MODELLING PEDESTRIAN ACCESSIBILITY USING GIS TECHNIQUES TO ASSESS DEVELOPMENT SUSTAINABILITY

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ABSTRACT

Pedestrian accessibility maps often display a Euclidean distance buffer (straight line between two points) around a destination facility. This paper discusses how a pedestrian network can be used to model the effect of gradient and demographics on walk speed, which influences the level of pedestrian access to key facilities. A bespoke GIS model was developed to undertake the assessment, which is explained along with the key assumptions made. The model was used to assess pedestrian access levels for five proposed development sites in the West Northamptonshire area, within Central England, to the key local facilities. The results quantified access using defined threshold journey times to provide the percentage of dwellings within this limit. This helped West Northamptonshire Development Corporation to consider the specific pedestrian access issues that each site may have, which forms part of their process of ensuring development sustainability. One of the key conclusions of the study is that this type of model could be applied to other geographical regions and scenarios (e.g. cycling assessments). More generally, the study showed that GIS is a key tool for improving the evidence base as part of the spatial planning process.

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1. INTRODUCTION

West Northamptonshire Development Corporation (WNDC) oversees development in their jurisdiction as the planning authority for all strategic decisions. The area lies in the heart of England, intersected by key strategic transport routes (e.g. M1 motorway). Central government has designated this as a flagship growth area, meaning that more jobs and houses will be created in future years. WNDC aims to ensure new homes are delivered sustainably. A key aspect of this role is to minimise the potential impact of additional trips generated from proposed developments. This includes minimising the potential issues caused by additional car trips and the associated effects on the environment. An effective method of achieving this aim is to promote walking as a means of transport by ensuring each site has adequate accessibility to key local facilities. This has traditionally been undertaken by mapping a two kilometre distance isochrone around the destination using the Euclidean distance (straight line between two points). Whilst this provides a quick and easy assessment, advancements in technology (principally through the development of Geographical Information Systems), has provided the means to add sophistication to this analysis. This was particularly important for the assessment in West Northamptonshire due to the topography of the five proposed development sites and the subsequent impact on walk speed.

In addition, the demographic profile of walkers was significantly different for certain destinations, changing the walk speed profile and thus journey time. Therefore, a bespoke model was created that considered these two main factors, with the aim of quantifying the level of accessibility for each site to the key facilities. These journey destinations were determined as part of a wider accessibility review by WNDC and their consultants.

This paper details the methodology for undertaking this study, including how the existing literature helped to formulate the relationship between speed, gradient, and demographics. The results of the analysis are presented, including an assessment of the transferability of the model to other geographical areas and applications.

2. METHODOLOGY

A GIS-based model was developed by AECOM as the main analytical tool to provide the pedestrian accessibility assessment required by the study. Existing policy in the UK recommends using a distance-based measure of accessibility (Planning Policy Statement 13). However, this measure (2km distance) does not consider the effects of gradient and demographics on the distance travelled. It can also be inaccurate where the least-cost route calculated does not consider the routing restrictions of a network. Before such a model could be developed, desktop research was undertaken to review the current literature for studies that quantified the relationship between walk speed, gradient, and the demographic type of the walker. The results of this review were used in the model, which provided pedestrian journey time isochrone maps. Further analysis in the GIS then identified the percentage of dwellings for each of the development sites within the individual isochrones to provide an assessment of accessibility.

2.1 Literature Review

It was acknowledged in the literature (Willis et al., 2004; Finnis and Walton, 2007) that a variety of factors influence walk speed. Some of these were not considered in the model (e.g. baggage, surface conditions, shoe type, numbers walking together, gender, time of day, etc.). It was determined that adding these specific variables would not have provided value to this study due to their complexity and the creation of a large number of potential scenarios. They could be added to the model if these factors were chosen for review.

It is reported in the literature that pedestrian walking speed is influenced by age, with the slowest walking speeds observed in older adults and younger children. The mean walking speeds for younger pedestrians (aged 16-25 years) were the fastest at 5.6kph. Knoblauch et al. (1996) revealed similar findings with people aged 65 years and over walking 0.26m/s slower than younger pedestrians. Himann (1988) also found walking speeds to significantly reduce after the age of 63 years, declining by 1-2 percent per decade up to the age of 62. Walk speeds also vary with age for children, which is important within this study for differentiating between primary and secondary school destinations. Gates et al. (2006) states an average speed of an adult assisted child as 4.4kph. Toor et al. (2001) reports a speed of 5-5.4kph for 9-14 year olds, which is significantly higher. Finnis & Walton provide the most suitable breakdown of speed by age group for this study due to their classification of age groups and large sample size. Table 1 below presents these results, with the speed of the older person (over 55) replaced by a lower speed taken from Willis et al (2004) that concurs with other results in the literature.

Age Group	**Speed (kph)**
Child with adult	4.3
Child (under 15 years)	5.0
Young Adult (15 to 30 years)	5.3
Adult (30 to 55 years)	5.3
Older Person (over 55 years)	4.2
Mean	**4.82**

Table 1 Relationship between age and speed that was used in the study

The relationship between walk speed and gradient is complex. One of the oldest and possibly most used correlations is Naismith's rule (Fritz and Carver, 2009). It is used by hill walkers and mountaineers to estimate the impact of gradient on walk time, specifying that walkers should *"allow 1 hour for every three miles / five kilometres forward, plus half an hour for every 1000ft / 300 metres of ascent."* For the purpose of this study, this correlation was considered inappropriate due to its broad application to hill walking. The most relevant study found in the literature was conducted in New Zealand by Finnis and Walton (2007). Their study was conducted in urban areas using a sample of 1847 pedestrians. They reported that walking speeds did not significantly vary from the base flat gradient speed up to 4°. However, speeds increased significantly between 4° and 5°, remaining con stant from 5° to 6° and then decreased significantly from 6° to 7°. Of part icular note is that speeds increased when gradient increased (to a threshold level), contrary to Naismith's rule (Table 2). This can be explained by walkers increasing their effort to walk up a slight gradient. The results of the literature review were used to determine speeds by gradient by four demographic types (commuter, non-commuter, adult with a child, and older person). These classifications were appropriate for the destinations types used in the assessment. They also matched those reported in the literature.

Influence		Mean Speed (kph)
Gradient	<2°	5.3 (88.08m/min)
	<2° w/o commuters	4.9
	4°	5.0
	5°	5.5
	6°	5.5
	7°	5.0
Slope Walking Direction	Uphill	5.3 (87.66 m/min)
	Downhill	5.4 (90.54 m/min)

Table 2 Finnis and Walton walk speed results

One of the key issues when quantifying accessibility levels is setting a threshold that defines an acceptable limit (usually denoted by journey time). Whilst it is accepted that people have different tolerances, a review of the literature was undertaken to determine this value. It was found that people have different limits according to the destination type for their journey. Newman and Kenworthy (2006) state that people are unlikely to walk more than 30 minutes to their destination, providing an indication of the potential maximum time. The results from the National Travel Survey (NTS) (DfT, 2006) provided greater detail by separating the results by destination type. The NTS reports that people are willing to walk further for commuting / business trips than they are to shopping facilities/personal business (Table 3). These results were used in the study to define a threshold walk time using a flat gradient walk speed in the calculation. A time-based measure enabled speed within the model to vary depending on the gradient of the route sections.

Trip Purpose	Number of Trips per Year	Trip Distance per Year (km)	Average Trip Distance (km)
Commuting / business	21	26	1.2
Education / escort education	44	43	1.0
Shopping	55	51	0.9
Other escort	12	11	0.9
Personal business	26	24	0.9
Leisure	48	51	1.1
Other	44	66	1.5
Total	249	274	1.1

Table 3 National Travel Survey 2006 average trip distance

2.2 Model Development

Data for the study was either purchased, obtained via Ordnance Survey's (OS) Pan Government Agreement with Local Authorities, or digitised where appropriate. The OS Integrated Transport Network (ITN) layer was used as the basis for the pedestrian network. This was supplemented with footpath and bridlepath information either supplied or digitised according to a variety of sources (OS maps, masterplan maps, site visit information). These two datasets were merged and checked to ensure all links were connected correctly for use in the model. The ITN layer is a modelled representation of the road network, so where required (e.g. junctions), the network was adjusted according to information obtained during site visits on where the pedestrian network differed. In the majority of cases, this was at traffic junctions. In addition to this process, links greater than 100 meters were split to ensure they did not exceed this length. This was required to correctly model the changes in gradient along each section of the route. Excessively long links could have fluctuations in gradient along its length, which would not be modelled.

OS digital height data (10m interval Digital Terrain Model) was then used to assign a height to the start and end points of all the pedestrian links in the GIS layer. The gradient of each link was calculated for both directions. Existing AECOM scripts written for use in ESRI ArcView software (using ArcObjects and VBA) were applied. The gradient was then used to calculate the walk speed and time to traverse the link in both directions depending on the demographic group type. The final stage of the model creation was to use ESRI GIS software to create a network dataset to draw the isochrone maps. For the purpose of this study, further analysis was required to calculate the percentage of dwellings within each travel time isochrone; the measure used to quantify overall accessibility for each site. A GIS layer was digitised from the masterplan information to define the extents of the housing blocks for each site. A point grid was drawn over the blocks, which were assigned dwelling numbers to provide the number of dwellings per point. The points were then used in the analysis to quantify the number of dwellings for each site within each of the time isochrones produced by the model.

2.3 Model Validation

The large sample size provided by Finnis and Walton (1847 observations) could not be replicated in this study due to resource constraints. Instead, a number of site visits were undertaken to walk key routes across the study area to determine if the speeds were realistic (i.e. did we need to consider other evidence) and also to review the network that we were using in the model. Each route was chosen due to the linkage it provided to key facilities. They were walked by one female and one male to ensure the effects of gender on walk speed were minimised in the grouping. The information was used to validate the walk speeds used in the model by directly comparing the model and site visit route times. The close correlation (<10% difference) was deemed acceptable and only changes to the network were made as a result of the validation stage.

2.4 Model Assumptions

Models inherently contain assumptions. They model reality using a rule-based system, which by their very nature do not apply to all scenarios. This model achieves its aims and objectives for the study by assuming the following:

- Walk speed does not slow with distance travelled;
- Gradient is constant between the start and end of each link;
- Walk speed is constant along a link;
- There is no delay due to crossing a road as it is assumed that pedestrians will choose to cross in a quiet place and there are minimal busy roads in the study area;
- Least-cost routes (fastest) are calculated, which does not consider route choice (e.g. due to busy roads, perceived risks such as crime, footpath conditions, etc.);
- Access to the network can occur at any point (i.e. not just at junctions);
- There are ‘free flow’ conditions on all of the footpaths;
- The isochrones are clipped at 100 meters from the network links, assuming that access can occur up to this distance from the link; and
- The analysis does not consider gender of those walking, time of day, and the quality of the route in relation to others.

3. RESULTS

Each destination was assessed to determine the percentage of dwellings that were within each isochrone. Figure 1 below shows an example isochrone map for one destination. Different maps could be produced for the same destination showing the effects on journey time of the different demographic profiles modelled in this study. Only one demographic group was assessed for each destination in this study, except for where a destination represented a cluster of facilities. Isochrones were drawn at five minute intervals, with an additional isochrone added to signify a ‘reasonable’ walk time threshold as defined by the NTS (13 minutes 20 seconds in Figure 1). The results for all of the destinations were then summarised in statistical tables to show the overall level of accessibility from the development sites. Where appropriate, these were classified by destination type.

The results demonstrated that the Euclidean distance measure is significantly different from those calculated using a network. The influence of gradient and more significantly demographic type on walk speed meant that the results also differed from a distance-based measure that was calculated using the network. Specific localised areas of significant gradient did influence the results, but the consistent variation in walk speed due to demographic type had a greater influence. The 2km distance coincides with a 25minute isochrone at a mean speed of 4.8 kph. This is significantly greater than all of the threshold times (e.g. 13 minutes 20 seconds) that are based on an average walk distance set out in the NTS.

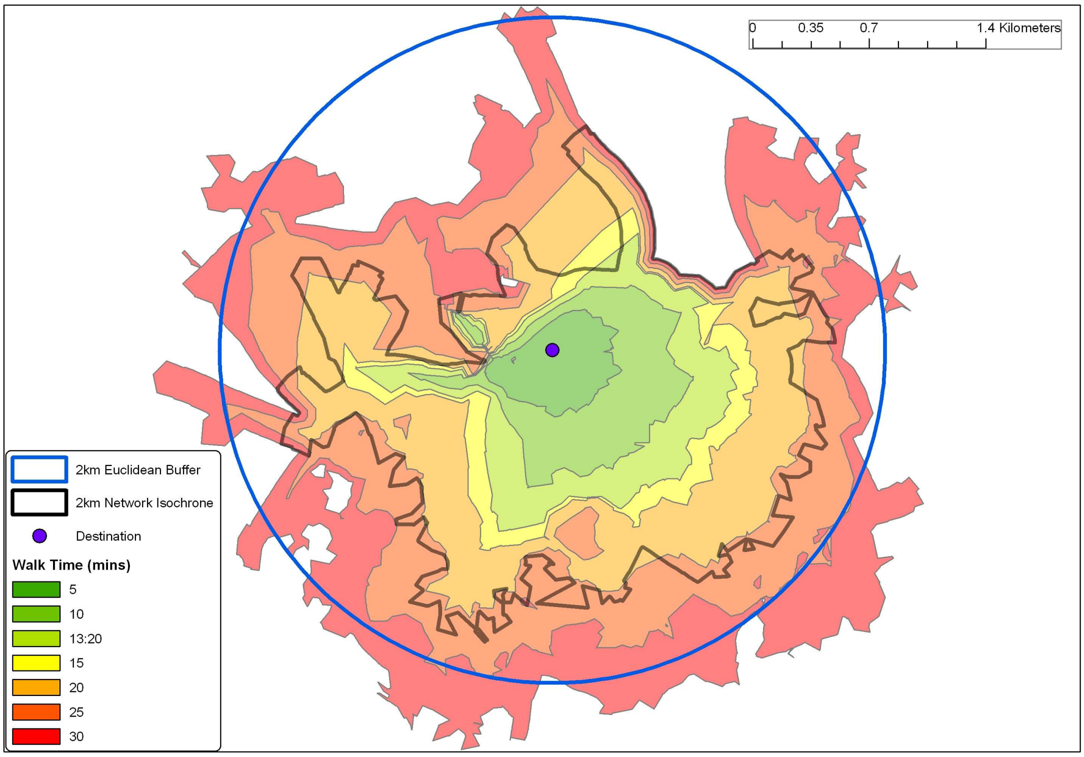

Figure 1 Map displaying walk time isochrones to a single destination

4. CONCLUSIONS

Through the use of innovative GIS modelling techniques, sophistication was added to the assessment of pedestrian accessibility. This improved the accuracy of the results in comparison with traditional methods. The threshold walk times were significantly shorter than the 2km distance measure suggested by PPG13. This questions the validity of this measure, but more importantly, this new approach allows organisations to understand access to key facilities for a variety of walking tolerances. Overall, the effect of demographics on walk speed was greater than that of gradient for this study area. However, the localised effect of gradient did influence access to facilities and should not be excluded from further work. The model makes a number of assumptions that could be reduced further by including additional factors. However, this would serve to increase the complexity of the results. This was not deemed necessary for this study, which already included factors that are not considered in other accessibility assessments.

The results of this study have been used by WNDC to assess the potential sustainability of development sites in West Northamptonshire with the aim of reducing the number of car trips from the sites and improving overall access for residents. This included an assessment of access to key facilities that were located on the site and within local urban areas. The model was also used to review the pedestrian network outlined in the masterplan, assessing whether additional routes were required to improve connectivity. Therefore, this is also a tool for helping planners to design a site.

This methodology is transferable to other geographical areas and studies. In order to do this, a review of the key factors influencing walk speeds for the study area would be required. This would not be a suitable technique where walking routes were overcrowded (e.g. transport hubs, or sporting events) as speeds would be influenced by the changes in pedestrian flow conditions, which is not considered in the current model. The model could be used to review cycle networks and access using this mode. A review of previous studies detailed in the literature would need to be undertaken to determine the relationship between cycle speed, gradient, and demographics.

The modelling exercise has shown that GIS techniques have advanced significantly from their formation in the 1960s. Importantly, applications such as this have provided publicity to a technology which can be applied to many analytical problems. The ability to develop the software is a powerful capability, providing geographical analysis and visualisation using a map base. With geography at the centre of many policy decisions, GIS is a key tool for improving the evidence base as part of the spatial planning process.

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