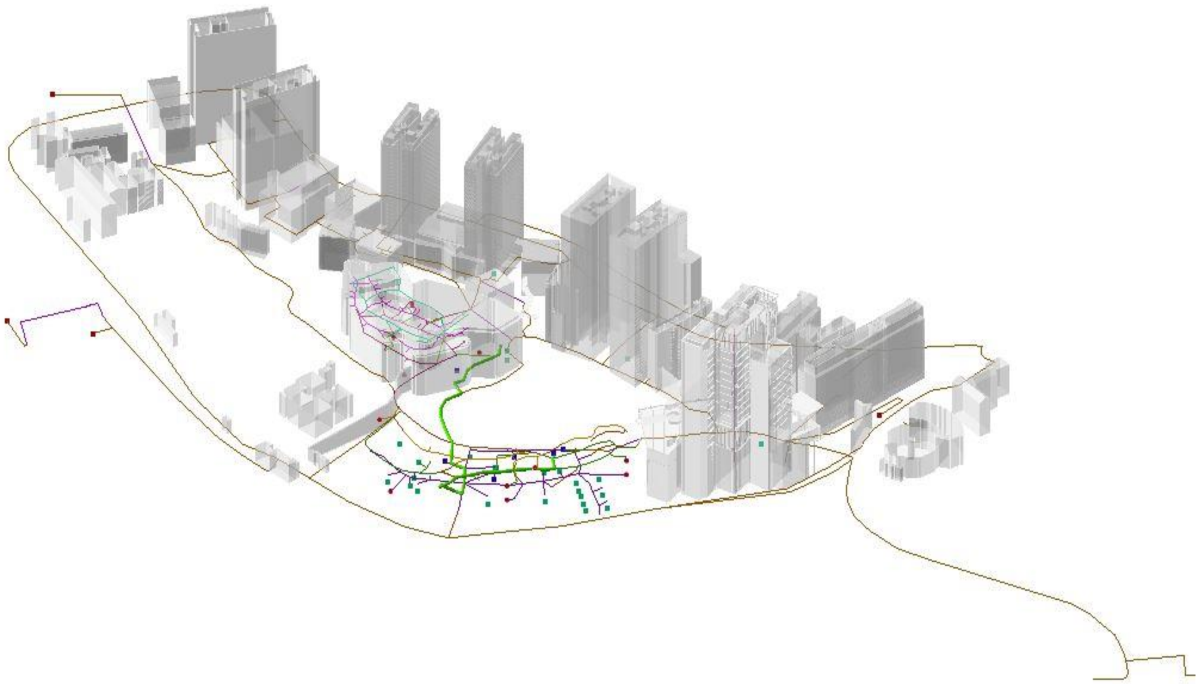

3D Pedestrian Network of UTown

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Contents

1 Introduction

As the need for sustainable alternatives of living are being researched, energy conscious institutions are working towards responsible energy consumption to ensure steps towards lowering their carbon footprint.

Due to the transition from a day-scholar high school lifestyle to a boarding university lifestyle, university students tend to be at a higher risk of adopting unhealthy habits. In studies in the United States, the college education years are believed to be the critical years for weight gain in students (Ford and Torok, 2008). This period is crucial for positively bringing about a change in the lifestyle of students, which would help them maintain disciplined and healthy habits in future. College campuses, having a captive audience of students and staff, are important institutions that can influence such changes on the higher levels of the social ecological model like environmental and infrastructural levels. (Bopp et al., 2011).

While convenient alternatives like internal shuttle bus services are present, the environmental and health benefits of walking have led to increased efforts to develop pedestrian networks. Researchers aim to promote pedestrian commute through the study of network infrastructure, traffic data, pedestrian behaviour and the multiple level influencing factors from the social ecological model (Bopp et al., 2011) for routing purposes. With this understanding, it will be possible to develop a more favourable pedestrian environment to attract new commuters, create a pedestrian network as an alternative to vehicular network as well as suggest routes based on commuter preferences. To carry out simulations and visualize routes, 2D or 3D models containing the various attributes can be used.

This project aims to create a 3D routing model of the pedestrian network of University Town at the National University of Singapore. Its method should be scalable for other cases of larger scale. Furthermore, the time required to map the network should be estimated. UTown was chosen to act as a proof of concept for future efforts to develop a 3D map of NUS, which is available for public use (see Figure 1).

Figure 1 Map of UTown

Source: http://utown.nus.edu.sg/contact/getting-here/

The complicated layout of the National University of Singapore campus was one of the motivations to develop the indoor 3D model. Danalet et al. (2013) found that for pedestrians on the EPFL campus, Lausanne pedestrians tend to travel on the more common external routes and not the shorter, internal routes due to a lack of knowledge of the shorter routes. This would imply that if these shorter routes between an origin and destination were made popular, those who previously did not walk would be more willing to walk.

Why 3D as opposed to 2D?

A 3D model provides a better understanding of the terrain, elevations, building shade and path and stairs gradient, all of which influence pedestrian route choices. In addition, in 3D maps, routes between 2 points having the same X and Y coordinates but having different Z coordinates, can be computed with ease by viewing the points from different angles.

2 Literature review

Different approaches to develop pedestrian networks have been attempted by researchers of which some were explored in this project. A manual network generation with field surveys appears to be a popular approach, which is also attempted in this project with ArcGIS tools. It involves georeferencing and drawing of network features based on field surveys.

Koh, Nah, Tan and Tan (2013) attempted to perform 3D routing of the Faculty of Arts and Social Sciences at NUS using ArcGIS, tools but were unable to construct links like stairs and elevators between points with different elevations and were able to only construct a 2.5D routing network.

Another approach that is also explored by the author is that of crowdsourced mapping. Typically, networks can be created and classified by members of a mapping project with manual drawings or GPS traces. A number of volunteers are required to provide GPS traces, which then are processed to eliminate outliers (Karimi and Kasemsuppakorn, 2012). It was found that the greater the number of GPS traces for a particular path, higher the accuracy of the network feature.

As previous researchers have attempted to develop realistic pedestrian distances between origins and destinations, this project will look to further work on it. Van Eggermond and Erath (2013) identify cases where actual travelled distance differs from crow fly distance and look into the method of measuring the same. Ground truthing is essential to identify these discrepancies.

3 Initial approaches and related challenges

In Week 1 of the project, a few approaches were attempted before choosing the most suitable path to meet the goals of the project. The following section is a summary of the different attempts.

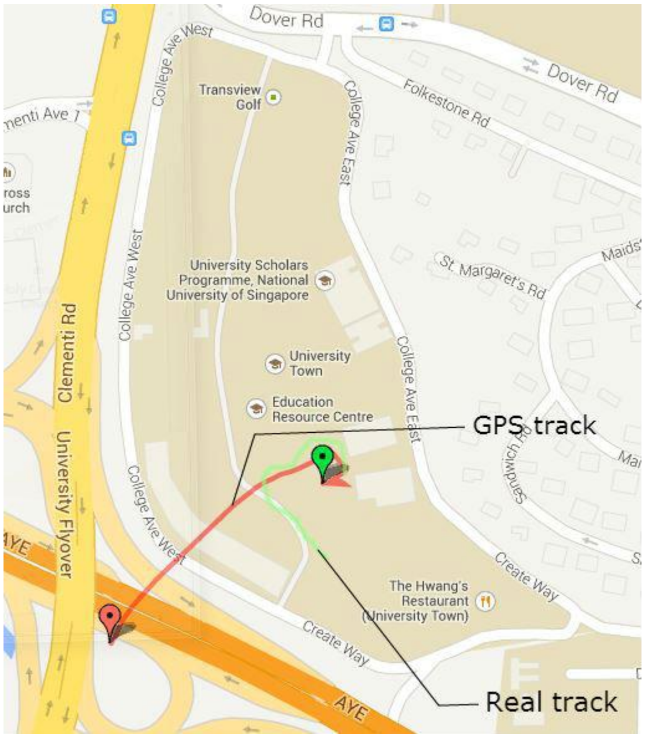
3.1 OpenStreetMaps

The author made use of the iD, in-browser editor of OpenStreetMaps to draw pedestrian networks for outdoor paths without elevations. However, indoor networks could not be built due to limitation of constructing 3D data with layers. In order to have indoor mapping, extensive research in Java OpenStreetMap Editor was required, which was not a feasible option in the given time period. OSM allows adding descriptive properties, open source, accessible and available to public

3.2 Smartphone GPS applications

The aim was to be able to use the traces to generate pedestrian path shape files. Indoor signals are poor and cannot obtain accurate tracking data outdoors. KML files of tracks did not coincide with paths when displayed with Google Maps (see figure 2).

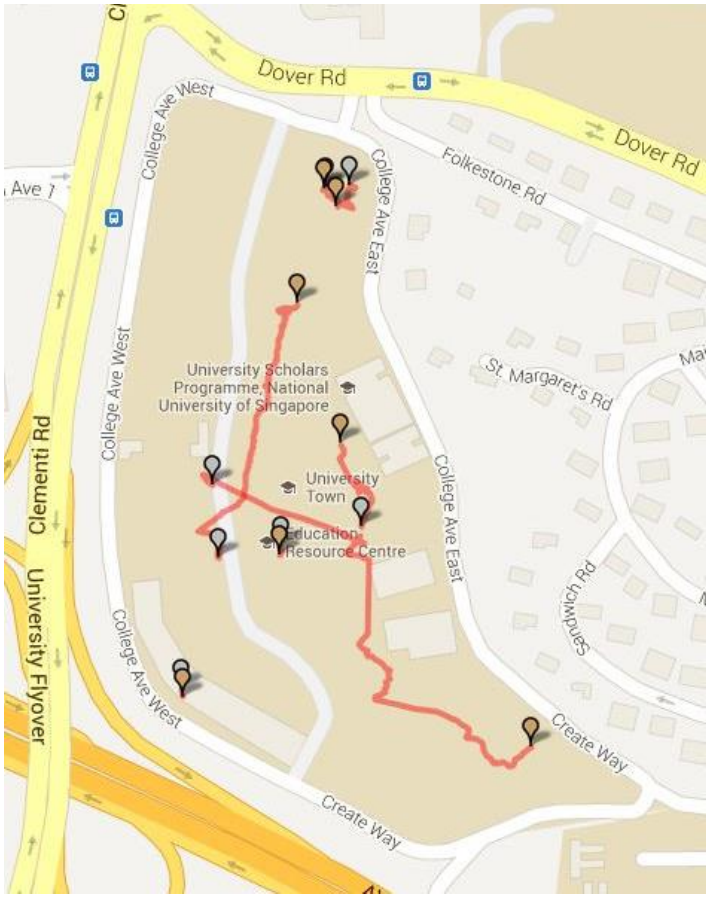
Figure 2 Example of GPS track compared to real track



3.3 MobiTest

The MobiTest device tracks movements using GPS signals. The aim here, again, was to use the shapefiles of the traces to construct links of the network. Traces were not accurate enough to be marked on narrow pedestrian paths, instead they were only able to give an approximate idea of the direction travelled along with start and end time of travel. The device also failed to capture intermediate data, which presents itself as end of a journey (brown marker) and start of a new journey (grey marker) at a different location as shown in Figure 3.

Figure 3 Example of tracks with high quality equipment



3.4 ArcGIS

Using publicly available floor plans, links, nodes and points of interest were constructed by manual drawing. Attributes were added to features in the network, which would allow routing based on different criteria like sheltered walkways, most human activity and least traffic.

4 Chosen methodology: ArcGIS

ArcGIS tools were employed to construct the network and enable routing in the network.

4.1 Assumptions

The following assumptions are made

- Links were drawn with the assumption that pedestrians prefer to walk at the centerline of a thoroughfare.
- Minor gradients in paths are ignored while assigning elevation to links but accounted for in the attribute "SurfaceQuality".
- Publicly displayed floor plans provide a fair indication of the real features

4.2 Coordinate systems

The map was created with the following coordinate systems

Projected: WGS 1984 UTM Zone 48N

Vertical: WGS 1984

4.3 Georeferencing on OSM shapefiles

Publicly available floor plans were georeferenced on OpenStreetMap shapefiles to get a better understanding of the possible paths for pedestrians.

4.4 Geodatabase and feature classes

The geodatabase, "UTown.gdb", consists of all the pedestrian network features of University Town. The feature classes were then included in a feature dataset called UTPedNet which had the appropriate coordinate system.

4.5 Constructing features

The network was drawn in ArcMap as described in this section.

Editor Toolbar was used to create features and *Snapping tool* was required to ensure multiple features at the same coordinates were constructed accurately. Since the feature dataset and feature classes were assigned a Vertical coordinate system of WGS84, the individual features could be assigned elevation values. For representation, approximations were made for elevations, when actual values were unavailable.

Line features representing stairs and elevators connected paths of different levels of the same building. Point features included points of interest like lecture theatres, food courts, sports facilities and toilets. These features can be viewed in ArcMap in 2D or in ArcScene for 3D view.

The multipatch shapefile of the 3D model of UTown was added to the layers.

4.6 Building network

After the construction of features of the network, a new network dataset was created in the feature dataset UTPedNet called UTPedNet_ND.

The network was then built to create links and nodes from the line features, common vertices and point features of the feature dataset.

4.7 Routing

Two Dimensional Map: The *Network Analyst* extension in ArcMap was employed to create routes between different stops on the network. In this case, it was difficult to view the route when the routes traversed different levels or elevations. This further necessitates 3D routing.

Three Dimensional Map: Using *Network Analyst* and *Geoprocessing* tools, an interactive route solver is built. This tool allows for interactive clicking on the 3D map to select "Stops" for the routes, which can be used in ArcScene.

4.8 Chosen attributes

One of the aims of the project is to be able to calculate routes based on different attributes. A set of attributes were assigned to each feature and each attribute had to be calibrated with the same data type. In other words, assign generalized costs for each attribute. For example, *Length* with units of metre or *Time* with units of minutes. This was required because the route-solving tool, the *Solve* tool, uses the shortest path algorithm or the Dijkstra algorithm (Environmental Systems Resource Institute, 2012). Depending on the impedance chosen, the best route or "the shortest route" is calculated.

The feature attributes are listed but the fields are yet to be populated after field surveys.

Attributes for line features representing paths

- Name
- QualityOfSurroundings
- Traffic
- SurfaceQuality
- Barrier
- ActivityLevel

- Greenery
- Covered
- Wheelchair
- Floor
- AC
- Width

Attributes for line features representing stairs

- Name
- Width Traffic
- Height
- Length
- Covered

Attributes for line features representing elevators

- Name
- Capacity
- WaitingTime
- Speed

Attributes for point features representing UTown points of interest

- Name
- Access
- Floor
- AC

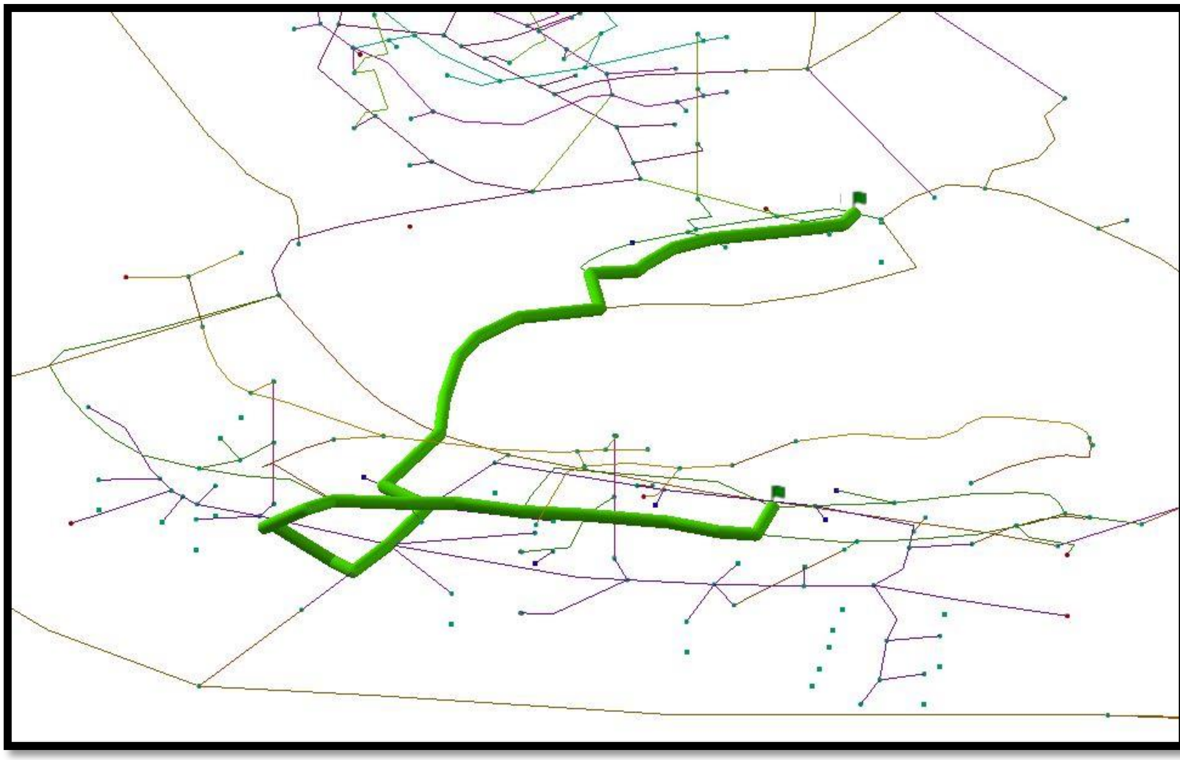
Attributes for point features representing food and beverage points of interest

- Name
- Floor
- Cafe
- Food court
- Restaurant

5 Results

The aim of creating a 3D routing network of UTown was achieved given the constraints of availability of topology and indoor 2D floor plans. Outdoor paths, stairs, indoor pedestrian networks for Stephen Riady Centre, Education Resource Centre and level 2 and 6 of CREATE Tower were created. “Stops” for routes can be placed anywhere on the UTPedNet_ND network that includes the above.

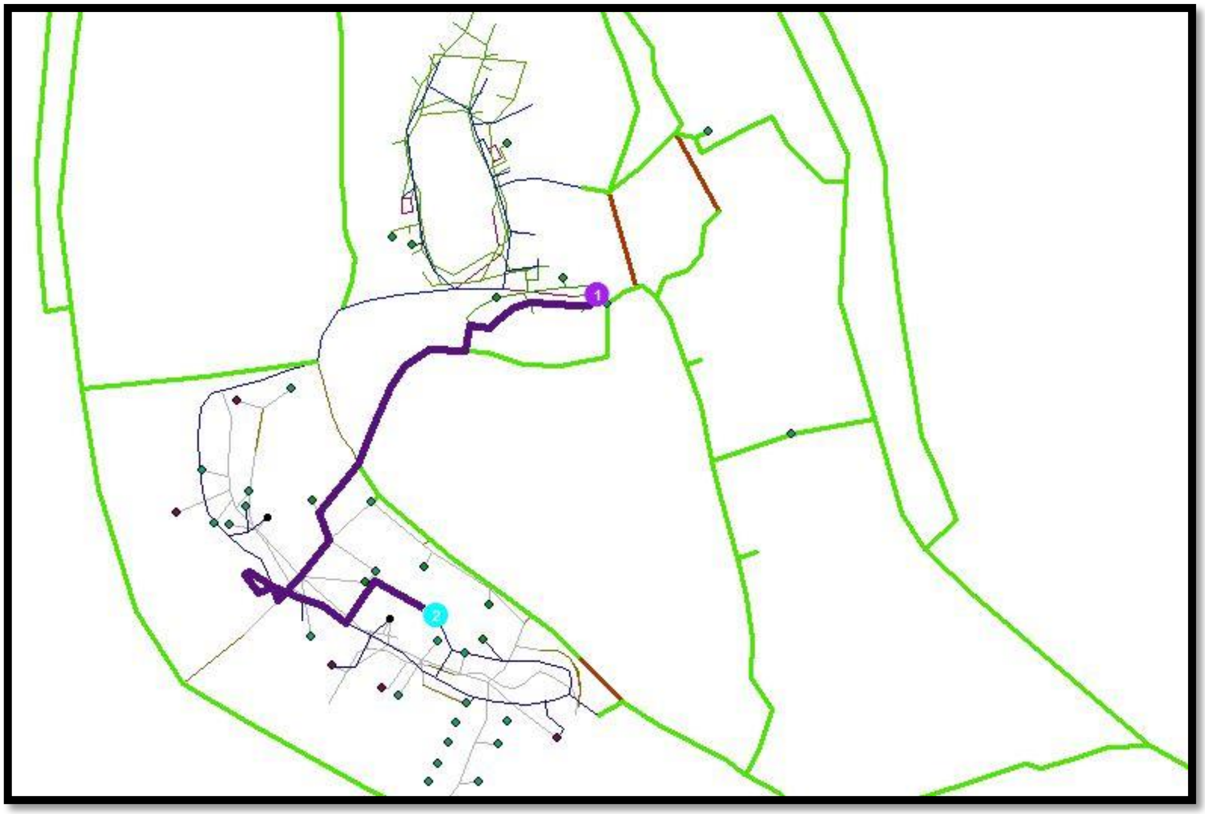
Figure 4 3D network: Route from ERC 1 to SRC level 2



Graphics: ESRI ArcScene 10.1

In the process of arriving at a 3D routing network, the 2D routing network was also constructed to check for connectivity. The same stops and routes as in the 3D examples are used in Figure 5 to highlight the differences.

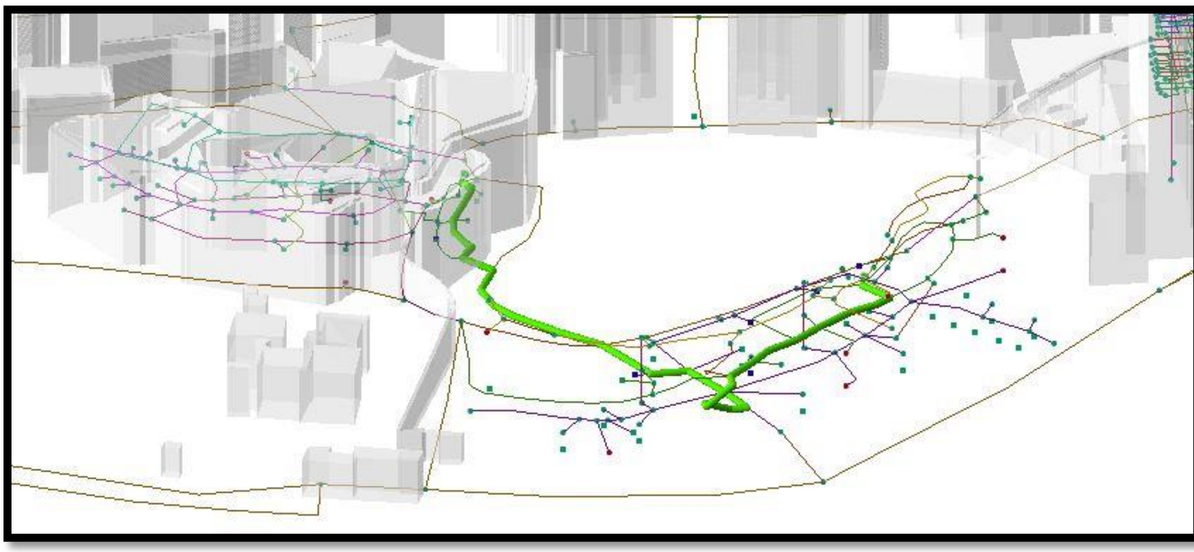
Figure 5 2D network: Route from ERC 1 (1) to SRC level 2 (2)



Source: ESRI ArcMap 10.1

The indoor networks were positioned within the 3D models of the buildings as shown in Figure 6. This provides better representation with reference features which improves understanding.

Figure 6 3D network: Route from ERC 1 (1) to SRC level 2 (2) with 3D model of buildings



Graphics: ESRI ArcScene 10.1

Given the knowledge of ArcGIS *Network Analyst Extension*, *Network Analyst* Toolbar and *Editor* toolbar as well as digitized floor plans, the network can be drawn and built quickly. The network of Education Resource Centre was built and checked for errors in one day. As the author was required to learn ArcGIS and had no prior experience in the field, familiarization with the software took 3-4 working days. However, such familiarization is largely subjective, hence, need not be considered.

6 Challenges

The work revealed a variety of challenges for future projects

- The 3D model of UTown, in the form of a multipatch shapefile, was not scaled correctly, which meant that, for accurate representation of the pedestrian paths, unrealistic elevations have to be assigned to the features.
- Snapping proved to be cumbersome while moving features as well as while placing "Stops" for routes. This led to either the network not being connected in the first case and "Stops" not being located on the network in the second case. A segment-by-segment

check of the links had to be undertaken to identify and correct the errors. These corrections were more easily resolved using ArcMap due to the presence of a superior *Editor* and *Network Analyst* Toolbar.

- Georeferencing of floor plans may not have been accurate due to the simplified images used. This may have led to paths links and nodes being displaced slightly from their real position.
- Acquisition of detailed digitized floor plans took more time than expected and prevented a more elaborate network from being created.

7 Learning outcomes

The experimenters were able to achieve the following learning outcomes

- ArcGIS: This project allowed the author to obtain a working knowledge of ArcGIS and in particular *Editor, Network Analyst, Georeferencing* tools. Similar projects would need in-depth understanding of these tools as well as basic understanding of *Model Builder* to build custom tools.
- Selection of attributes for different features led to research into the influencing factors for pedestrian mobility, which were based on the social economic model. The factors included individual preferences like the presence of elevators, interpersonal factors like the activity level and organizational factors like presence of certain amenities in the proximity.

8 Recommendations

This model is a proof of concept for future projects of similar scale and purpose. It is recommended that a similar approach be adopted to increase the 3D indoor mapping in university campuses such that pedestrian mobility is promoted. Some recommendations are

- Follow similar conventions as adopted by this project for lumping criteria together, as having individual descriptive attributes for a large-scale mapping project can be a tedious task
- Attributes such as SurfaceQuality and ActivityLevel, when assigned generalized costs will have subjective values that depend on the decision maker. There is a need to look into a simplified method to rate features for different attributes. This would allow routing based on these criteria as well.
- It is advisable to categorize features in different layers, especially features at different elevations. This allows for ease in editing and analyzing the network.
- It is recommended that floor plans of buildings are georeferenced so that possible indoor routes can be marked

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