Pedestrian Movement Tracking and Tracing in Public Space

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Abstract: Population increase in the Urban areas made crowd management a hot topic today. Pedestrian decision making and movement patterns are critical in a variety of application domains. Mass event planning, mass gathering, individual location planning, and public space planning need to know how actual pedestrian movement happens. For planning such areas, architects and planners are keen on understanding empirical data of the pedestrian movements, and it is important for planning and designing public spaces.

The paper discusses the investigation carried out in a workshop to capturing empirical data of pedestrian movements in public space in China. It addressed the outcome of tracking and tracing pedestrian movement in temple premises with traditional methods vs. available technology. Further, this is an attempt to discuss the pros and cons of current trends in technology of movement tracking and tracing and its implication towards Architecture, Urban Design, and Urban Planning.

KeyWords: Pedestrian movement, Public space, Tracking and tracing

Introduction

Public life and Public space

Good Architecture and Urban Planning ensure proper interaction between public life and public space (Jan Gehl, 2013). But it is often forgotten since it is easier to work with form and space where public life is temporary and difficult to describe. With the development of the technology of pedestrian movement tracking, it was no longer abended. The field developed every day, and the requirement of the movement details on-demand within the research field. Technological innovations such as big datasets, e.g., Global Positioning System(GPS) and Wi-Fi technology, contributed to the people's movement tracking and analysis (Hanzl and Ledwoń, 2017).

Agent-Based Modeling (ABM) and Cellular Automata(CA) have been using for predicting unforeseen situations of human movement. Hence, pedestrian movement-related empirical data used to understand the situation, built up the case, calibrate, and validate the same. Further, pedestrian tracking data used for understanding route selection mechanisms (Ray, 1982), design and planning pedestrian facilities, wayfinding techniques in public spaces (Gallay, 2010), and checking urban guidelines(Willisô, 2004). The pedestrian movement pattern adds another valuable dimension related to planning and designing. It was mostly researched in critical areas such as emergency evacuation, crowd planning, event planning, special space planning, and panic situation planning. Not only that, but many different fields are also interested in capturing real human movement for other purposes.

Whyte (2009) has studied the social life of small urban spaces and how space affects user behavior. Human movements are closely related to urban planning and ordered the spatial structure (Batty M, 2001). Gehl (2013) examines

the state art of the pedestrian movement in Urban Spaces. Further, he discusses several measures using observing and trace, mapping, photographs, test walk, and keeping a diary.

In this paper, researchers focused on capturing pedestrian movement patterns, understand collision negotiation, avoidance of route choices, grouping related differences, and route choices. The workshop was carried out to capture pedestrian movement in traditional public space and to find out Urban planning and designing aspects. Further, this is an attempt to critically review the traditional way of tracking pedestrian movement vs. the latest methods available.

Methodology

To understand the pedestrians movements in a particular location, understanding the pathways and its statistics are equally important. Due to the fast development of technology, there are many different ways of tracking and tracing pedestrian movements. Pros and cons of available technologies are discussed as the first part of the paper.

Through the review, available literature selected a method of Pedestrian Movement tracking for the project. Direct Observation, GPS tracking, and chosen video-based tracking for the project. Accordingly, collected data on the field, after collecting data, process the data for taking the output of human movement pathways.

The second part of the paper discussed about implementing the selected method in the field and compare the outcome with the traditional methods. Further, analysis of the process outcome also covered. Finally discussed the tracking of pedestrian movement and its implications towards the Urban planning and design.

Technologies of pedestrian tracking

Monitoring motion behavior of pedestrians known as tracking pedestrians and convert it to a line known as tracing of the movement. When tracking is done for a considerable time period, known as capturing trajectory data of the pedestrian. The counting of the pedestrian equally important for the project. But this research is focusing on tracking of pedestrian behavior. The data is using for calibrating pedestrian movement as a social force model (Helbing, D., Molnar, P. Schweitzer, 1994).

The pedestrian tracking methods are categorized into instructive and non-instructive approaches based on tracking. The instructive approach requires a pedestrian with tracking device. They are limited to the locations where managing devices are possible. However, Non-instructive approach is to use devices that are already used by the pedestrian (e.g., mobile phone) or without any individual devices; video cameras and visual monitoring methods are some of the examples commonly used.

In recent years a number of pedestrian tracking and counting technology have developed. But pedestrian tracking technology is not mature as pedestrian counting technologies. Further, the accuracy level of tracking technology is even lesser than the pedestrian counting technologies (Timmermans, 2009). In the laboratory environment, the accuracy level is less than 3 cm been achieved. But most of the tracking technology is not developed to deal with real-world situations.

The main objective of this section is to discuss different techniques for tracking and tracing pedestrian movements. The technology will be discussed under the main application of technology, limitation of the technology, and the accuracy and reliability of the technology.

Method Description Tracking /tracing Accuracy Constrain

Shadowing The oldest form of tracking manual Less spatial accuracy Output can be personal bias. Sample size is limited

Video-based tracking Detecting pedestrian movement through videos Tracking and tracing can be automated, but unknown accuracy level More accuracy level where video taken in bird eye view. Clarity of the object and people,

Horizontal laser scanners scanners fixed close to the floor level. Snapshot was taken every 10th second to be on 10 Hz frequency to be used special software The average deviation was amount to 3m the number of cameras and locations also matters in that case.

Passive Infrared based method Use typical temperature of the people in the environment. Passive infrared sensors have been used to detect and localize humans because of their simplicity and less privacy concerns to be used special software accuracy of 0.5 m was achieved by maximum overlap. Number of equipment matter for the

Intrusive localization methods Used to equip people with devices. Such as GPS, WLAN or Bluetooth, and smartphones. to be used special software Accuracy level depending on the equipment used. Laboratory conditions achieved 3cm with GPS. Unique for the equipment used.

Table 01: Pedestrian movement tracking method (Source: Author)

method	Description	Tracking /tracing	Accuracy	Constrain
Shadowing	The oldest form of tracking.	manual	Less spatial accuracy	Output can be personal bias. Sample size is limited
Video-based tracking	Detecting pedestrian movement through videos	Tracking and tracing can be automated, but unknown accuracy level	More accuracy level where video taken in bird eye view.	Clarity of the object and people,
Horizontal laser scanners	scanners fixed close to the floor level. Snapshot was taken every 10th second to be on 10 Hz frequency	to be used special software	The average deviation was amount to 3m	the number of cameras and locations also matters in that case.
Passive Infrared based method	Use typical temperature of the people in the environment. Passive infrared sensors have been used to detect and localize humans because of their simplicity and less privacy concerns	to be used special software	accuracy of 0.5 m was achieved by maximum overlap.	Number of equipment matter for the
Intrusive localization methods	Used to equip people with devices. Such as GPS, WLAN or Bluetooth, and	to be used special software	Accuracy level depending on the equipment used. Laboratory conditions achieved	Unique for the equipment used.

	smartphones.		3cm with GPS.	

selecting of technology for tracking and tracing the pedestrian movement

After studying available technology of pedestrian tracking, considering cost, time, and technological, selected methods for the project as traditional method (Shadowing), GPS method, and video tracking. Shadowing is important to capturing general understanding of the place. Compare to other methods in GPS method processing data is easy and has considerable accuracy level. In video method, output accuracy is more compare to other methods but processing data is complex due to the unknown accuracy level of tracing software.

Project

Project methodology

The traditional way of tracking pedestrian movement was carried out as the first step. Two significant methods were executed to tracking the pedestrian movement. There are direct human observations and questionnaires carried out with the pedestrian. Direct observation is done by two groups using two methods. They are observing from higher ground and by following the pedestrian.

Having compared the available techniques for tracking people's movement, GPS tracking and video tracking were selected as a new technological methods due to the accuracy level, time is taken, resources required, and the cost.

People were employed for GPS tracking. "GPS beacon" (data pusher type), which updating attitude and speed in every 10s interval used for the project. Further, the data extracted from the server of www.gps1314.com. The team members waited at the entrance, and after a short interview with the pedestrian, the GPS given to the pedestrian. Instructed the pedestrian to carry the GPS while they were

moving in the premises. Qualitative data regarding the journey and the respected pedestrian data were noted with the interview. Such as reason of the visit, pedestrian profile, time is taken(start time, end time), etc. Subsequently, the data processed using GIS software.

For the video, tracking, use MEVIC pro 2 drones in birds eye view in open space at the premises. The video camera set different timing of the day and different days of the week. Due to the cost and unknown accuracy level of the video processing software, the movement pattern was processed manually.

Selecting site

The project was carried out to tracking pedestrian data under limited site constrain and simple nature of the site. Thus the case selected where non-motorized environment, well-defined entry and exits, and where both open-air and indoor area available. Considering the factors, complexity, and controllable complexity the Longshan temple at Anhai China selected as the case for the project. The place built-in 1896 in Chin dynastic period.

Since it is a traditional place, user behaviour cannot predict easily. The place functions as believers place and also function as a tourist place. Since the nature of the place, four types of users recognized in the place.

Output of the methods and analysis

The output of Direct Observation

Figure 01 shows the output of direct observation. The team waited at the entrance, and the shadowing was done by following the pedestrians. Further, some of the team members
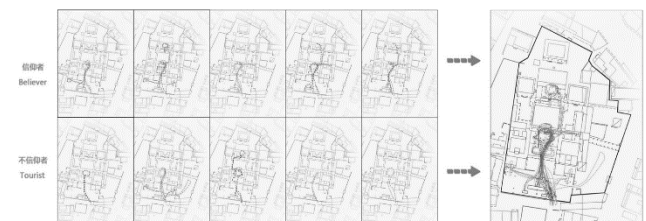
are observed from higher ground and tracking pedestrians. Since it is manually done, the accuracy level is in question. Also, it needs too many people for tracking. Hence it is expensive to carry out this method. This method is not suitable for crowded places since challenging to track when it is crowded.

Figure 01: Direct Observation

Source: Author

The output of video-based tracking

Figure 2 shows the output of video-based tracking. Setting a video camera is challenging for video tracking. The number of cameras depending on the area wanted to cover. Further, it will differ in open areas and covered areas too. The clarity of the video also depending on the hight that the camera sets and the condition of the ground. For the processing of the video, we can use the software. Due to the cost and unknown accuracy level, use manual processing used for the project. Hence it is difficult to trace for the crowd scenarios. Through the method complex task, the route trajectory of pedestrian movement is detailed compared to other methods. Here we used a drone technology that was limited to apply for open space. Accuracy level is more due to slow-motion video play and can play n number according to your need. Less time take, and less workforce compare to other methods. But need more skills to manage technical data related to the method.
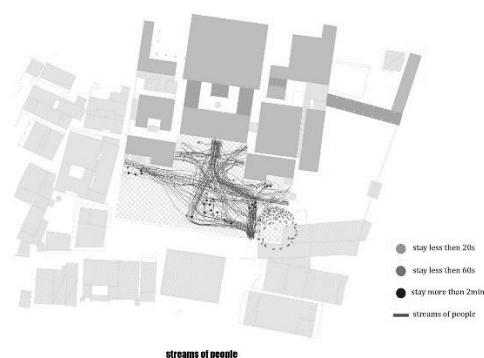

streams of people

Figure 02: Video output

Source: Author

The output of GPS tracking

Figure 03 a, b, c, and d shows GPS tracking output of Local beleivers pathways. The GPS device gives co-ordination every 10 Sec (Figure 03a). With the help of GIS create connect the pathway of the pedestrian (Figure 03b). Hence the movement pathway is not as smooth as human movement tracking. The device itself has an accuracy level as well as sometimes weather conditions also matter for the tracking. The data can easily process with GIS software.

With the intence of the pathways moderate pathways identified according to the users (Figure 03 C). Further heat maps generated with GIS (Figure 03 d).

The method is flexible to track people in an indoor and outdoor environment both. To maximize the number of output, and collect group movement, tracking needs more number of devices. From a questionnaire before the journey matter to categorized data according to the user category.

Conclusions

This field of research is emerging research and challenging with the new inventions in the field. The main objective of this project is to capturing pedestrian movement, tracing the same for Urban planning and designing. This research will act as the basement to many researches, not only Urban planning and designing but also for the many other fields. The traditional method of pedestrian tracking is compared with other means of monitoring, considering the cost, time, and availability of technologies. The tracking method output result cannot compare due to each method result will depending on time carried out on the project technology itself and the limitations of the methods. But the selected method gave a single form of output, which is

the line diagram of pedestrian movement pathways. Researchers in the strong contensious that the understanding of how space is working will improve the space experience and enhance the quality of space through planning and designing will be possible in the future.

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Geospatial based Land suitability assessment for waste dumping
A case study on Kesbewa DSD, Sri Lanka.

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Abstract: In the current context, waste dumping could be identified as the foremost and rising issue of Sri Lanka. Still, Sri Lanka has not followed a proper waste recycling system and as a result, the number of waste dumping sites was increased in nearby suburbs and those locations endangered to nature. Therefore, systematic waste disposal and scientific location selection for waste dumping is a national requirement.

This study investigated the waste dumping problem in the third high populated area in Colombo District, the Kesbewa Divisional Secretariat Division. The suitability of waste dumping of each land parcel was analyzed by utilizing both raster-based and vector-based approaches. Data were collected from Survey Department of Sri Lanka and open-source satellite data platforms. There are eight data layers manipulated over the study such as Building, Land use, Slope, Waterbody, Road, Reservation, and Population. Further, an investigation performed by using the Geographical Information Sciences (GIS) environment with the use of ArcGIS 10.5 software.

Finally, prepared the factor maps and identified the suitability of land parcels for waste dumping. Further, it has revealed that the existing Karadiyana waste disposal site only has 38% of suitability and not in suitable condition for waste dumping. In addition, it directly connected to the nearby Bolgoda river and emphasized as a major warning to human and environment in future. Consequently, in order to overcome that issue

identified three suitable locations for waste dumping by the study in the Kesbewa area.

Keywords: GIS, Karadiyana, Kesbewa, Waste dumping

Introduction

The Colombo District includes with 13 local authorities and has three final disposal sites (DS). Among the disposal sites, the Karadiyana DS is
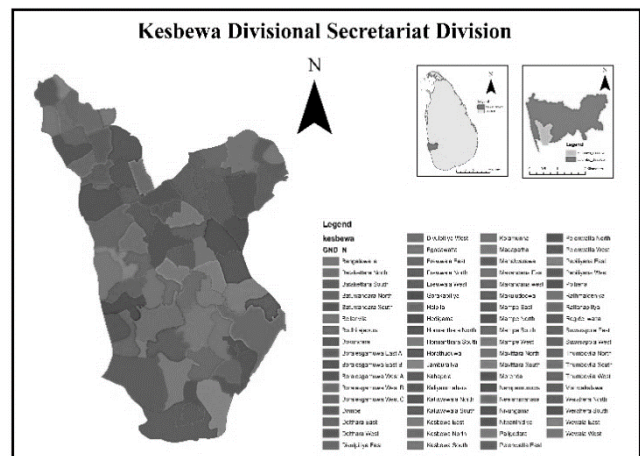
located in the very south of the district and receives waste from Moratuwa Municipal Council, Mount Lavinia – Dehiwala Municipal Council, Sri Jayawardanepura Kotte Municipal Council, Maharagama Urban Council, Panadura Urban Council, Kesbewa Urban Council and Boralegamuwa Urban Council ('Karadiyana Garbage Dump – Environment Foundation (Guarantee) Limited'). The disposal site is operated by the Waste Management Authority of the Western Province and the area of the DS is approximately 10.12ha ('Putrescible Waste

Landfills as Bird Habitats in Urban Cities: A case from an Urban Landfill in the Colombo District of Sri Lanka', 2019) .

Kesbewa Divisional Secretariat Division was the target area for this study. It is situated in the Western Province of Sri Lanka, Colombo District, bordering to Lake Bolgoda, and between Latitude 6°44' to 6°51' North and Longitude 79°54' to 79°58' South (Fernando, G. M. T., Sangasumana, V., & Edussuriya et al., 2015). The division's total land area is of 61.44 square kilometres, and the population is 245,232 (ABS, 2012). Kesbewa DSD is the 3rd highest populated DSD in Colombo district. Therefore, generate high waste loads daily. Garment and agricultural industries (rice and rubber plantation) are the main industries of Kesbewa DSD (Fernando, G. M. T., Sangasumana, V., & Edussuriya et al., 2015).

This study is select a suitable location in Kesbewa Divisional Secretariat Division (DSD) by using suitable criteria and analyse the suitability of the Karadiyana garbage dump in Kesbewa Divisional Secretariat Division.

The Kesbewa Urban Council function solid waste management and sewage treatment activities based on the section 118-120 of the Urban Council Ordinance No. 61 (1939) and the Public Nuisance Ordinance (1863) and they haven't formulated any master plan or action plan relevant to solid waste management yet (Kogyo Co, 2016).

Uncontrolled open dumping and improper waste management causes for various problems such as including contaminating ground and surface water, attracting insects and rodents, increasing
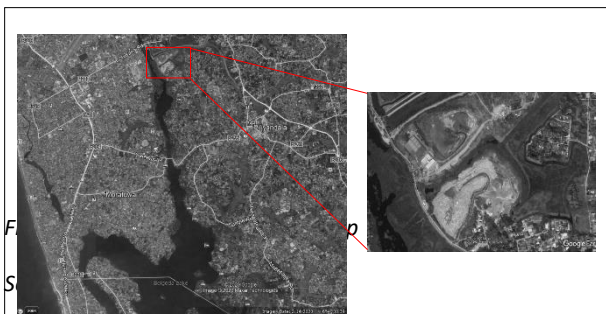
flooding due to blocked drainage canals or gullies and generation of toxic, and heavy rainy days residents have to face lot of difficulties due to the waste mixed water flow ('Karadiyana garbage dump becomes threat for area residents _ mirrorcitizen'). Landslide of The Meethotamulla garbage dump, lot of wastes are disposed here. All these problems directly effect on social, environmental sustainability of the ecosystems.

Geographic information system (GIS) is an efficient tool which can do several analyses. It efficiently stores, retrieves, analyses and display information according to our purpose. The software has an ability to manage large amount of spatial data from various sources and its saves time. The objective of this study is to select a suitable site using the GIS and assessment about the Karadiyana garbage dump.

Methodology and experimental design
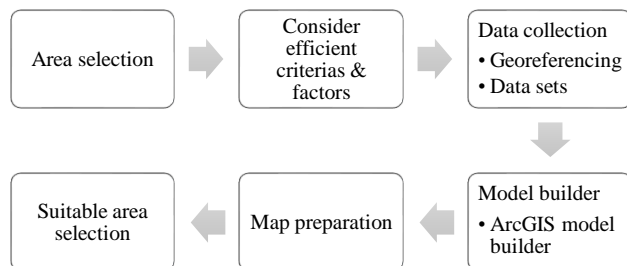
Six steps in the methodology which used to select

Figure 3. Methodology Flow

the suitable sites for waste dumping as seen in Figure 5. Firstly, identified the study area. After that consider suitable criteria and factors, and did Data Collection according to developed criteria and factors in this study area for map preparation. In here, used model builder for vector based analysing part by using ArcMap 10.5 licensed software and finally prepared factor maps through the GIS based model and find the suitable areas.

Efficient criteria and considering factors

In this analysis used eight map layers for the study. Building, Land use, natural, River, Road, Place, and Population. And used a DEM to consider the elevation. then want to gain what are the suitable areas. So, considered some factors to fulfil this case study.

Table 1. Criteria and references

Criteria	References
Building	('GIS application in locating suitable sites for solid waste landfills Jayawickrama, N. T. and Weerasinghe, V. P. A', no date)
Land use	(Balasooriya et al., 2014)
Waterbody	('GIS application in locating suitable sites for solid waste landfills Jayawickrama, N. T. and Weerasinghe, V. P. A', no date)
transportation	(Balasooriya et al., 2014)
slope	('GIS application in locating suitable sites for solid waste landfills Jayawickrama, N. T. and Weerasinghe, V. P. A', no date)
Population	(Balasooriya et al., 2014)
Reservation	('GIS application in locating suitable sites for solid waste landfills Jayawickrama, N. T. and Weerasinghe, V. P. A', no date)

Experimental Materials

GIS Software:

GIS Software can produce the graphic displays of geographic information for analysis and presentation. It also can store the geographical features and their characteristics. This software has the many kind of Benefits, such as, better information management, higher quality management, improve the project efficiency etc. in here, used ArcMap 10.5 licensed software.

Model Builder:

This tool allows to access the data stored inside a parent container, Such as fracture classes or tables inside a geodatabase

Results

In the analysing part, analysed those data with raster-based analysis.

In here, recognized what is the most suitable area for the waste dumping in Kesbewa Divisional Secretariat Division, after prepared the factor maps for each criterion.

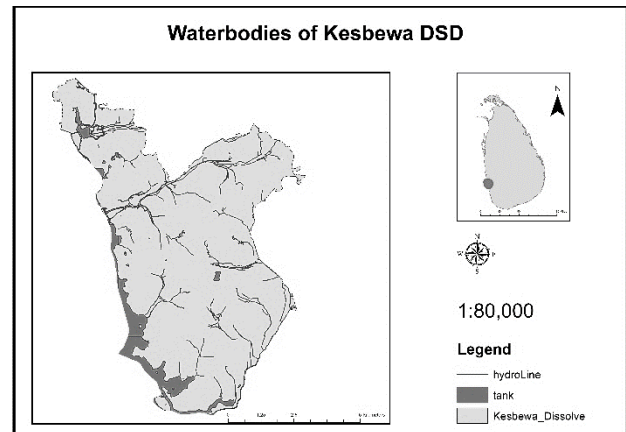Using ArcMap 10.5 licenced software and derived the maps

Figure 4. Waterbody Map of Kesbewa DSD

There are some waterbodies in the Kesbewa DSD and had to consider it. Specially, Bolgoda lake is in the Kesbewa DSD. If waste dumping is near for the waterbodies it will directly affect for the ground water coverage. And it will cause for the water pollution and in future, people will have to face some difficulties like lack of pure water.
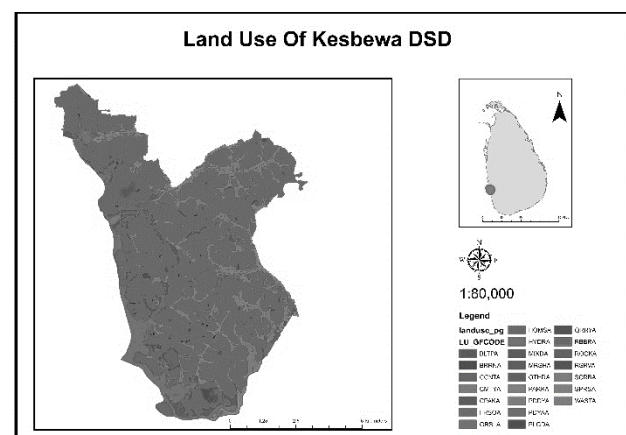

Figure 5. Land Use Map of Kesbewa DSD

People can't waste dumping in some locations like Cultivation area, Forest area, Boggy Area, Rock area, Built-up area, Sand area and water area. Normally suitable locations for waste dumping is
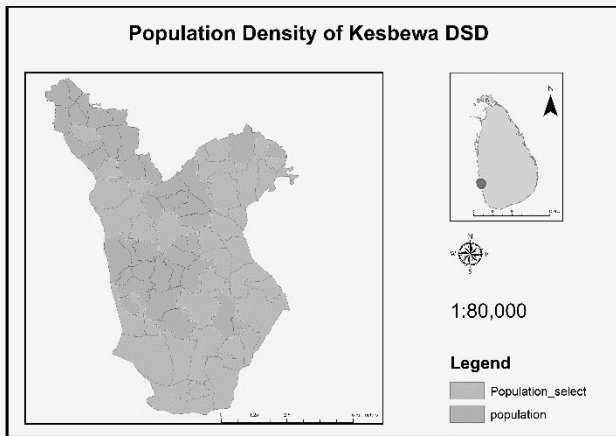

Figure 6. Population Density Map of Kesbewa DSD

Bare area. In here, consider Barren lands, Waste Land, Grassland, Scrub land.

Kesbewa DSD rank as the third highest population density in Colombo District(ABS, 2012). Population density of all GNDs in Kesbewa DSD is higher than 1000sqkm('Divisional Secretariat - Kesbewa - Statistical Information'). Minimum population density value is 1312.209961sqkm and the highest value is 22201.400391sqkm('Divisional Secretariat - Kesbewa - Statistical Information'). So, in here selected population density less than 4500sqkm areas for analysis.
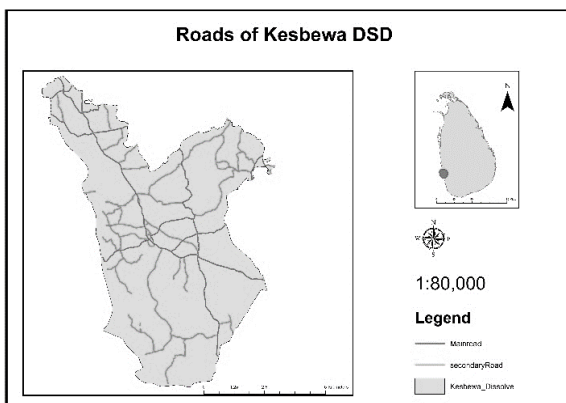
Figure 7. Road Map of Kesbewa DSD
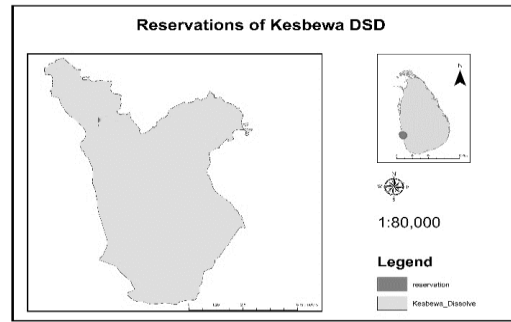
Figure 8. Reservation Map of Kesbewa DSD

Waste dumping site must locate with some distance from the road area. Because Kebewa is populous area. If the suitable location is far away from the transportation network, authority has to disburse more cost for solid waste collection and transportation.
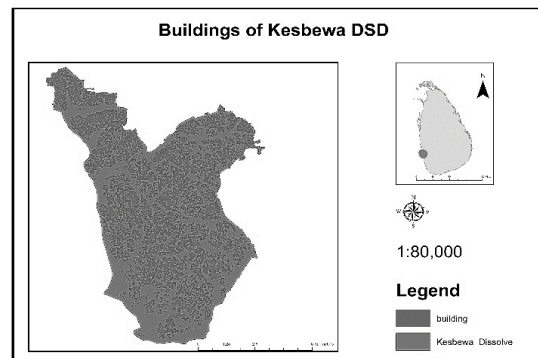

Figure 9. Building Map of Kesbewa DSD

Bellanwila – Attidiya sanctuary is the one of the reservations in Kesbewa DSD

There are lot of buildings in Kesbewa DSD due to the urbanization. But waste disposal site is not in a Build-up area.
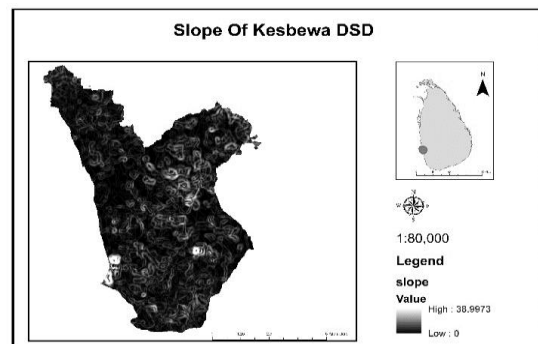

Figure 10. Slope Map of Kesbewa DSD

Normally, Kesbewa DSD is not in high altitude category. It is very close to sea level. This is very important for the waste dumping. If the slope is high, it is not suitable for waste dumping.
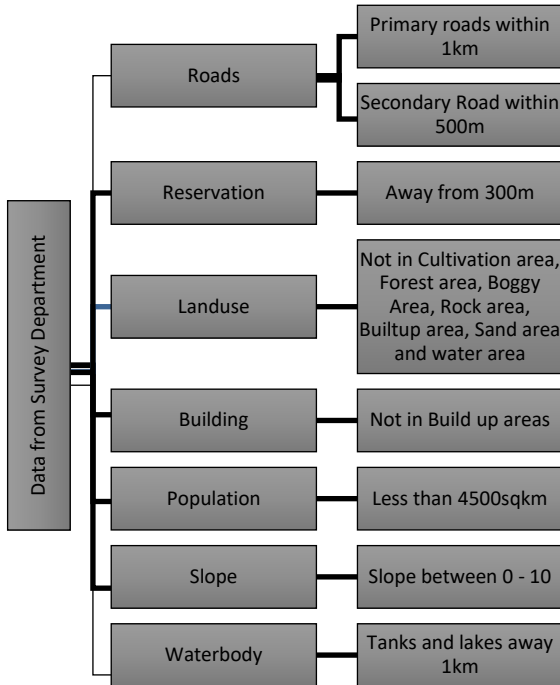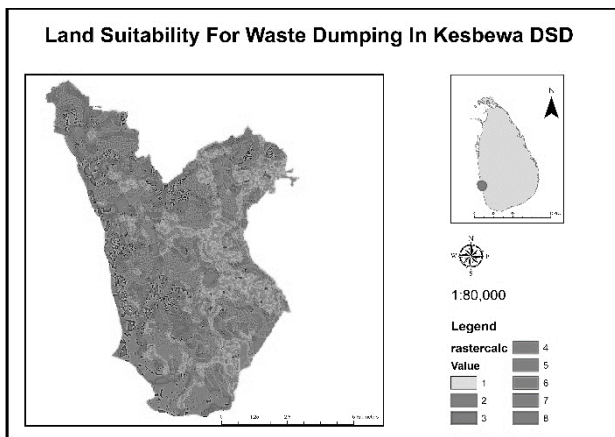

Figure 11. data processing

Figure 12. Suitable area for waste dumping

Finally, selected the suitable location intersecting the above criteria at last, by using a Raster format. The output represents with suitable areas and unsuitable areas. Land suitability is representing with a numbering system. E.g. Value No. 1 means only satisfy a one criteria and no.8 means satisfy the all criteria.

For easiness of the study again reclassify the data; the area which satisfy only five conditions as not suitable areas, the area which satisfy only six conditions as moderately suitable areas, the area which satisfy only seven conditions
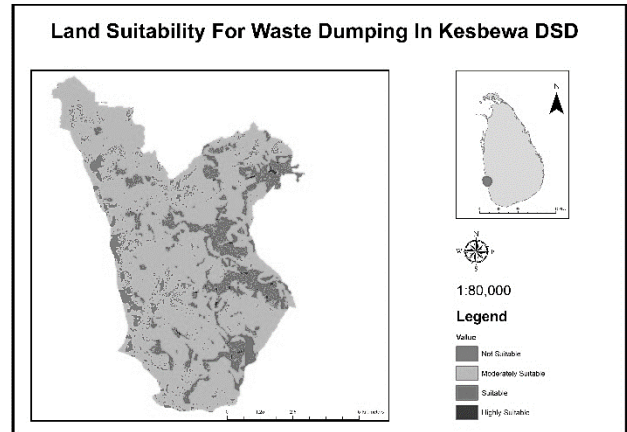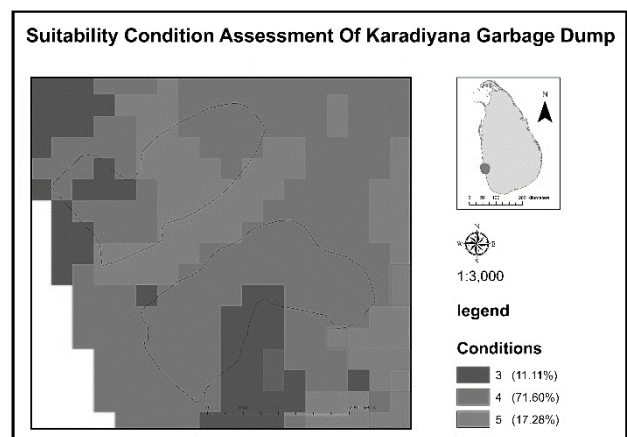

Figure 13. Reclassification of the suitable locations

as suitable areas and finally the area which satisfy all conditions as most suitable areas,

Finally, selected the Karadiyana area from Google Earth and Georeferenced to the ArcMap workspace to consider the suitability of Karadiyana Garbage Dump in Kesbewa DSD.

Enlarge karadiyana and only add that area.

According to this analysing, Karadiyana garbage Dump is not in the selected suitable area of Kesbewa Divisional Secretariat Division. The Bolgoda lake is very close to the Karadiyana garbage dump. It is a big issue. Karadiyana garbage dump may be a risk for the residents and directly cause for the contaminating ground and surface water in future Not only human, also it constrained for the animal's lives. It may be affected for the landslide in future.

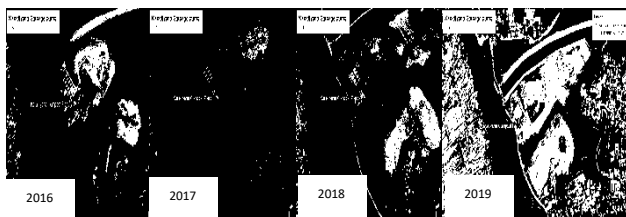Analysing the changes in Karadiyana Garbage Dump, can get an idea how the area is changed.

Figure 15. Changes in Karadiyana Garbage Dump

Source: Google Earth

Discussion and Conclusion

This analysis includes how to select a suitable area for waste dumping by using different criteria. The ArcMap licensed software is very useful for the investigation of this study. ArcMap licensed software is convenient for students to use for their project works.

There are several methods for waste disposal; landfill, waste compaction, composting, biogas generation. But unfortunately, in Sri Lanka, mostly use the open dumping landfill method. These areas generally satisfy the minimum requirements for the site selection. If select the suitable areas for waste dumping, it will protect the groundwater as well as surface water for the plantation and human purposes. In this base of Analysis suitable area for waste dumping in Kesbewa DSD was not in the Karadiyana area. However currently karadiyana is use for waste dumping. Although it's not satisfied basic

conditions that required (Figure: 14). Under this investigation, we have considered eight Characteristics to select to a suitable location for waste dumping.

Authority can do the landfilling as Open dumping and closed dumping. The most common one is open dumping. According to our analysis, we have found some suitable areas and three of them identified as ideal locations. Actually, authority can use these areas for closed dumping. And recommend using these places as a cycle. One

Figure 14. Karadiyana Garbage Dump

place used as a closed dumping area and rotate to another area. After that rotate each one, the first area that was chosen may be compost and again suitable for waste dumping. Rotating and closed dumping methods are very important because it prevents the landslides of the garbage dump.

The progress of the development control needs to be monitored and evaluated annually and to take remedial actions to rectify incompatible development activities. Monitoring the application of the regulation within the zones need to analyse properly by the GIS tool. GIS is very helpful for analysing and make predictions. Zoning and their regulations and promoting or discouraging the activities need to do then and there with the evaluation of GIS.

Acknowledgement

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