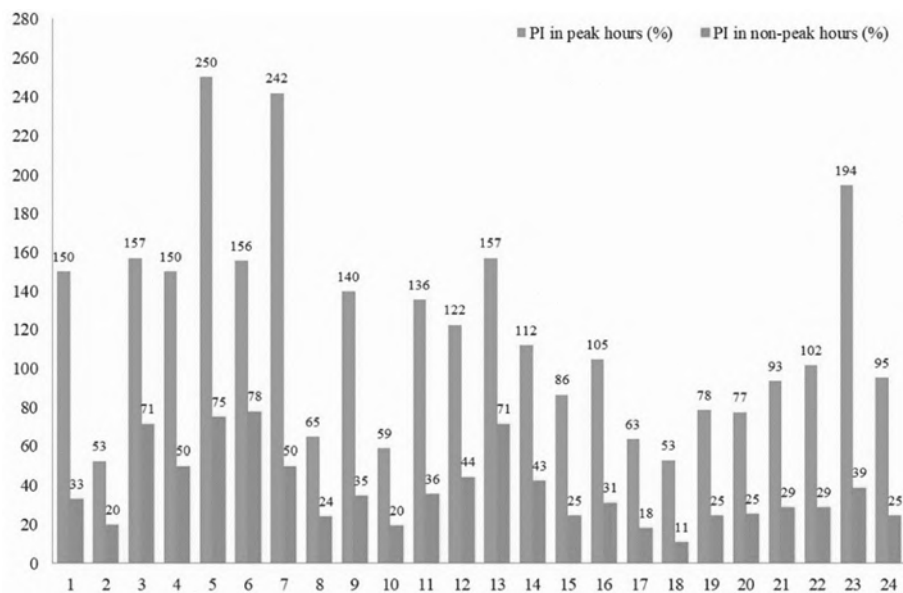


Figure 2: Parking index of hospitals in peak and non-peak hours

Source: Field Survey.

In case of non-peak hours, the parking index of respective parking facilities is relatively lesser in comparison with the parking index of these facilities in peak hours. Parking facilities in these hospitals in non-peak hours is on an average 32 per cent of the parking index in peak hours.

Sikka Hospital: The area of plot is 900 sq. yards and has a built up area of 1430 sq. yds. The required parking as per the norms is worked out to be 18 ECS and the parking facility made available by the hospital is six ECS. The gap in parking is observed to be 12 ECS. Parking load on the site at the peak time is 270 vehicle minutes and hence the parking index comes out to be 150 per cent. The analysis and accumulation curve is derived through the in-out survey of parking (Table 5 and Figure 3).

Table 5: In-Out survey of parking facility at Sikka Hospital (peak hour)

Initial Count (no. of vehicles)	Time duration (min)	Time interval (min)	In (no. of vehicles)	Out (no. of vehicles)	Accumulation (no. of vehicles)
10	30	0-5 mins	10	8	12
		5-10 mins	9	7	14
		10-15 mins	7	12	9
		15-20 mins	6	7	8
		20-25 mins	5	5	8
		25-30 mins	9	13	4
		Average	8	9	9

Source: Field Survey.

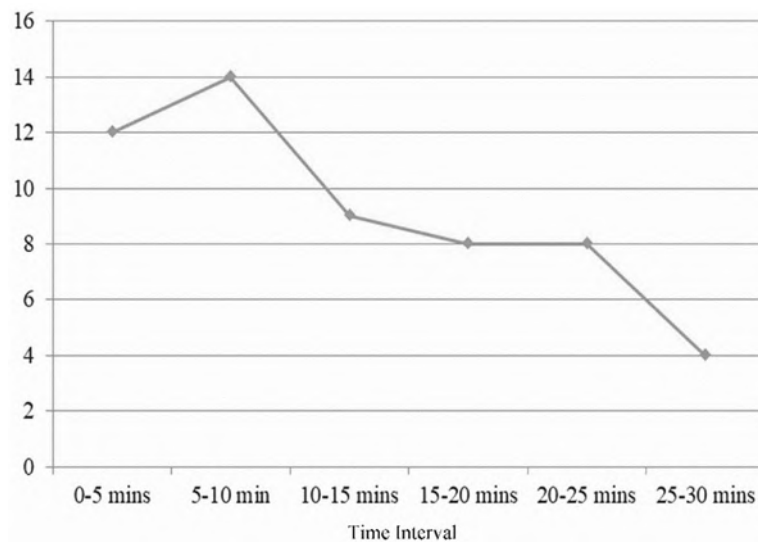


Figure 3: Accumulation curve for parking facility at Vedanta Hospital (peak hour)

Source: Calculated data.

Vedanta Hospital: The area of plot is 640 sq. yards having built up area of 2050 sq. yds. The required parking as per the norms is worked out to be 27 ECS and the parking facility made available by the hospital is only 20 ECS. The gap in parking is observed to be seven E.C.S. Parking load on the site at the peak time is 840 vehicle minutes and hence the parking index comes out to be 140 per cent. The analysis and accumulation curve is derived through the In-Out survey of parking (Table 6 and Figure 4).

Table 6: In-Out survey of parking facility at Vedanta Hospital (peak hour)

Initial Count (no. of vehicles)	Time duration (min)	Time interval (min)	In (no. of vehicles)	Out (no. of vehicles)	Accumulation (no. of vehicles)
24	30	0-5 mins	18	16	26
		5-10 mins	15	19	22
		10-15 mins	19	14	27
		15-20 mins	17	13	31
		20-25 mins	14	16	29
		25-30 mins	16	11	34
		Average	17	15	28

Source: Field Survey.

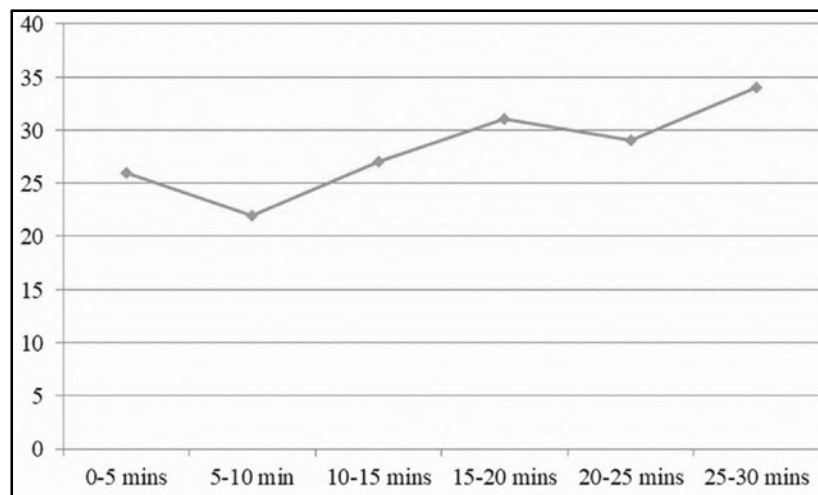


Figure 4: Accumulation curve for parking facility at Vedanta Hospital (peak hour)

Source: Calculated data.

Apex Hospital: The area of plot is 1800 sq. yards having built up area of 4860 sq. yds. The required parking as per the norms is worked out to be 61 ECS and the parking facility made available by the hospital is only 12 ECS. The gap in parking is observed to be 49 ECS. Parking load on the site at the peak time is 870 vehicle minutes and

hence the parking index comes out to be 242 per cent. The analysis and accumulation curve is derived through the in-out survey of parking (Table 7 and Figure 5).

Table 7: In-Out survey of parking facility at Apex Hospital (peak hour)

Initial Count (no. of vehicles)	Time duration (min)	Time interval (min)	In (no. of vehicles)	Out (no. of vehicles)	Accumulation (no. of vehicles)
18	30	0-5 mins	5	3	20
		5-10 mins	7	2	25
		10-15 mins	9	5	29
		15-20 mins	8	7	30
		20-25 mins	4	2	32
		25-30 mins	9	5	36
		Average	7	4	29

Source: Field Survey.

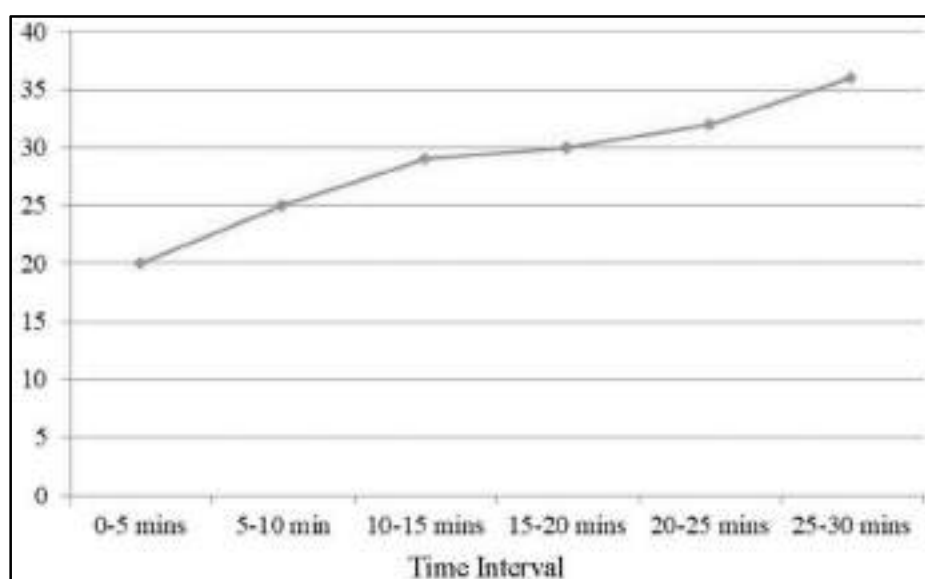


Figure 5: Accumulation curve for parking facility at Apex Hospital (peak hour)

Source: Calculated data

Patel Hospital: The area of plot is 20,000 sq. yards having built up area of 29,400 sq. yds. The required parking as per the norms is worked out to be 367 ECS and the parking facility made available by the hospital is 375 E.C.S Figure 6. The parking is observed to be surplus of eight ECS Parking load on the site at the peak time is 11,430 vehicle minutes and hence the parking index comes out to be 102 per cent. The analysis and accumulation curve is derived through the in-out survey of parking Table 8 and Figure 7.



Figure 6: Parking at Patel hospital

Source: Field Survey

Table 8: In-Out survey of parking facility at Patel Hospital (peak hour)

Initial Count (no. of vehicles)	Time duration (min)	Time interval (min)	In (no. of vehicles)	Out (no. of vehicles)	Accumulation (no. of vehicles)
416	30	0-5 mins	30	42	404
		5-10 mins	29	50	383
		10-15 mins	41	47	377
		15-20 mins	34	37	374
		20-25 mins	39	37	376
		25-30 mins	44	49	371
		Average	36	44	381

Source: Field Survey.

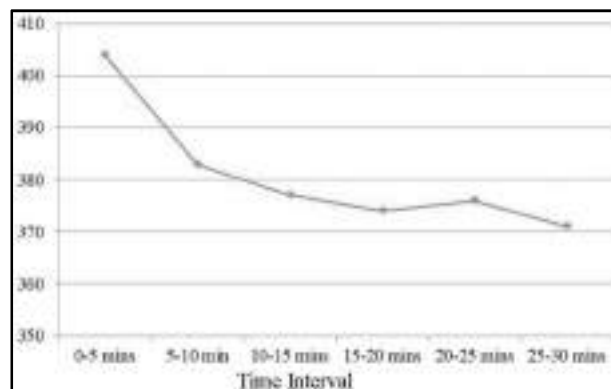


Figure 7: Accumulation curve for parking facility at Patel Hospital (peak hour)

Source: Calculated data.



Figure 8: Parking at GNM hospital

Source: Field Survey

Guru Nanak Mission Hospital: The area of plot is 50,000 sq. yards having built up area of 20,930 sq. yds. The required parking as per norms is worked out to be 261 ECS. and the parking facility made available by the hospital is 18 ECS. Deficiency in parking is observed to be 243 ECS (Figure 8). Parking load on the site at the peak time is 1,050 vehicle minutes and hence the parking index comes out to be 194 per cent. The analysis and accumulation curve is derived through the in-out survey of parking (Table 9 and Figure 9).

Table 9: In-Out survey of parking facility at Guru Nanak Mission Hospital (peak hour)

Initial Count (no. of vehicles)	Time duration (min)	Time interval (min)	In (no. of vehicles)	Out (no. of vehicles)	Accumulation (no. of vehicles)
23	30	0-5 mins	9	8	24
		5-10 mins	15	7	32
		10-15 mins	6	6	32
		15-20 mins	9	9	32
		20-25 mins	13	4	41
		25-30 mins	14	8	47
		Average	11	7	35

Source: Field Survey

In context of this study, the meaning of encroachment is taken as an infringement of the vehicles on the private properties of the residents and on the road carriage way. Encroachment further causes many adverse impacts on the surroundings. One such impact is reduction in road's carrying capacity. The capacity is defined in terms of traffic volume. The reduction in road's carrying capacity due to encroachments further raises many issues like traffic bottlenecks on the road leading to congestion and slow movement of the traffic. The rise in pollution is another matter of concern due to encroachments of vehicles (Francis, Spooner and Matthews, 2015). The formula used for working out the reduction in road carrying capacity is:

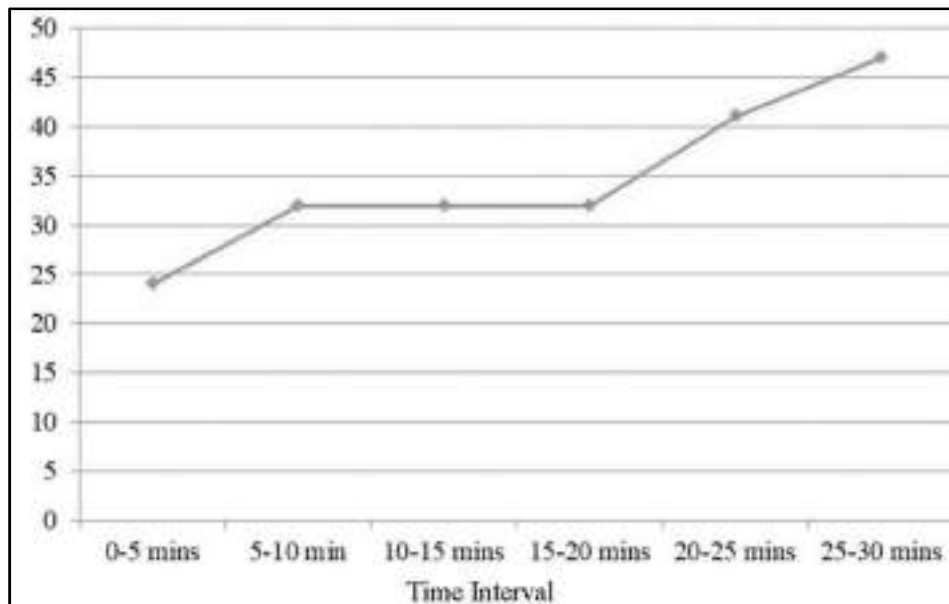


Figure 9: Accumulation curve for parking facility at Patel Hospital (peak hour).

Source: Calculated data.

Percentage reduction in road carrying capacity =

$$\frac{\text{Width of Road Encroached}}{\text{Existing Width of Access Road}} \times 100$$

The encroachment on the streets and roads adjoining the hospitals has been evaluated based on the formula for percentage reduction in road carrying capacity (Table 10). This is done on the basis of field survey carried out for the study. The reduction in road carrying capacity is calculated on the basis of number of bays encroached by parking of vehicles and the width of road that is encroached.

Table 10: Reduction in road carrying capacity due to encroachment

Sr. No.	Name of Hospital	Existing Width of Access Road	No. of bays encroached by parking	Width of road encroached	Length of road encroached	Percentage Reduction in Road Carrying Capacity
1.	Sikka Hospital	24'	1	8'	105'	33.3
2.	Sachar Hospital	80'	—	—	—	—
3.	Orthonova Hospital	60'	1	8'	150'	13.3
4.	DMC Hospital	24'	1	8'	80'	33.3
5.	Bowry Hospital	24'	1	8'	120'	33.3
6.	Satyam Hospital	60'	2	16'	180'	26.6
7.	Apex Hospital	52'	2	16'	210'	30.7
8.	Mannat IVF Hospital	26'	—	—	—	—
9.	Vedanta Hospital	80'	2	16'	260'	20
10.	Jammu Hospital	52'	—	—	—	—
11.	Sigma Hospital	70'	1	8'	190'	11.4
12.	Dada Hospital	160'	1	8'	240'	5
13.	Doolba Hospital	48'	1	8'	140'	16.6
14.	Joshi Hospital	56'	2	16'	210'	28.5
15.	Tagore Hospital	60'	—	—	—	—

16.	SGL Hospital	34'	1	8'	200'	23.5
17.	Genetis Hospital	40'	—	—	—	—
18.	Cardionova Hospital	46'	—	—	—	—
19.	NHS Hospital	52'	—	—	—	—
20.	Johal Hospital	60'	1	8'	160'	13.3
21.	Patel Hospital	20'	1	8'	172'	40
22.	Sacred Heart Hospital	42'	—	—	—	—
23.	Guru Nanak Mission Hospital	60'	2	16'	190'	39
24.	Capital Hospital	82'	—	—	—	—

Source: Field Survey.

Clearly, reduction in road's vehicle carrying capacity is seen as a result of lack of parking spaces provided by the hospitals. Out of total the 24 hospitals, nine hospitals, i.e. Sachar hospital, Mannat IVF hospital, Jammu hospital, Tagore hospital, Genesis hospital, Cardionova hospital, NHS hospital, Sacred heart hospital, and Capitol hospital do not show any encroachments around them. 15 hospitals, i.e. Sikka hospital, Orthonova hospital, DMC hospital, Bowry hospital, Satyam hospital, Apex hospital, Vedanta hospital, Sigma hospital, Dada hospital, Doaba hospital, Joshi hospital, SGL hospital, Guru Nanak Mission hospital and Johal hospital show encroachments around them which in turn reduce the carrying capacity of road. Fifty eight per cent of the total hospitals in the city show encroachment around them and 42 per cent of the hospitals in the city do not show any encroachment around due to sufficient parking facility available with the hospitals.



Figure 10: Encroachment around GNM hospital

Source: Field Survey

Guru Nanak Mission Hospital: The road is encroached by the vehicles as the hospital does not have enough parking spaces. The congestion around the hospital can be seen in the Figure 10.

Orthonova Hospital: One aisle is encroached by the vehicles around the hospital as there is a lack of parking space in the hospital premises. This further causes congestion on the road and bothers the users.

Bowry Hospital: One aisle is encroached by the vehicles around the hospital as there is a lack of parking space in the hospital. Encroachment can be seen in Figure 11. This encroachment around the hospitals causes congestion and deteriorates the quality of life of the residents.



Figure 11: Encroachment around Bowry hospital.

Source: Field Survey.

Major Findings

Major findings have been mentioned in context of the facts, causes and implications. The facts are supported with numbers and percentages derived through various field surveys. In other words, implications are the conclusions which are drawn out of the facts and causes.

The 54 per cent of the total hospitals, i.e. 13 hospitals are observed to be deficient in parking facilities. 58 per cent of the total hospitals, i.e. 14 hospitals experience over-utilised parking facilities. Out of total 24 hospitals, 14 hospitals are observed to have over-utilised parking facility with a parking index more than 100 per cent and 10 hospitals are characterised with having under-utilised parking facility, i.e. the parking index is less than 100 per cent. 58 per cent of the total hospitals have over-utilised parking facility and 42 per cent of the total hospitals have under-utilised parking facility. The lack of on-ground vigilance by the civic bodies is one of the reasons that the hospital authorities do not provide enough parking which is supposed to be provided as per the norms. Deficient parking space causes over-utilisation of the existing parking space. Over utilisation of parking spaces and lack of provision of parking space by the hospital causes the vehicles to be parked on the streets. On streets, parking becomes an issue for the residents and users in the surrounding areas. Reduction in road carrying capacity around the hospitals is resulted because of encroachments. The encroachments around the private hospitals have been studied and analysed. Deficient parking space provided by the hospital causes on-street parking by the visitors. Encroachment is also caused by the over-utilisation of parking spaces available for visitors. Encroachments are a result of deficient parking spaces. Deficiency in the number of parking spaces is the responsibility of hospitals as the hospitals failed to provide the required number of parking spaces.

Conclusion and Recommendations

The parking spaces made available are not sufficient as per the norms and even if the parking spaces are made available as per the norms, the existing parking is overburdened and hence leads to encroachment on the roads abutting the healthcare facilities and private spaces around. This proves that the norms which are considered by the authorities for provision of parking spaces in the healthcare facilities are not enough to cater to the needs of the visitors. Existing norm for provision of parking by healthcare facilities is: 1.00 ECS for every 80 sq. yds. of built up/covered area on all floors.

Preventive Measures: In consideration to parking load and encroachments on the roads observed in the field survey, the requirements have been calculated and recommended guidelines of 1.75 ECS for every 80 sq. yds. of built up/covered area on all floors shall be proposed (Table 11).

Table 11: Proposed revised ECS

Sl. No.	Name of Hospital	Plot area (sq. yd.)	Built up area (sq. yd.)	Required parking (E.C.S.) (as per norms)	Parking available (E.C.S.)	Gap in parking (E.C.S.)	Accumulation	Revised ECS
1	Sikka Hospital	900	1430	18	6	12	9	0.80
2	Sachar Hospital	1680	2910	37	40	Surplus by 3	21	1.00
3	Orthanova Hospital	500	1440	18	7	11	11	1.76
4	DMC Hospital	500	760	10	4	6	6	0.96
5	Bowry Hospital	400	870	11	4	7	10	2.00
6	Satyam Hospital	1000	3150	40	9	31	14	1.12
7	Apex Hospital	1800	4860	61	12	49	29	1.29
8	Mannat IVF Hospital	950	2190	28	37	Surplus by 9	24	2.02
9	Vedanta Hospital	650	2040	27	20	7	28	3.45
10	Jammu Hospital	1200	4000	50	56	Surplus by 6	33	2.20
11	Sigma Hospital	1000	2160	27	14	13	19	1.52
12	Dada Hospital	1800	4200	53	9	44	11	0.49
13	Doaba Hospital	1600	4590	57	7	50	11	0.55
14	Joshi Hospital	1800	8600	108	120	Surplus by 12	134	5.96
15	Tagore Hospital	4000	13080	163	175	Surplus by 12	151	3.02
16	SGL Hospital	4000	13600	170	195	Surplus by 15	204	4.08
17	Genesis Hospital	2600	3800	47	60	Surplus by 13	38	1.17

18	Cardionova Hospital	1200	3800	48	55	Surplus by 7	29	1.93
19	NHS Hospital	4500	9750	121	130	Surplus by 9	102	1.81
20	Sacred Heart Hospital	4000	10350	129	75	54	58	1.16
21	Johal Hospital	3500	10640	133	59	74	55	1.26
22	Patel Hospital	20000	29400	367	375	Surplus by 8	381	1.52
23	GNM Hospital	50000	20930	261	18	243	35	0.06
24	Capitol Hospital	28000	24040	300	318	Surplus by 18	302	0.86
	Average Revised ECS							1.75

Source: Calculated data

Curative Measures: The hospitals in which parking facility is not enough, undertaking from the respective hospital authorities will be taken that within three years the parking spaces in close vicinity would be created to fulfill the parking requirements failing then the hospital will be sealed by the authorities.

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Performance Evaluation of the Management of Community Dogs in Himachal Pradesh: A Case Study

Nagarloak
55(3), 104-116
July-September, 2023
© 2023 IIPA
DOI: <https://doi.org/10.32381/NL.2023.55.03.7>

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Abstract

Street dogs live in proximity with humans, and therefore, have frequent interactions with them. The rising population of these community dogs and their interaction with humans has increased the various risks to the society and themselves as well. There are about 62 million community dogs in India wandering on the roads. Apart from their existence and dignified right to life, their interaction with humans has resulted in danger of getting several tropical diseases like rabies. In India, there are about 20,000 rabies cases of total 59,000 world cases which account about 36 per cent of the total world cases of rabies due to which Asia is also known as rabies capital. Against this backdrop, the management of community dogs has become pertinent in the present time. Therefore, to protect humans from any form of tropical diseases caused by these community dogs, it is pivotal to ensure compliance of policy framework and animal birth control rules formulated by the Government of India. The present study evaluates policy and its implementation by the local government in Himachal Pradesh, India.

Keywords

Local Governance, Stray Dogs, One Health, Rabies, SDGs.

Introduction

Every organism, be it human or other animals, has its own importance in the ecosystem. Animals on earth have been co-existing with humans since the very

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existence of humankind. Co-existence may be defined as a dynamic but sustainable outlook where humans and animals co-adapt to living in shared terrain and where human interactions with animals are managed by effective and efficient institutions that ensure long-term animal population continuance and social legitimacy (Carter and Linnell, 2016). The term “community” is generally associated with human beings living together in a particular area; but the animals also have their own community. The word community may be stated as organisms or animals living together which interact, and they can be of same species or not, as long as they live together in same place or region (Biology online, n.d.). The community animals having co-existed with humans included dogs, cattle, cats, etc. Specifically, dogs have the closest proximity with humans in the community. According to *The State of Pet Homelessness Index Report*, approximately 62 million community dogs live in India. In the same report, they state that the majority of India’s population comes across a community dog at least once a week (End Pet Homelessness, 2021). In Chandigarh, the administration of Chandigarh has stated that homeless dogs may not be called strays, instead, they should be called ‘community dogs’ (Malik, 2018).

Role of Local Authorities in Management of Community Dogs

Indian Constitution has enshrined some authority and responsibility to local bodies in order to deal with local issues at the village level as well as in the urban areas. According to 73rd and 74th Constitutional Amendment Acts, 1992, there are functions entrusted to these local authorities which are mentioned in 11th and 12th Schedule of the Indian Constitution. The 11th and 12th Schedules of Indian Constitution, have 29 matters and 18 functional items respectively. These mention the functions to be performed by the local authorities in rural and urban areas respectively. The 12th Schedule of Indian Constitution clearly mentioned that it must be the function of municipality to prevent cruelty to animals in urban areas (Constitution of India, 2021). Community dogs live in close proximity with humans, resulting in more interaction among them. Therefore, it becomes necessary, according to law, to manage these community animals in a humane manner. For that purpose, local authorities play a significant role in the management of community dogs in India. Therefore, the population control programmes of these community dogs must be executed in a just and humane manner keeping in view the provisions of the Constitution of India.

The media reports point out a quite large number of dog bite cases in Himachal Pradesh. As mentioned above, there are about 24,000 cases being reported in Himachal Pradesh every year and 150 alone in Shimla city every month, which is a major concern to human health (Chauhan, 2019). Therefore, there is an urgent need for the efficient and effective management of community dogs in Shimla.

Community Dogs Sterilisation

The Animal Welfare Board of India has framed rules and regulations for the population management of these community animals. For community dogs it has Animal Birth Control (Dogs) Rules, 2001. According to these rules and guidelines, the owner of pet dogs shall be responsible for the controlled breeding, immunisation, sterilisation and licensing in accordance with these rules. Street dogs shall be sterilised and immunised by participation of animal welfare organisations, private individuals and the local authority. There will be a committee constituted which shall be responsible for planning and management of dog control programme in accordance with these rules. The local authorities will be obliged for the management of the whole process from capturing community dogs to providing them with adequate shelter. The dogs shall be captured by using humane methods such as lassoing or soft-loop animal catchers such as those prescribed under the provisions of Prevention of Cruelty (Capture of Animals) Rules, 1979. Only one lot of dogs at a time shall be brought for sterilisation, immunisation at one dog kennel or dog pound and these dogs shall be from one locality. Two lots from different areas or localities shall not be mixed at the same dog pound or dog kennel. Female dogs found to be pregnant shall not undergo abortion (irrespective of stage of pregnancy) and sterilisation and should be released till they have litter [Animal Birth Control (Dogs) Rules, 2001].

Human-Animal Conflicts

Due to a large number of communities co-inhabiting, there are many serious conflicts among them. Human beings and animals also face many conflicting aspects in their daily lives which threaten their health and even lives. Health threats which are due to human-animal conflicts have been increasing over the last two decades, especially with human/dog interactions. The increased health threats to humans by animals are caused by various inter-related global aspects which are generally related to human behavior and environmental changes due to humans and animals' co-existence (WHO, 2011). Another important issue that we need to focus is garbage management and its relationship with stray animals' management because garbage dumps help in the breeding of stray dogs (Chandran and Azeez, 2016).

The free roaming homeless or community dogs cause problems to children and old people due to various factors. Along with this, these dogs are often carriers of various diseases including rabies as one of the most fatal diseases. Rabies is hundred per cent fatal and hundred per cent preventable disease. Thousands of people die from rabies every year (95 per cent of total occur in Africa and Asia). The disease causes around 59,000 deaths every year, of which 20,000 deaths are in India. This means that India alone accounts for more than one-third of the world's total deaths due to rabies (Radhakrishnan et al., 2020). Apart from rabies, humans are also exposed to pathogens

because of the poorly managed faeces of animals, specifically, in areas where animals live in close contact to humans, especially, community dogs (Gauthami et al. 2017). This then becomes a major concern in the management of community dogs (Mittal, 2019).

Keeping the health hazards in view, there are various measures taken by the local authorities to tackle the problem of diseases carried by community dogs. In the Indian context, the management of the community dogs in urban areas is the responsibility and function of urban local bodies. It is enshrined as a function of the municipality under the 12th Schedule of the Indian Constitution (Constitution of India, 2021). There are various Acts and Rules that the government has enacted in order to manage these community animals in an effective manner (Animal Welfare Board of India Acts and Rules) which include Animal Birth Control (Dogs) Rules, 2001. There are other Acts and Rules which are adopted by the states at their level in order to augment federal legislation with the objective of the management of community dogs. In Himachal Pradesh, there have been several measures initiated in order to manage the population of community dogs and mitigate the human animal conflict. Thus, the federal, state and municipal legislation regarding the management of community dogs aims at resolving conflict along with ensuring their rights for coexistence.

The population of community dogs has been increasing day-by-day and it is a primary concern to manage their population in a humane and scientific manner. There have been various problems caused by these community dogs including deadly disease rabies and on the other side the community dogs also face various kinds of cruelties which are caused by humans including road accidents, throwing stones, beating unnecessarily, etc. Sustainable Development Goal III has also specified the need for a good health and wellbeing which says for preventing society from deadly diseases including rabies (United Nations), which makes it more significant to conduct research on this problem. To get rid of these harms and problems, it is necessary to implement some effective measures.

However, the question arises whether these policies are effective. According to Saskia (2020), the present framework and laws at National and International levels have failed to yield fruitful results in resolving human animal conflicts. The present study aims to analyse and evaluate the policy framework adopted at local level, Himachal Pradesh, to mitigate human-animal conflict by implementing laws laid down by Animal Welfare Board of India. In particular, the present study aims to analyse and evaluate the performance management of Municipal Corporation Shimla in management of community dogs. This study is important to understand and evaluate the implementation of measures for the management of community dogs. Apart from the direct study of the application of policy, the study is quite significant for a systematic theorisation of animal rights vis-a-vis human-animal conflict.

Methodology

The Municipal Corporation Shimla was selected as the area of study since Shimla is a populated city which has about 24,000 community dogs. Further, Shimla is a focal area for the incidences of dog bites (Chauhan K, 2019). Certain areas within Shimla were identified as areas where there are a greater number of dog bite cases (e.g., Sanajauli, The Mall, Sabji Mandi, etc.).

Data was collected through both primary as well as secondary methods. The secondary data was collected from various publications, research papers pertaining to rabies in India, official records and the website of Shimla Municipal Corporation. They were chosen by searching keywords i.e., rabies, management of stray animals and local governments in India. To evaluate the process of management of community dogs, primary information was collected through interviews. An interview schedule was administered to the 10 officials of Municipal Corporation concerned directly with administration of policies regarding community dogs and 25 Animal Welfare members of organised groups (operating through social media platforms in Shimla). They were divided through stratified random sampling into two zones. In order to corroborate the findings, five focus group interviews (total of 32 respondents) were conducted. Focus groups consisted of five to eight participants from line officials of municipal services, local people, and resident welfare associations of most vulnerable areas in terms of dog bite victims over the three months from the areas that are prone to dog bites. The theme of focus groups remained on issues ranging from management of community dogs, awareness about the prevalent issue of increasing population and its solution. Data was analysed by using thematic content analysis and observation of responses being generated from different stakeholders. The focus groups were specifically taken to assess the perception of residents about the issues of stray dogs and their management.

Case Background

About Shimla

Shimla is the capital of Himachal Pradesh, a northern state of India. Shimla is a beautiful city covered with a forest area and has diverse vegetation. Table 1 presents a detailed demography of its inhabitants. The elected body of the Shimla Municipal Corporation has 39 councillors out of which 34 councillors are directly elected and 5 are nominated by the Government of Himachal Pradesh. The tenure of the corporation is five years. The elected councillors elect the Mayor and Deputy Mayor amongst themselves for a tenure of two and half years.

Table I. Demographic data of Shimla City- as per Census 2011

Shimla City	Total	Male	Female
City Population	169578	93152	76426
Literates	146062	81495	64567
Children (0-6)	13571	7179	6392
Average Literacy (%)	93.63	94.79	92.19

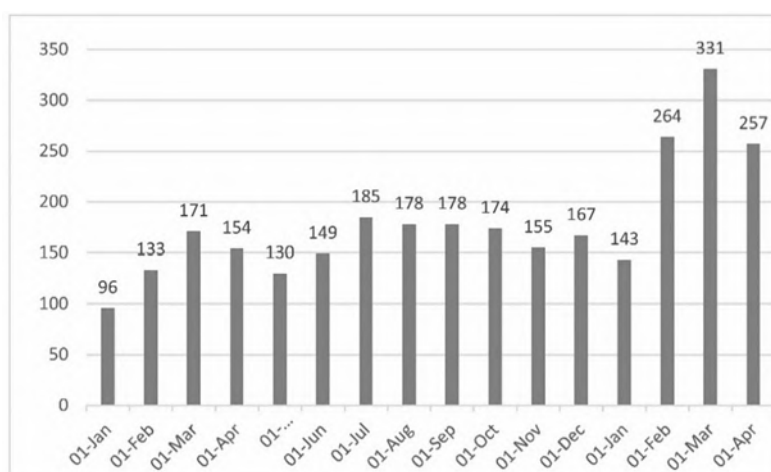
Source: Census 2011.

Along with the human population, the population of community dogs is also increasing rapidly. This is creating conflict among them. The rising population of dogs, causing overpopulation and has many problems associated with it. Due to overpopulation, there will be problems of habitation, food, hygiene, spread of diseases and many more. Therefore, in order to avoid these problems, the management of these community dogs should be seen as a priority for the local authorities.

Medical Facilities

The city of Shimla has two major medical hospitals which are Indira Gandhi Medical College (IGMC) and Deen Dayal Upadhyaya Zonal Hospital (formerly known as Ripon Hospital)). These two hospitals handle most of the cases of dog bites in Shimla city. These hospitals are located within the city and about a distance of five km from each other.

There are approximately 24,000 community dogs in the city of Shimla. Dog bite cases in Shimla were 1870 in 2021 and 1081 in the first four months of 2022. Thus, negative interactions between dogs and humans are a serious matter for the Municipal Corporation. The councillors of Shimla need to deal with the dog bite cases and the overpopulation of community dogs in a humane manner.

**Figure I.** Reported Dog Bites from January 2021 to April 2022

Source: Compiled from data collected from the Centre for Disease Control and Prevention (CDC), Shimla (2021).

Table 2. Dog Bite Cases by Category

Dog Bite Cases in Category-1	Dog Bite Cases in Category-3
4	20
23	81
24	132
5	66
4	20
15	116
9	111
30	104
24	86
33	99
28	105
Total = 199	Total = 940

Source: Compiled from data collected from CDC Centre, Shimla (2021).

Category-3 dog bites are more significant

There are three categories of dog bites, namely, category 1, 2 and 3. Category 1 has the minimum health effect as it involves only licking without exposure and category 2 has more health impact compared to category 1 as it involves scratches without bleeding or licks on broken skin. Category 3 bites are more dangerous as it involves a deep cut and bleeding. There are more bites in category 3 and this presents more health vulnerability to dog bite victims. The management of community dogs is seemingly being taken in a manner that seems to indicate a lack of knowledge, due to which dog bites cases are increasing. Moreover, there is no documented proof of category 2 bite with official records (Table 2).

Major Findings

The findings highlight several key aspects of how community dogs are managed in Shimla. The research uncovered nine major aspects of community dog management. These are summarised as follows:

Alarming Number of Dog Bites

Dog bites are directly proportional to the number of rabies cases. The more bites in any given sector will lead to an increase of rabies in that sector. According to statistics from the authorities, the number of dog bites in Shimla, specifically, in selected areas which include, The Mall, Sanjauli, area of Sabji Mandi (vegetable market), Bus stand, etc., are alarming and pose a significant health risk to inhabitants. These areas are

highly congested in terms of population density along with open vegetable markets and access to slaughter houses. Uncontrolled feeding on dead carcasses by community dogs and poor sanctions by Municipal Corporation Shimla, is another contributing factor to the rising community dog population and thus increasing the number of bites.

Poor Solid Waste Management Practices

Solid waste management is an important aspect in order to manage community dogs effectively. To ensure appropriate hygiene in living spaces, be it home, the streets or any other area, waste management is a key aspect. The waste management is one of the major functions of municipal administration, on which depends the prevention of diseases of various types. A primary reason for the increasing number of community dogs and their aggressive behaviour (bites) is the poor management of garbage. This creates the availability of food in open spaces, where these community dogs can breed and grow. Therefore, it can be seen that the rising number of community dogs is due to inadequate measures taken by the local authorities in waste management. Veterinarian officers opined that there is no coordination between different administrative departments. This indicates that important factors are not taken into account during the planning process of community dog population control.

Lack of Proper Planning and Policy Implementation

In order to make any policy work effectively, there is always an urgent need for its proper planning. However in the research findings, it was found that there are many loopholes in the functioning of the Shimla Municipal Corporation in managing community dogs. For example, there is no proper census of community dogs. There is a lack of staff and resources which makes it difficult to manage community dog population.

Apart from poor planning, findings show there is an absence of a scientific approach in tackling the rising population. There is no involvement of organised animal lovers in policy framework and its implementation. Yet the sterilisation of community dogs is the only way to tackle their increasing population. However, there is no proper framework to do this job efficiently and systematically in the current model utilised by the city. Based on the interviews with city officials, it was observed that street dogs are randomly picked up for sterilisation without gauging the ratio of high or low-density population between humans and dogs.

Failure of Sterilisation Project

A project named, Animal Birth Control/Anti Rabies of Stray Dogs in Shimla and the surrounding villages, was executed by the Stray Dogs Birth Control Society, Shimla Municipal Corporation. The main objective of this project was to make Shimla rabies

free. This project was started in 2006. The protocols of this project were: Catching, Transportation, Tranquilisation and General Anesthesia, Procedure, Post-operative care and Release. Several stray or abandoned dogs were sterilised which helped in the population control in some areas (Projects, 2006). The programme was abandoned in 2011 due to administrative reasons. This programme was discontinued in accordance with the notification of the Animal Welfare Board of India due to awaited approval of Ministry of Environment and Forest, New Delhi for the continuance of this programme. This delay led to failure in the objectives of the programme and as a result, the population of dogs increased drastically.

The officials of Shimla Municipal Corporation accepted that there is no definite approach being adopted for sterilising community dogs. Presently, the neutering programme is being carried out on a small level by the Shimla Municipal Corporation on a random basis. Although they have confirmed reports about a new draft of the policy pertaining to neutering is under consideration, they are awaiting approval from the state government.

Community Dog Adoption Policy in Shimla

In October 2019, the Shimla Municipal Corporation (SMC) initiated a stray dog adoption policy under which the people adopting community dogs in the city will get hundred percent concession on garbage collection charges along with free registration and vaccination of adopted dogs. Apart from these incentives, they will also get the convenience of free parking in the city (Chauhan, 2019). Up to the year 2022, more than 200 community dogs had already been adopted by residents of the city under the adoption policy (Stray Dogs., Shimla mc. Hp. Gov. In). The programme yielded fruitful results to some extent. However, critics have stated that the programme was ill-conceived and there was no mechanism devised to monitor the health and welfare of the adopted dogs. Officials of veterinary public health office stated that the attraction to adopt community dogs has failed due to half-hearted approach and lack of political will. Thus, one can state that no sustained campaign or effort is being carried out at the level of the Municipal Corporation for the adoption of stray dogs.

Defunct Functioning of SPCA

The population of dogs is on rise day-by-day in the city of Shimla and there are various organisations which work towards the management of community dogs. One of those organisations is the Society for Prevention of Cruelty to Animals (SPCA). Unfortunately, it is found to be non-functional in the city of Shimla. The Society for Prevention of Cruelty to Animals is a network of non-profit animal welfare organisations around the world which work towards the prevention of cruelty to animals. The fact that it is not functioning in Shimla is a significant downfall in this

case. If functioning, the SPCA could act as a monitoring agency in a functional mode so that while implementing the dog population control policies, cases of cruelty to animals could be sorted. On the basis of the research survey and a telephonic interview with the President of SPCA, it was found that they are operating without any infirmary and proper infrastructure. In this case, this is a significant policy failure of both the SPCA and the city. By establishing a stronger presence of the SPCA, it could be considered a pivotal agency in mitigating human-animal conflict and management of community dogs.

Lack of Infrastructure and Budgetary Provisions

Every programme in order to be implemented effectively, needs financial support and a great infrastructure. While interviewing a veterinary public health officer, it was found that there was a lack of resources and manpower which creates inefficiencies in the management of community dogs. Consequently, it led to the increase in the population of community dogs in various sectors of Shimla. There is no dedicated shelter and sterilisation Centre being operated by SMC. They are quite hopeful to resolve this dilemma in the proposed policy which is under consideration at the state level.

Lack of Awareness Among Masses

One of the important findings which surfaced during the focus group discussions is the lack of awareness among various stakeholders. For example, they are not even aware of the procedures in case of a dog bite. The Shimla Municipal Corporation has failed to generate and disseminate crucial information about sterilisation, dog bites and prevention. There is no proper public relations mechanism in Shimla city in regard to this. Although there are animal activists and dog lovers who are working in this direction, it has yielded no fruitful results. On the basis of interviews carried out with select animal lovers, it was found that they are carrying out campaigns on their own for the welfare of animals within the community.

Ineffective Grievance Redressal Mechanisms

Every problem needs a grievance redressal mechanism, which needs to be effective in its actions. The research findings showed that the grievance redressal mechanisms are not satisfactory and there is a lack of services regarding a grievance redressal system. In this backdrop, there is no special helpline number for an emergency in the case of dog bite which may be rabies. However, the vaccination is available in Deen Dayal Upadhyaya Hospital (Rippon) and Indira Gandhi Medical College (IGMC) but how many people know that? Dog bite victims at both hospitals stated that they approached several channels within the health system and various authorities before reaching out to these hospitals.

These nine aspects uncovered indicate serious issues in the management of community dogs and their interaction with humans.

Discussion and Conclusion

Research findings made it clear, that there are many loopholes in the management of community dogs in the city of Shimla. In order to make the city healthy and harmonious for all its inhabitants including animals, the local authorities should take some effective and integrated measures. There is a dire need for proper sensitisation of all stakeholders. There should be a proper and systematic understanding of dog ecology, reproductive cycles and census which will help the authorities to create a better plan to allocate adequate resources along with strict adherence to the protocol provided by the Animal Welfare Board of India (Gupta and Gupta, 2019). The municipality needs to provide more resources for an effective policy initiative towards reducing the number of stray dogs.

The increase in the community dog population is a concern for human health as it leads to dog bite cases, which further lead to incidences of rabies and other infectious diseases. The main area of breeding for community dogs is the garbage dumps and open feeding spaces. Therefore, local authorities should also work towards effective disposal of the garbage and follow optimum solid waste management practices in the city. There should be a dedicated and sustained campaign for the vaccination of stray dogs in a scientific manner along with involvement of resident welfare associations and organised groups of animal lovers. Further, a special helpline number should be made operational in the case of an emergency for a dog bite, so that the victim of a dog bite can get immediate assistance from the hospitals like first aid, counselling, and post-prophylaxis vaccination services. Municipal Corporations can also venture into a public/private partnership for tackling the issue of managing community dogs.

There need to be public relations campaigns in order to win the trust among every section of society. This is necessary to break the myths of rabies and coexistence with community dogs. The pivotal outcome of discussions with various stakeholders brought forth that there is a need to have continuous dialogue to expand the dominant notion of humans over non-human species. This echoes the beliefs of Chakrabarty (2009) and Sundberg (2014).

The failure of alliances in eradicating community dog populations in different regions are due to failed Animal Birth Control (ABC) programmes, the lack of effective policy, its implementation, and the lack of political will. There is a significant need to create a consortium among all stakeholders to investigate deeper into the issue.

The Constitution of India enshrined the authority and responsibility to local bodies to deal with the management of stray animals and the prevention of cruelty to animals

(Article 243 W). Dogs that live in close proximity to people results in complex interactions which is a crucial point in the impact intersectionality of dogs and human health. As India accounts for 36 per cent of total deaths due to rabies across globe, it makes it more pertinent to manage community dogs to promote a healthy community for people and animals and to do so in a humane manner. One of the rabies eradication agendas have driven the creation of international, cross-sectoral coalitions across public health, animal welfare and local government. In this backdrop, the present study evaluated the procedures of Animal Welfare Board of India being operationalised by Shimla Municipal Corporation pertaining to management of community dogs and found it lacking in effectiveness. Yet, it is given the power by the Indian Constitution to solve the issue from a grassroots level. The findings of the study indicates that although there are possible solutions there seems to be a stumbling block that prevents action. It is with this in mind; the present study argues that further in-depth analysis is required at a policy making-level to delve deeper into the issue and its long-term solutions.

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BOOK REVIEW

A to Z of Sustainable Development A.K. Jain, Bookwell
(www.bookwellindia.com) Delhi ISBN: 978-81-952900-1-7, Rs. 1995/, p. 326

Today, the issues of environmental pollution and climate are at the forefront. After 75 years of Independence, about half of the population still lives in unplanned areas and slums. The 2021 Niti Aayog report states that 65 per cent of 7938 cities and towns in India do not have a Master Plan. Still, we follow the colonial model of 20- year Master Plans, which do not address urgently to the impending urban issues of pollution, water and energy shortages, joblessness, climate change, transportation, utilities and pandemics. By 2030, India will be the most populated country, with over 1.5 billion inhabitants, over a sixth of world's population. India will have the world's largest workforce and the world's third largest economy. The ongoing process of urbanisation is vital for economic growth, as 70 per cent of new jobs will be created in cities, putting pressure on infrastructure and the environment. The cities in India are facing the challenges of pollution, water and energy shortages, jobs, transportation, and utilities. Climate change has become an imminent reality with a rise in global temperatures, changes in rainfall, floods, droughts and intense heat waves. The increasing emissions, heat, and fossil fuel usage for transportation and electricity are affecting the micro-climate and human health.

In 2015, the United Nations adopted the Sustainable Development Goals to make the world more liveable, green, pollution-free and resilient. According to A.K. Jain, the author, this transition can be synergised by partnerships and exchange of innovative technologies. India is at a unique position for cooperation at the global level and has been working on new initiatives in the urban sector for sustainable development, which include the following:

- SUNDAR India (Sustainable Urban Network for Dynamic and Resilient India)
- Net Zero Green Growth, Decarbonisation
- LiFE (Lifestyle for Environment) Mission
- Strategic partnership for the implementation of the Paris Agreement
- International Solar Alliance
- Establishing Climate Centre for Cities
- Institutionalisation of Capacities on Climate Change

- Sustainable, circular systems for solid waste management, including plastic waste and e-waste
- Enabling Gender-Responsive and Universal Urban Mobility
- India Urban Data Exchange, National Urban Learning Platform, Smart Code, National Urban Development Mission, GIS-based Property Records and Transaction
- Global initiative on disaster risk management
- *Saptrishi* Priorities for Green Growth
- Sustainable Procurement and Lifestyle Analysis
- PM Gati Shakti Master Plan for infrastructure projects.

The book highlights that the cornerstone of making a city resilient and low-carbon is to adopt a circular construction lifecycle approach. Optimum use of land and natural resources, lifestyle for environment and new partnerships are critical elements of a sustainable habitat, which connect the nature with the people. It entails an integrated approach towards the nature (climate, greens and low-carbon), the people (socio-economic, circular economy, culture, education, health, mobility, community participation) and fourth industrial revolution [(digital planning, smart, intelligent and interconnected processes, Supervisory Control and Data Acquisition (SCADA), blockchain, discreet optimisation, algorithm, Artificial Intelligence, big data, etc.)].

As urban transport contributes nearly two-thirds of the total suspended particulate matter and 18 per cent of carbon emissions, it is necessary to provide sustainable modes of transit run by alternative fuels, like electric batteries, green hydrogen, ethanol blended gasoline, etc. In existing Indian cities, the 15 minutes Paris model, can be adapted, which means a maximum 15 km distance by metro/trams, 8 to 10 km by bus/car/2 wheelers, 2 km by cycle and 1 km by walk. Existing roads need to be revamped and landscaped to enhance space for pedestrians, cyclists and public transit systems.

The heating, lighting, cooling, ventilation, and powering of buildings are responsible for approximately 40 per cent of the total energy use. A low carbon and green building aims to be resilient, sustainable and net zero. It is a synergy between various components such as energy, water, materials, wastes, land, indoor environment, etc. As buildings are the largest energy users, incorporating energy storage into them will increase the resilience of the total energy distribution network and enable widespread use of renewable energy.

In a dense built-up area, the hot air dome, i.e. heat island, affects the microclimate. The author suggests the preparation of a city-wide Heat Mitigation Plan and mandatory use of heat reflective and permeable materials for rooftops, pavements and roads,

insulated with white paint and cavity walls. Water fountains, vegetation and cross ventilation can also mitigate the urban heat.

Airshed planning, use of cooler and light shaded surfaces/materials are some other methods to reduce urban heat and air pollution. The use of prefabricated and recycled materials, including construction and demolition wastes in construction and repair of roads and buildings can help in reducing urban heat, air pollution and dust.

A city should be able to grow its own food and minimise its footprint. This is possible by vertical farms, rooftop and household agriculture and by using wastewater for irrigation.

To realise the theme of *Vasudhaiva Kutumbkam*—One Earth, One Family, One Future, it is necessary to make the human settlements inclusive, resilient and sustainable. A.K. Jain, the author, opines that we need to work on innovative and comprehensive measures to improve the built environment, livelihoods, urban governance and structural transformation propelling green growth, prosperity and equity. Success hinges upon adoption of development.

The book 'A to Z of Sustainable Development' by A.K. Jain in its 26 chapters covers critical aspects of carbon footprint, climate change, ecology, energy, green buildings, heritage, housing and slums, infrastructure services, natural resources, transport and water. The book with more than 110 visuals helps the readers to understand the ideas, principles and concepts of total sustainability.

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