SPATIAL DECISION MAKING WITH GIS

THE ACME INTERNATIONAL INDUSTRIES HEADQUARTERS LOCATION CASE STUDY

BOO, G., VRIJE UNIVERSITEIT, AMSTERDAM.
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INTRODUCTION

In the last decades, the use of GIS in decision making policies has become a key element in the implementation of scientific methods for a multitude of problem-solving strategies (Longley *et al.*, 2011). In fact, GIS's main advantage is its ability to provide a kit of conceptual and technical tools designated to collect, analyze, visualize and model geographical and non-geographical data. As a result, spatial decision-making processes employing GIS are widely appreciated within many fields, from academics to business (Van Manen *et al.*, 2009). The topic of this assignment is an interesting example of GIS's heterogeneous applications, where spatial decision-making tools are employed in the definition of a facility's suitable future location.

ACME International Industries recently expanded its business in Europe and has decided to locate its new European headquarters within the region of Anytown, the Northwest of England. In the search for an ideal location, ACME intends to employ GIS in order to set a spatial decision-making process, analyzing the following location criteria:

- Communication Network Connectivity, in order to transfer goods from/to the ACME headquarters by road and rail;
- Public Transport Accessibility: bus or train stations, for the headquarters' employees;
- Sizable Potential Workforce Proximity: proximity to a workforce of 5,000 employees, intended to man a range of technical, scientific, management and sales positions.

As a result of these criteria, the central question of the assignment is: in searching for the most appropriate headquarters position, how do different elements of a spatial analysis process contribute to a successful study of the ACME location criteria? A secondary question concerns the relevance of GIS as a spatial decision-making tool in the ACME headquarters location case study.

The main hypothesis and answer to the central question is that it is possible to effectively investigate and identify the location criteria and determine a suitable site for the ACME headquarters through different stages of spatial analysis process. The secondary hypothesis is that GIS is an effective spatial decision-making tool in the ACME headquarters location case study, because the spatial component is a key variable of the problem. In order to test these hypotheses, a standard spatial analysis procedure is employed (deSmith *et al.*, 2005): the available data is reviewed; then the methodology is chosen and applied in the spatial analysis. The results of the spatial analysis are then presented on annotated maps. The problems, findings and recommendations on how the spatial decision-making process can be improved are finally summarized in the conclusion.

PART 1
DATA REVIEW

A primary stage in the spatial analysis process is the review of the available data, through a preliminary examination in a GIS environment (deSmith *et al.*, 2005). The GIS-package employed in the assignment is ESRI ArcGIS 9.3.1. with a purchased ET GeoWizards extension. Once the datasets are displayed, the element which first catches the eye is their cartographic scale. In fact, datasets' resolution is 1:50'000, which is much too small to determine a 'precise point' location in the Anytown region (Montello, 2001). Moreover, the datasets' projection and coordinate system are not determined, therefore the first necessary GIS operation is setting the data projection to the British National Grid system by using the Define Projection Tool (Data Management extension). Raster datasets are issued from different organizations, and the Anytown ward attributes are determined with different scales of measure: ordinal and interval. In order to compare this thematic information in an analytic hierarchy process, it is necessary to convert raster datasets into an ordinal ranking scale (Bernasconi *et al.*, 2010). The operation is performed with the Reclassify Tool (Spatial Analyst extension), by ranking ward raster attributes from lowest to highest values.

To establish the data employed in the spatial analysis, it is necessary to propose three postulates in order to choose the pertinent data for the study of ACME's localization criteria. First, the road and railway network connectivity can be analyzed based on information about road network structure and train station locations. Second, bus and train station positions allow public transport accessibility study. Third, the sizeable potential workforce proximity can be analyzed according to the presence of educated people, workforce availability and population distribution information from Anytown's wards. The datasets selected according to these assumptions are presented in **[Figure 1, p.5]**.

Railway, Roads, Bus_Station and Railway_Station datasets have been selected since they offer useful information about communication network connectivity and public transport accessibility. The sizeable potential workforce proximity is represented by Population, Jobseekers and Education datasets **[Map 1, p.6]**. The Education dataset ranks qualifications amongst adults and children of different ages (British Government, 2011) and provides information about wards where educated people – suitable for the requested positions – live. The Jobseekers dataset ranks people under state pension age who are available for and are actively seeking for work (British Government, 2011), *ergo* provide information about wards with potential workforce. The Population dataset ranks the number of residents in each ward, thus providing information about the location of sizeable population.

The Deprivation, Income, Health, Access and Employees datasets have been rejected because the information they offer is not useful to determine the sizeable potential workforce proximity. Unemployment dataset only provides information about people who want to work

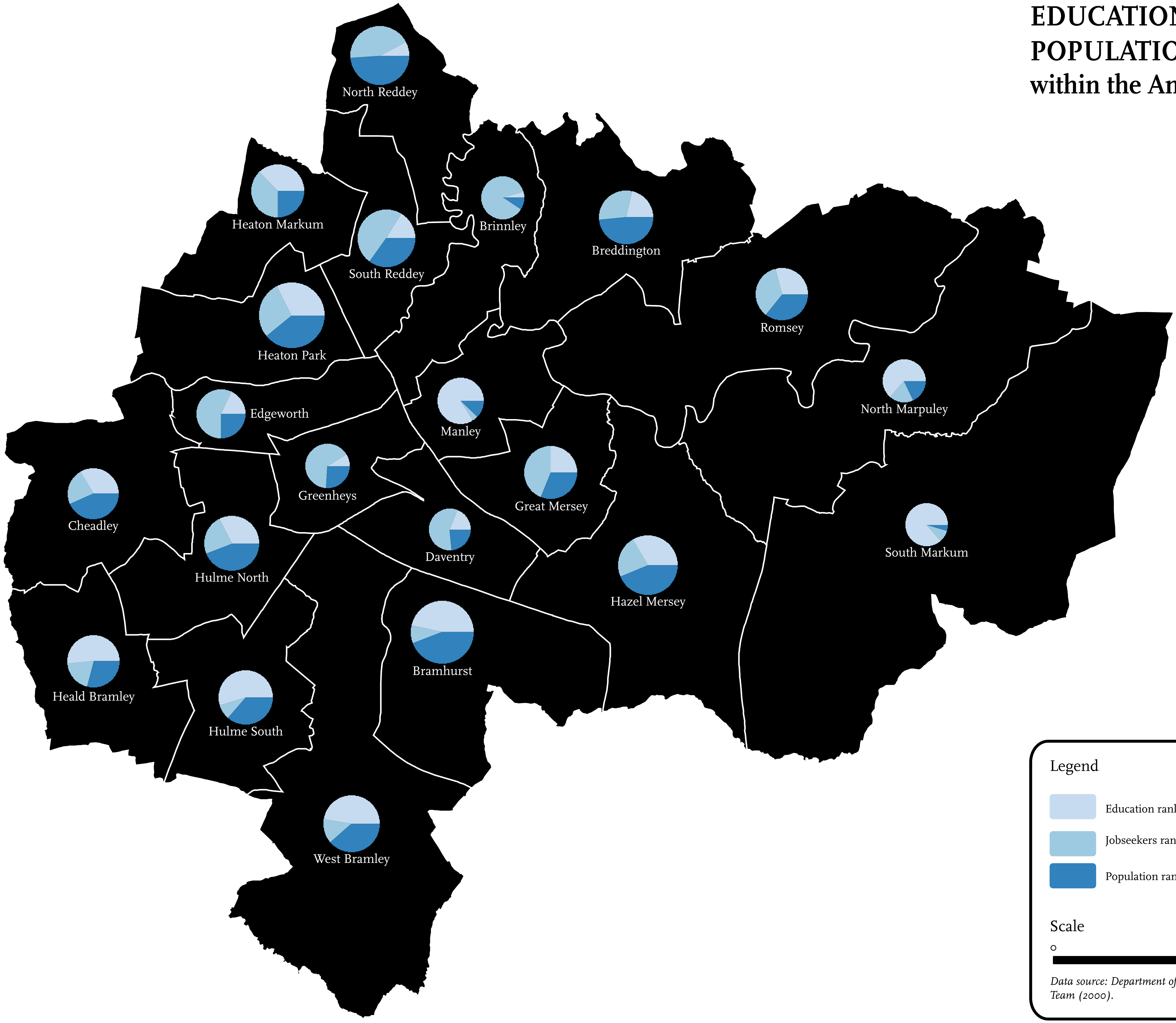
Name	Description	Operation(s)	Type	Attribute	Source
Bus_Stations	Major bus stations	Projection definition	Vector point	None	Greater Anytown Municipal Transport Unit
Railway_Stations	Railway stations	Projection definition	Vector point	None	Railtrack
Rail	Rail network	Projection definition	Vector polyline	None	Railtrack
Roads	Road network (A class and above)	Projection definition	Vector polyline	None	Greater Anytown Municipal Transport Unit and the Association of Greater Anytown Authorities
Anytown	Ward administrative boundaries	Projection definition	Vector polygon	Name, area and perimeter	Ordnance Survey
Education	Education, training and skills	Projection definition/ Reclassification	Raster	Ward education rank (1 = lowest)	Oxford Index Team (2000)
Jobseekers	Jobseekers allowance claimants	Projection definition/ Reclassification	Raster	Ward jobseeker rank (1 = lowest)	Department of Social Security Information Centre (1998)
Population	Population	Projection definition/ Reclassification	Raster	Ward population rank (1 = lowest)	Department of Social Security Information Centre (1998)

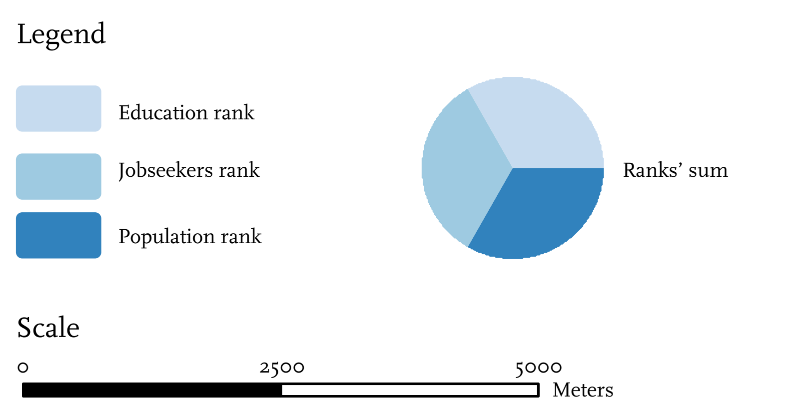
[Figure 1] The datasets selected for the spatial analysis

but are unable to do so (British Government, 2011), but it does not specify the reasons (unemployment, illness etc.). University dataset has been rejected because it does not offer information about the presence of workers with technical and sales position backgrounds.

[Map 1]

EDUCATION, JOBSEEKERS AND POPULATION
within the Anytown region

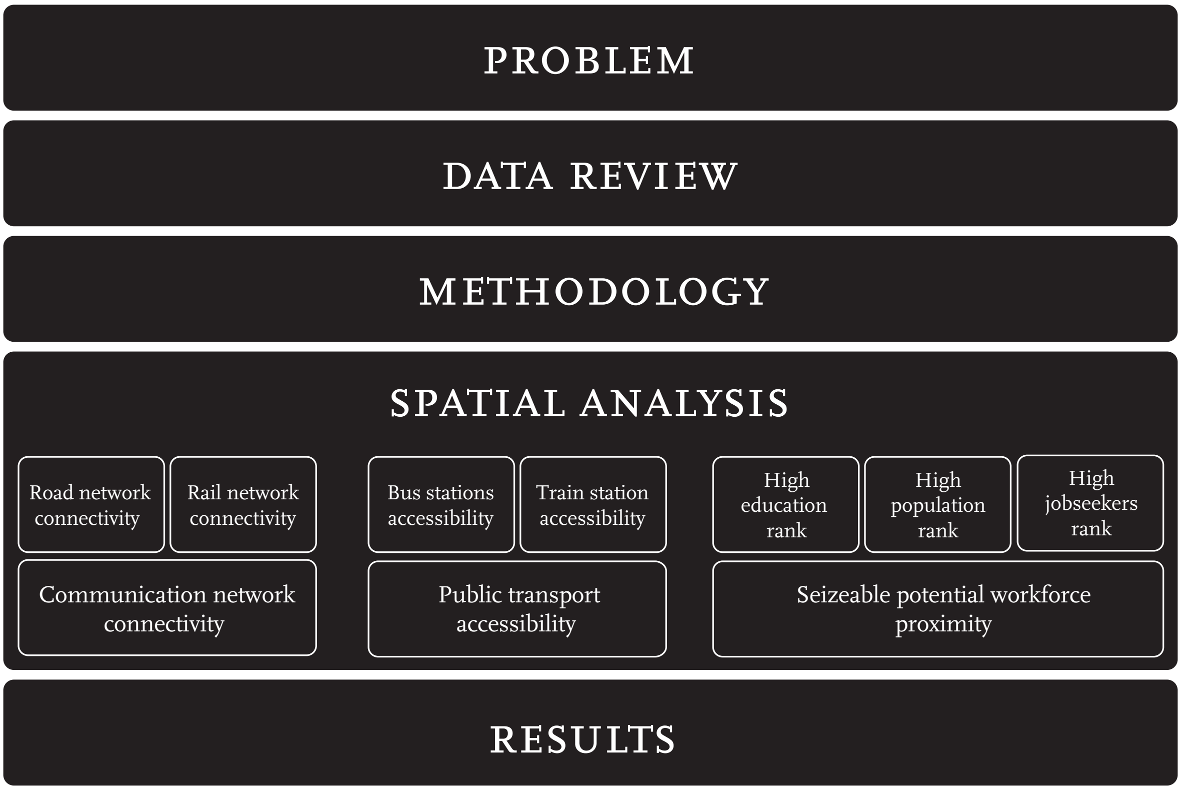




Data source: Department of Social Security Information Centre (1998), Oxford Index Team (2000).

PART 2
METHODOLOGY

After the available datasets have been selected and prepared for the spatial analysis, it is possible to proceed to the definition of a methodological approach to the problem (deSmith *et al.*, 2005). The methods employed in the spatial analysis are hereby presented in a way that identifies personal and common assumptions as well as choices. This section influences the whole spatial decision-making process **[Figure 2 *below*]**, by determining the acceptance or rejection of methods, techniques and tools.



[Figure 2] The process of spatial analysis

The spatial analysis is approached through the cartographic modeling (or algebra) method, a procedure examining spatial data by decomposing datasets into individual characteristics that can be transformed and combined into new variables through specific procedures (Tomlin, 1990). As for the data review, spatial analysis operations are performed in an ESRI ArcGIS 9.3.1 environment by using the ESRI ModelBuilder application. The aim of the analysis is to use the selected datasets to generate, through interacting spatial operations, a cartographic model allowing the evaluation of the three location criteria in search of a suitable place for the ACME headquarters. Specific methods are then employed in the investigation of the three ACME location criteria.

2.1 COMMUNICATION NETWORK CONNECTIVITY

Connectivity refers to the density of connections in a communication network and the directness of links. The term is employed in the analysis of different spatial phenomena. Various evaluation methods have been developed in the planning and transportation literature (Victoria Transport Policy Institute, 2011). In the spatial analysis, a connectivity study based on the presence of intersection in both road and railway network is employed. Concerning the railway network, the best connectivity is necessarily around train stations. Road network connectivity is assessed according to the number of intersections within a square kilometer. Here, a higher intersection density indicates an area with a better road network connectivity (Victoria Transport Policy Institute, 2011). Best-connectivity locations in the communication network are then estimated in proximity to train stations and roads with the best network connectivity. The lack of data concerning the communication network (directions, classes etc.), denies the possibility of producing a more comprehensive analysis.

2.2 PUBLIC TRANSPORT ACCESSIBILITY

Accessibility generally describes the capacity to reach a geographic location, where variables are space and time. Although it seems like a simple concept, accessibility is vague and difficult to clearly define and measure (Curtis and Scheurer, 2010). In order to determine public transport accessibility, a simple walkable catchment radius approach, combining bus and train stations' accessibility, has been selected. Following several examples in scientific literature, the walkable catchment for bus stations is set to 400 meters and 800 meters for train stations (Curtis and Scheurer, 2010; Andersen and Landex, 2008). Locations with good public transport accessibility are therefore within bus or train stations catchment areas. The lack of exhaustive data about the public transport networks (routes, frequencies etc.) hinders a multi-criteria accessibility analysis.

2.3 SIZABLE POTENTIAL WORKFORCE PROXIMITY

In this case study, it is assumed that the sizeable potential workforce proximity is determined by weighting socio-economic datasets according to population data (Frohlich *et al.*, 2001). This operation is based on the EDUCATION, JOBSEEKERS and POPULATION raster datasets, where values have been previously ranked in an ordinal scale. In order to smooth extreme differences caused by artificial ward boundaries, the socio-economic datasets are then filtered by considering neighbouring locations (UNIGISa; UNIGISb). Sizeable potential workforce proximity is therefore assessed by the sum of the two socio-economic indicators previously weighed according to the population data (Bernasconi *et al.*, 2010). Even though the weighting of hierarchical values is a common scientific method, its implementation in this case study is personalized due to the lack of reference relevant for spatial analysis. Furthermore, it is not possible to employ a method to locate a 'precise point' on the map, because of the inaccurate spatial resolution of the raster datasets.

Finally, the suitable location for the ACME headquarters is determined according to the analysis of the three location criteria. The site will be selected by overlaying locations with a good connectivity to the communication network, good accessibility to public transport and proximity to sizeable potential workforce. The results of the spatial analysis are finally presented as commentated maps showing spatial patterns of the three location criteria and the suitable (part of a) ward for the ACME headquarters.

PART 3
SPATIAL ANALYSIS

Following the definition of a methodological approach, it is possible to begin the spatial analysis of the three ACME location criteria in search of a suitable location for their headquarters. A cartographic modeling method is employed in order to develop and present procedures and operations employed in the spatial analysis (Tomlin, 1990). The cartographic model includes the following elements (UNIGISc):

- Spatial datasets selected in the data section;
- A flowchart representing the process of spatial analysis;
- A presentation of the process of spatial analysis in plain language;
- An explanation of the operations and commands employed in the spatial analysis.

The spatial analysis is detailed in a flowchart **[Figure 3, p.11]**, which is created from the ESRI ModelBuilder application, chaining together spatial operations and analytical functions by using the output of an operation as the input to another one (Environmental Systems Research Institute, 2009). The flowchart resumes the structure of the spatial analysis.

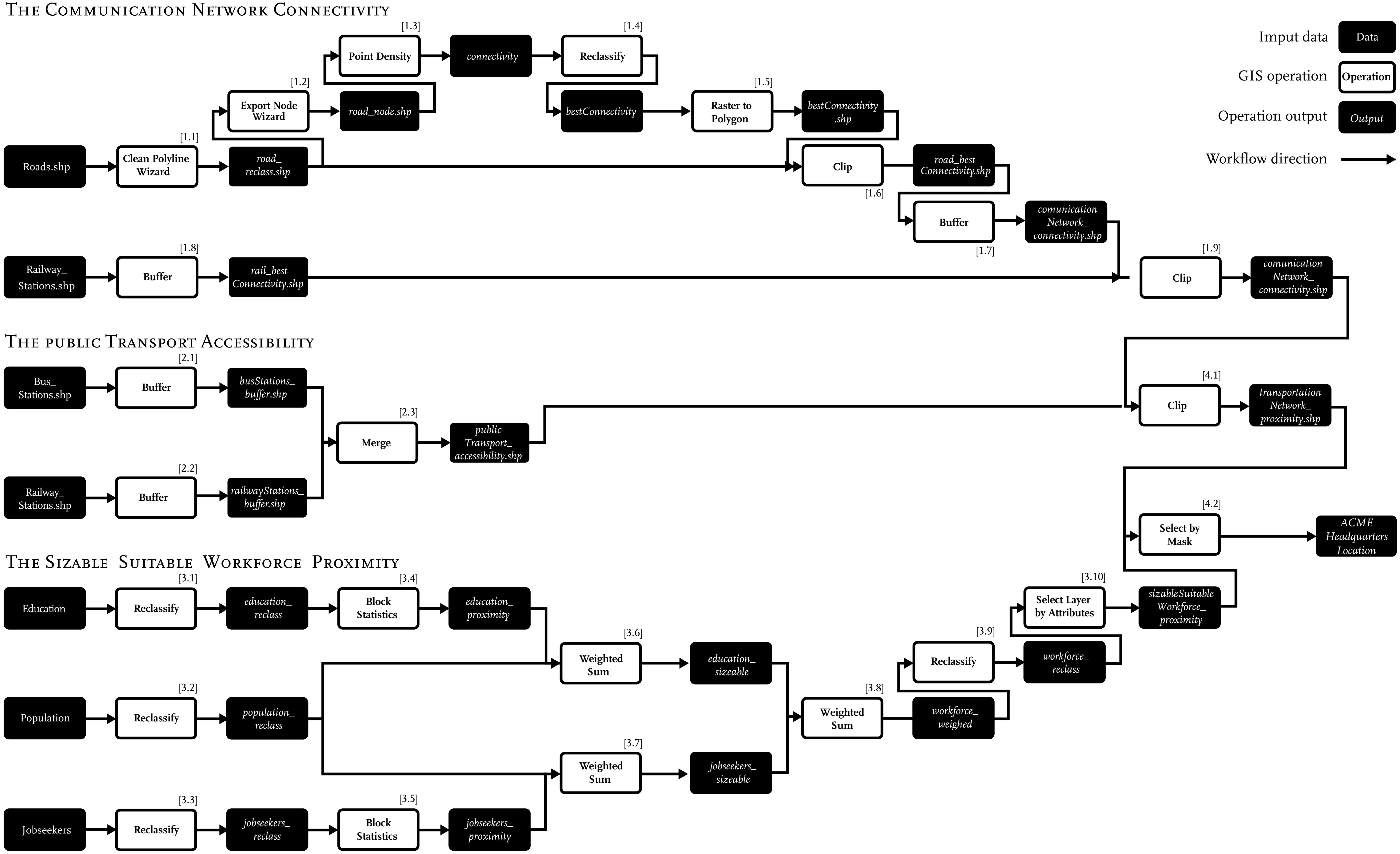
3.1 COMMUNICATION NETWORK CONNECTIVITY

In order to calculate the road network connectivity, it is first necessary to extrapolate the intersections – or nodes – from the road network, where the cul-de-sac heads must not be included. This spatial operation is performed using the ET GeoWizards extension. The Clean Polyline Wizard (ET GeoWizards)**[Figure 3–1.1]** is first employed to optimize the topology of the Roads polyline feature. Then, the Export Nodes Wizard (ET GeoWizards)**[Figure 3–1.2]** creates the ROAD_NODE point features, where the intersections of the polyline feature are located **[Figure 4 *below*]**.

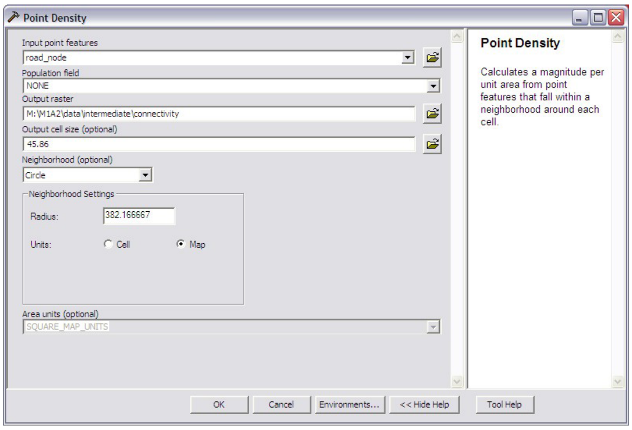
[Figure 4] Export Nodes Wizard dialog window.

[Figure 3]

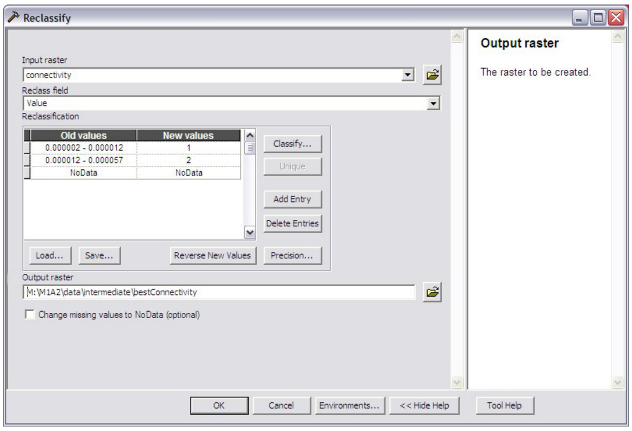
ACME HEADQUARTERS LOCATION
Spatial operations workflow



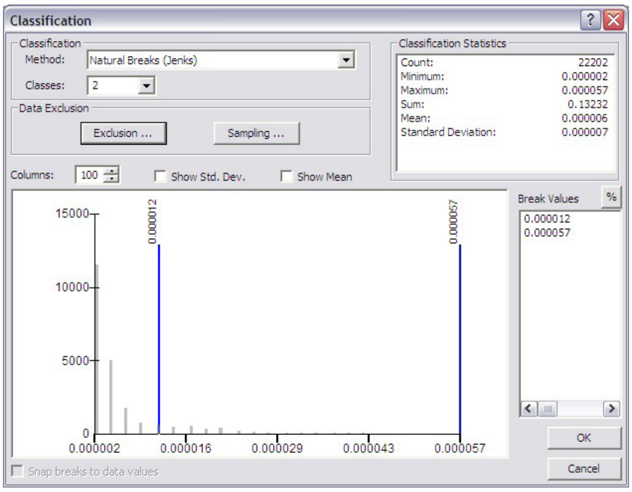
Once road network nodes have been identified, intersection point density – namely connectivity areas – can be determined. Consequently, locations with poor road network connectivity can be rejected from the analysis. This spatial operation is carried through the Point Density Tool (Spatial Analyst extension)**[Figure 3–1.3]** that generates the CONNECTIVITY raster feature where every pixel is associated to an intersection point density value. Here default parameters are employed **[Figure 5 *below*]**. The Reclassify Tool (Spatial Analyst extension)**[Figure 3–1.4]** allows reclassing the raster dataset into two road network connectivity classes, where locations with good road network connectivity are kept **[Figure 6 *below*]**. Classification has been made according to the Natural Breaks (Jenks) method **[Figure 7]**:



[Figure 5] Point Density Tool settings window.



[Figure 6] Reclassify Tool settings window.



[Figure 7] Reclassify Tool classification settings window.

Finally, roads with good network connectivity can be located. A suitable location for the ACME headquarters can therefore be defined within a radius of 800 meters around these roads. In order to perform this last operation, the bestConnectivity raster dataset is converted to a polygon through the Raster to Polygon Tool (Conversion extension)**[Figure 3–1.5]** and then clipped through the Clip Tool (Analysis extension)**[Figure 3–1.6]** to the road_bestConnectivity polyline feature. The 800 meters buffer is then applied by using the Buffer Tool (Analysis Extension)**[Figure 3–1.7]** on the clipped Roads polyline feature.

Railway network good-connectivity locations are obviously around train stations. For this reason it is possible to find a suitable location for the ACME headquarters within a radius of 800 meters around train stations, according to the railway network connectivity criteria. This operation is applied by simply creating an 800 meters buffer feature around the Railway_Stations point features by using the Buffer Tool (Analysis Extension)**[Figure 3–1.8]**.

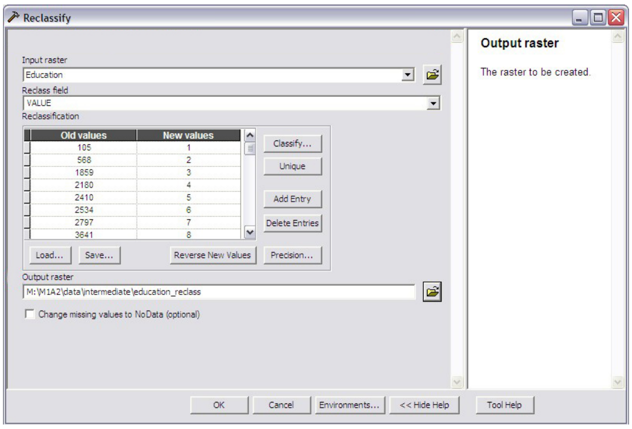
Once good-connectivity locations to the road and railway network have been established, it is possible to identify areas with good communication network connectivity. Those areas are located at the intersection between the road network connectivity location and the railway network connectivity location. The Clip Toolbox (Analysis Extension)**[Figure 3–1.9]** is employed in order to perform this spatial operation.

3.2 PUBLIC TRANSPORT ACCESSIBILITY

Public transport accessibility is determined according to bus or train stations' walkable catchments. Bus stations accessibility is set to a radius of 400 meter while train station accessibility radius is set to 800 meters. The buffer areas have the best public transportation accessibility. The buffering operation is carried out with the Buffer Tool (Analysis Extension). For the Bus_Stations point features the parameter is set to 400 meters **[Figure 3–2.1.]** and for the Railway_Stations point feature to 800 meters **[Figure 3–2.2]**. The resulting buffer polygons are then merged through the Merge Tool (Data Management extension)**[Figure 3–2.3]**.

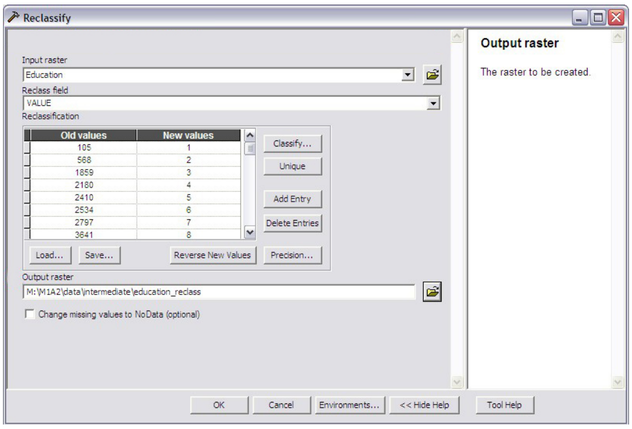
3.3 SIZABLE POTENTIAL WORKFORCE PROXIMITY

The sizeable potential workforce proximity criterion is studied through spatial analysis of Education, Jobseekers and Population raster datasets, previously ranked in an ordinal scale. The Education dataset shows values based on Anytown's wards' education rank. The Jobseekers dataset orders the wards values according to their jobseekers rank. The Population dataset is ranked according to wards' population. The ranking operation is performed by using the Reclassify Tool (Spatial Analyst extension) for the three raster datasets: Education **[Figure 3–3.1]**, Jobseekers **[Figure 3–3.2]** and Population **[Figure 3–3.3]**. No special classification method has been employed; the datasets are classed in an ordinal scale, from lower to higher value **[Figure 8, p.14]**.



[Figure 8] Reclassify Tool settings window.

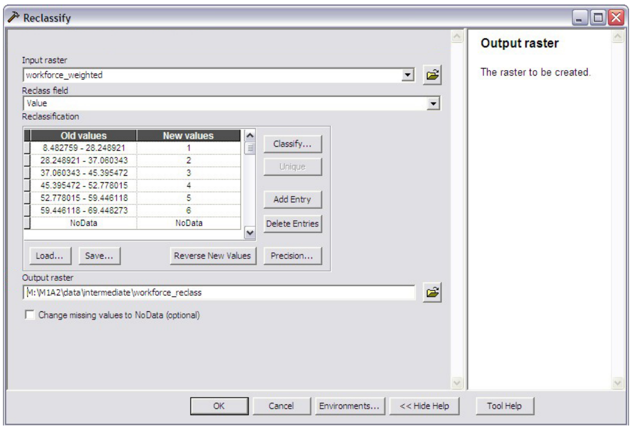
Once the datasets have been classified, it is possible to smooth artificial differences – caused by the wards' rigid borders – of the Education and Jobseekers datasets, by computing patterns occurring in the neighbor locations (UNIGISb). The operation is carried by applying the Block Statistic Tool (Spatial Analyst extension) to the Education **[Figure 3–3.4]** and Jobseekers **[Figure 3–3.5]** raster features. Default parameters are used to calculate the filtered values, except for the statistical operation, where the median value has been employed in order to determine the pixels' central tendency **[Figure 9 *below*]**. The resulting raster datasets are then reclassified from lower to higher values by using the Reclassify Tool (Spatial Analyst extension) in order to proceed to the next step.



[Figure 9] Block Statistics Tool settings window.

The Education and Jobseekers datasets can then be weighed according the Population raster feature values, because the sample size is commonly assumed to be a relevant factor in the analysis (Frohlich *et al.*, 2001). Since ratios like percentages are not meaningful for the raster datasets measurement scale, a simple sum of Education and Population values on one side and Jobseekers and Population values on the other is calculated. Those operations are performed with the Weighed Sum Tool (Spatial Analyst extension) **[Figure 3–3.6, 3.7]**, where values are combined, through a simple sum, in two new raster datasets.

Finally the two raster features – representing the workforce suitability (the Education dataset) and availability (the Jobseekers dataset) – can be combined in order to provide information about sizable potential workforce proximity. This data can then be classified in order to extrapolate the best sizable potential workforce. This operation is performed by using the Weighed Sum Tool (Spatial Analyst extension)**[Figure 3–3.8]** where the raster values are added and then combined in a new raster dataset. The Reclassify Tool (Spatial Analyst extension) **[Figure 3–3.9]** then allows the reclassifying of the raster values in six classes using Natural Breaks (Jenks) method **[Figure 10 *below*]**. Then, pixels in the higher class are selected through the Select Layer by Attributes **[Figure 3–3.10]** – where the SQL formula is 'VALUE = 6 OR VALUE=5' – and exported, creating a raster feature presenting only the most suitable sizable



[Figure 9] Reclassify Tool settings window.

potential workforce location.

3.4 THE ACME INTERNATIONAL HEADQUARTERS LOCATION

Once spatial patterns for the three ACME location criteria have been identified, it is possible to extrapolate a location that would best serve for the ACME International headquarters. The site can be selected by overlaying locations with good connectivity to the communication network, accessibility to public transport and proximity to sizeable potential workforce. This last operation is performed in two stages: first by clipping the two polygons, representing the Communication Network Connectivity and Public Transport Accessibility, with the Clip Tool (Analyst extension) **[Figure 3–4.1]**. The resulting polygons will be intersected with the raster feature presenting the most suitable Sizable Potential Workforce location, through the Extract by Mask Tools (Spatial Analyst extension) **[Figure 3–4.2]** and the remaining pixels will represent the suitable location for the ACME Headquarters.

PART 4
RESULTS

The final step in the process of spatial analysis is the output presentation: a summary of what has been done and the interpretation of the final results (deSmith, 2005). In this section, the outputs of the ACME location criteria spatial analysis are introduced and presented on maps. A suitable location for the ACME International headquarters is discussed and proposed in relation to the analyzed criteria. The suggested location for the ACME headquarters is finally presented on a map.

4.1 COMMUNICATION NETWORK CONNECTIVITY

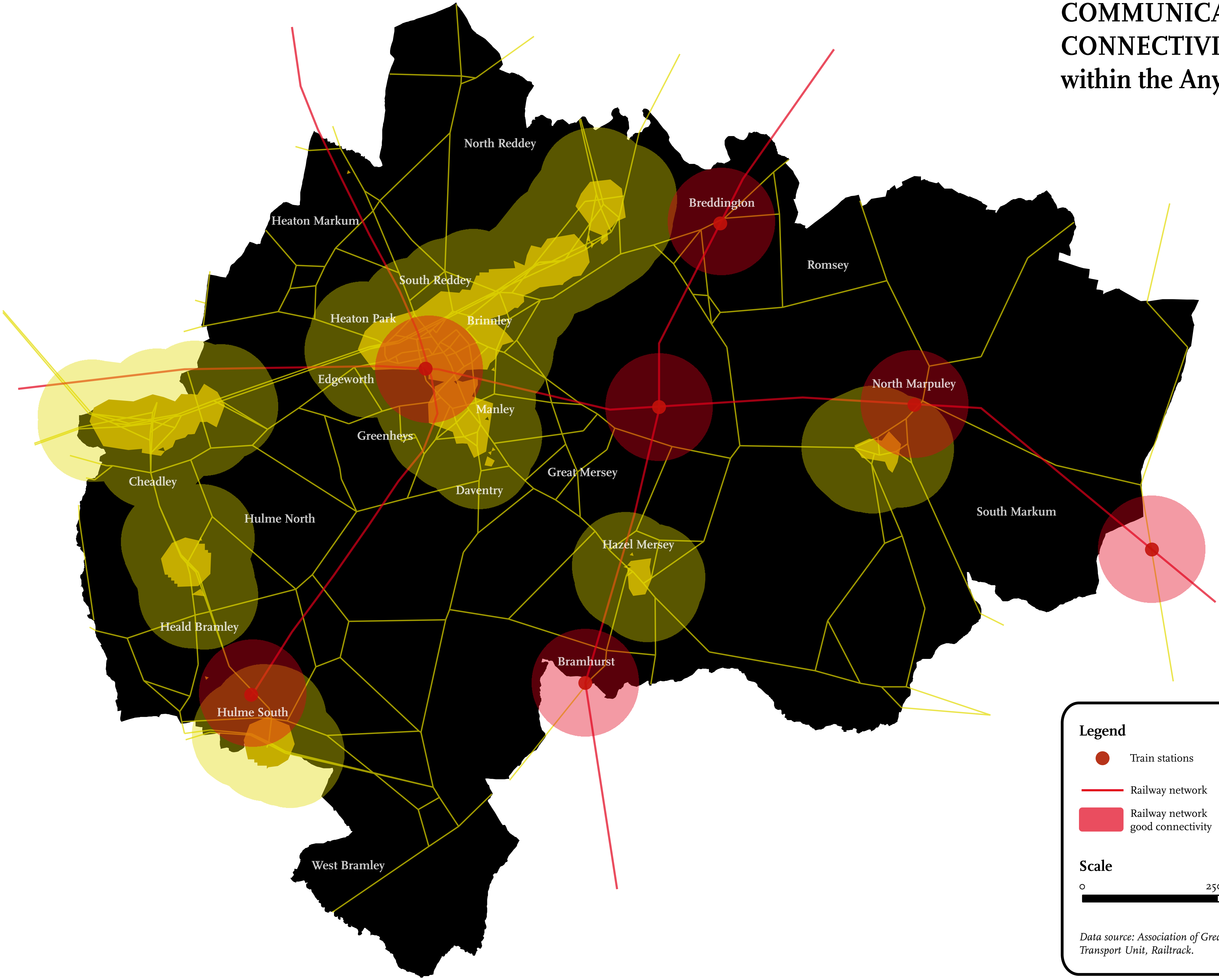
As stated in the methodology, the communication network connectivity criterion has been analyzed by examining the position of intersections – or nodes – in both road and railway networks. In fact, a good-connectivity location is generally conceived within a network composed of many links and intersections, and minimum cul-de-sacs dead-end (Victoria Transport Policy Institute, 2011). This criterion is a key factor in the choice of a facility location, since good connectivity to the communication network allows direct linkage, which minimizes time and distance for the transportation of goods, as well as the facilitation of access to wider markets.

A preliminary examination of the Anytown road network shows a radial structure, developing from the supposedly center of the region (the areas surrounding Brinnley and Manley) in the direction of the periphery **[Map 2, p. 17]**. Furthermore, a few concentric axes connect sectors outside the center. As it is possible to expect, good-connectivity locations can be find around Brinnley and Manley – in the central part of the Anytown region. A few good-connectivity clusters are also located in the west of the region, and presumably connected to a freeway. In fact, according to the network structure, the Cheadley good-connectivity area appears to be located on a freeway main junction. In the southeast of Anytown, two good-connectivity clusters seem on the edge of the road network and are definitely too small to qualify as ACME's headquarters suitable location. Railway network structure develops in a sort of shifted grid, where a rail line cuts the center of the region from east to west by intersecting two axes orientated in direction north-south. The east-west rail link seems to be the more efficient in the coverage of the region because it connects to four over seven Anytown train stations. Railway network connectivity is inevitably related to the presence of train stations, which serve as center of transportation for goods and people. In this context, it is interesting to notice that a train station – placed at the intersection between two rail lines – is located in Edgeworth, in the center of Anytown region.

As previously stated, places with good communication network connectivity are located at the intersection of places with the best road and railway network connectivity. In the spatial analysis, an 800 meters catchment radius is provided around those good-connectivity lo-

[Map 2]

COMMUNICATION NETWORK CONNECTIVITY
within the Anytown region



Legend

- Train stations
- Railway network
- Railway network good connectivity
- Road hubs
- Road network
- Road network good connectivity

Scale

0 — 2500 — 5000 Meters

Data source: Association of Greater Anytown Authorities, Greater Anytown Municipal Transport Unit, Railtrack.

cations in order to determine a suitable placement for ACME's headquarters. This operation highlights three areas with good connectivity to the communication network. The largest area is located in the center, between Brinnley, Edgeworth, Greenheys, Heaton Park, Manley, and South Reddey. A second good-connectivity cluster is in the southwest of Anytown, between Heald Bramley and Hulme South. A third one is in the southeast of the region, between North Marpuley and South Markum.

According to the spatial analysis of the communication network connectivity criterion, the areas mentioned above may qualify as potential locations for the ACME headquarters. Nevertheless, it is necessary to mention that the regional situation of those best-connectivity locations is very different. Therefore, the costs and benefits of the connectivity can vary widely. Even though the Anytown region center seems to have the best communication network connectivity, resilience factors such as road capacities or train frequencies can affect the accessibility of a location (Victoria Transport Policy Institute, 2011). In this context, the availability of data is a crucial element for a more comprehensive network connectivity analysis.

4.2 PUBLIC TRANSPORT ACCESSIBILITY

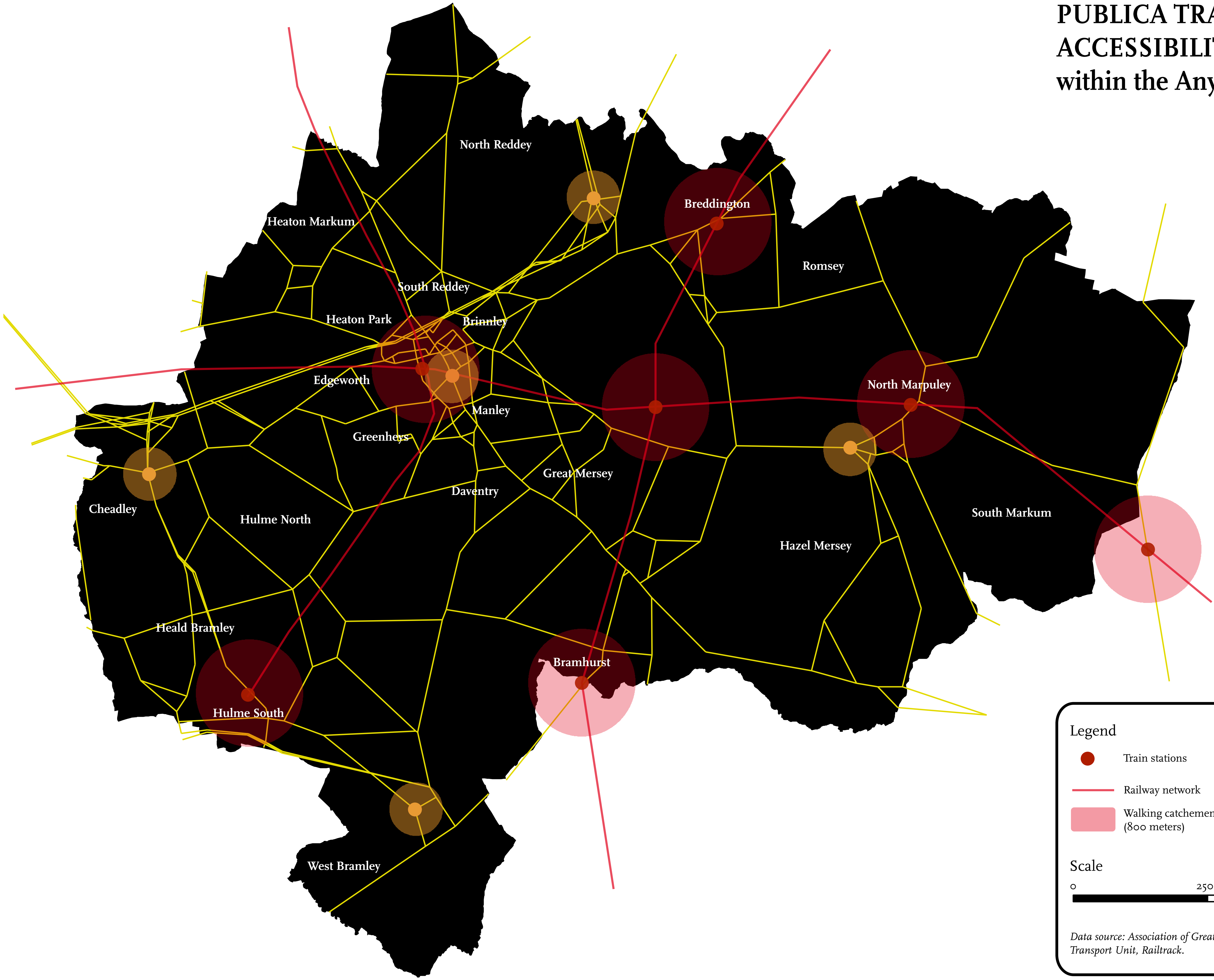
The public transport accessibility criterion has been analyzed based on the geographical position of bus and train stations, and the walkable catchment areas around those points. In fact, the ACME headquarters should be located within an area accessible by public transport, where walking distances from bus or train stations are perceived as reasonable. According to transportation and planning literature those walkable catchments are set to 400 meters (five minutes' walk) for bus stations and 800 meters (ten minutes' walk) for train stations (Andersen and Landex, 2008).

A preliminary examination of the Anytown bus station locations shows a homogenous distribution of stations across the region, especially in the periphery **[Map 3, p. 19]**. In fact, four over five bus stations are located at the edges of the region (in Cheadley, North Marpuley, West Bramley and in the northeast of Brinnley) and only one is located in the central area, southwest of Brinnley. By comparing bus locations to road network good-connectivity areas issued from the precedent spatial analysis, it is also possible to notice that bus stations generally have good connectivity to the road network. Train stations are also homogeneously distributed within the Anytown region and mainly located on the rail line cutting the center of the Anytown region from east to west. This line connects the central ward of Edgeworth to Hazel Mersey, North Marpuley and South Markum. A direct connection to the center is also provided from the Hulme South train station with the eastern intersecting rail line. The train stations located in Bramhurst and in the northwest of Breddington have a reduced accessibility to the center, and in general to the whole railway network, because they are not directly connected.

Locations with good public transport accessibility are therefore located within joint walking catchment areas of bus and train stations. According to the spatial analysis, it is possible to find ten areas accessible by bus or/and train within the Anytown region. The biggest catch-

[Map 3]

PUBLICA TRANSPORT ACCESSIBILITY within the Anytown region



Legend

Train stations

Bus stations

Railway network

Road network

Walking catchement (800 meters)

Walking catchements (400 meters)

Scale

0 2500 5000 Meters

Data source: Association of Greater Anytown Authorities, Greater Anytown Municipal Transport Unit, Railtrack.

ment area is located between North Marpuley and South Markum, where both bus and train stations are in proximity. The second accessibility area is located in Anytown's center, between Edgeworth and Brinnley, where a train and a bus station are almost contiguous. Other accessibility areas are related to a single mode of transportation, where train stations accessibility is more relevant, because of the size of their catchment areas.

The spatial analysis of the public transport accessibility criterion yields ten areas which are potential locations for the ACME headquarters. Even though public transport stations are widely considered as accessibility key elements (Andersen and Landex, 2008), a deeper network analysis allows a better understanding of locations' strengths and weaknesses. Data about public transport routes and frequencies is useful in the implementation of a service area approach and in setting a hierarchy of public transport stations according to their performances (Andersen and Landex, 2008).

4.3 SIZABLE POTENTIAL WORKFORCE PROXIMITY

The sizeable potential workforce proximity criterion is determined by weighting Education and Jobseekers datasets according to the Population value (Frohlish *et al.*, 2001). As a result of the spatial analysis, the ward boundaries are now smooth and the (part of) wards with sizable potential workforce are highlighted. ACME's headquarters are supposed to be located in proximity of those (part of) wards, in order to fill the 5'000 available technical, scientific, management and sales positions.

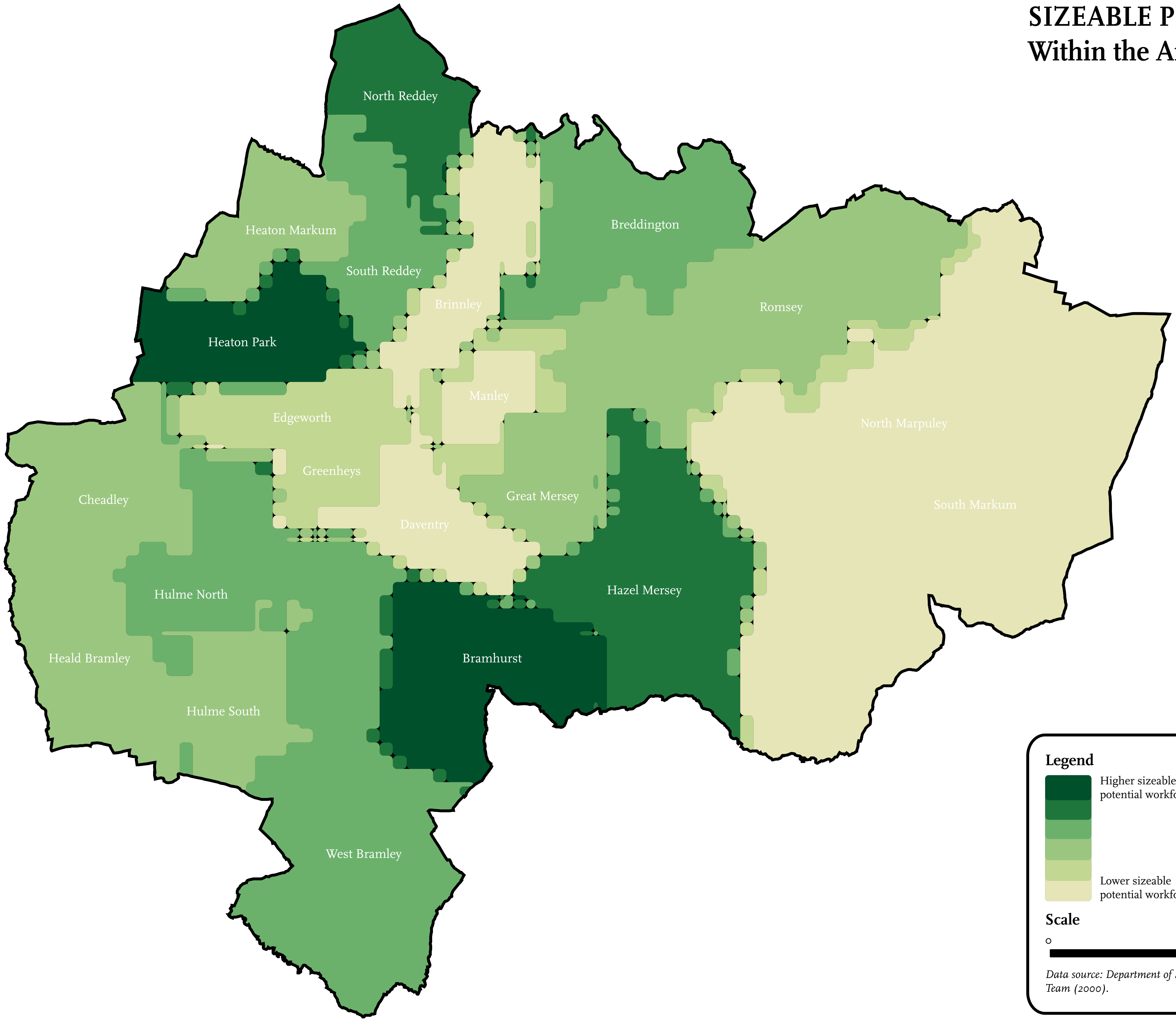
A prior inspection of the Education, Jobseekers and Population raster datasets, as presented in the Data section provides interesting elements, useful in the evaluation of the output **[Map 4, p. 6]**. Educated people are generally located in the southern periphery of the Anytown region – especially in Bramhurst, Hulme South, Heald Bramley, South Markum and West Bramley – except for the central areas of Heaton Park and especially Manley. This phenomenon can be explained according to the suburbanization process, supporting the establishment of the higher socio-economic class – in search of better quality of life – in the suburbs (Gregory *et al.*, 2009). Jobseekers are principally located in the center-north, mainly in Brinnley and Edgeworth, and more generally in the north of Anytown region. In fact, deprived people are often located in proximity of regional centers – where economic and social activities are concentrated – in order to avoid the cost of transportation (Gregory *et al.*, 2009). Population repartition shows that the most populated wards are generally located in the west periphery of the Anytown region, from North Reddey to Bramhurst. Central areas present different amount of population, but they are generally less populated.

According to the spatial analysis of the sizeable potential workforce dataset, we can see that the most suitable wards for the ACME headquarters are Bramhurst, Hazel Mersey, Heaton Park and North Reddey **[Map 4, p. 21]**. Bramhurst and Hazel Mersey are located in the south of Anytown region. Both are wards high population and education values but the Jobseekers value is low. North Reddey is also one of the most populated wards, with the highest jobseek-

[Map 4]

SIZEABLE POTENTIAL WORKFORCE

Within the Anytown region



Legend

Higher sizeable potential workforce

Lower sizeable potential workforce

The sizeable potential workforce indicator has been calculated according to Anytown wards' ranks of jobseekers allowance claimants data and educational achievements data. The information has been weighed by wards population rank data.

Scale

0 2500 5000 Meters

Data source: Department of Social Security Information Centre (1998), Oxford Index Team (2000).

ers rank but low education level. Heaton Park's Jobseekers value is distinctively the highest, in addition to a high value in the population and education ranks.

As previously mentioned, the spatial analysis of sizeable workforce repartition, four suitable wards present high ranks have been selected. But dynamics influencing those results are different according to the ward geographical locations and characteristics. A higher population rank can have the same value as the sum of average ranking for education and jobseeker. This ambiguity can be linked to the choices of ranking datasets in an ordinal way and then weighting them according to the population (Frohlich *et al.*, 2001). Those choices have been nonetheless necessary because of the datasets heterogeneous sources. Another element reducing the precision of the spatial analysis is the raster resolution, that doesn't allow finding a suitable 'precise point' location for the ACME headquarters.

4.4 THE ACME HEADQUARTERS LOCATION

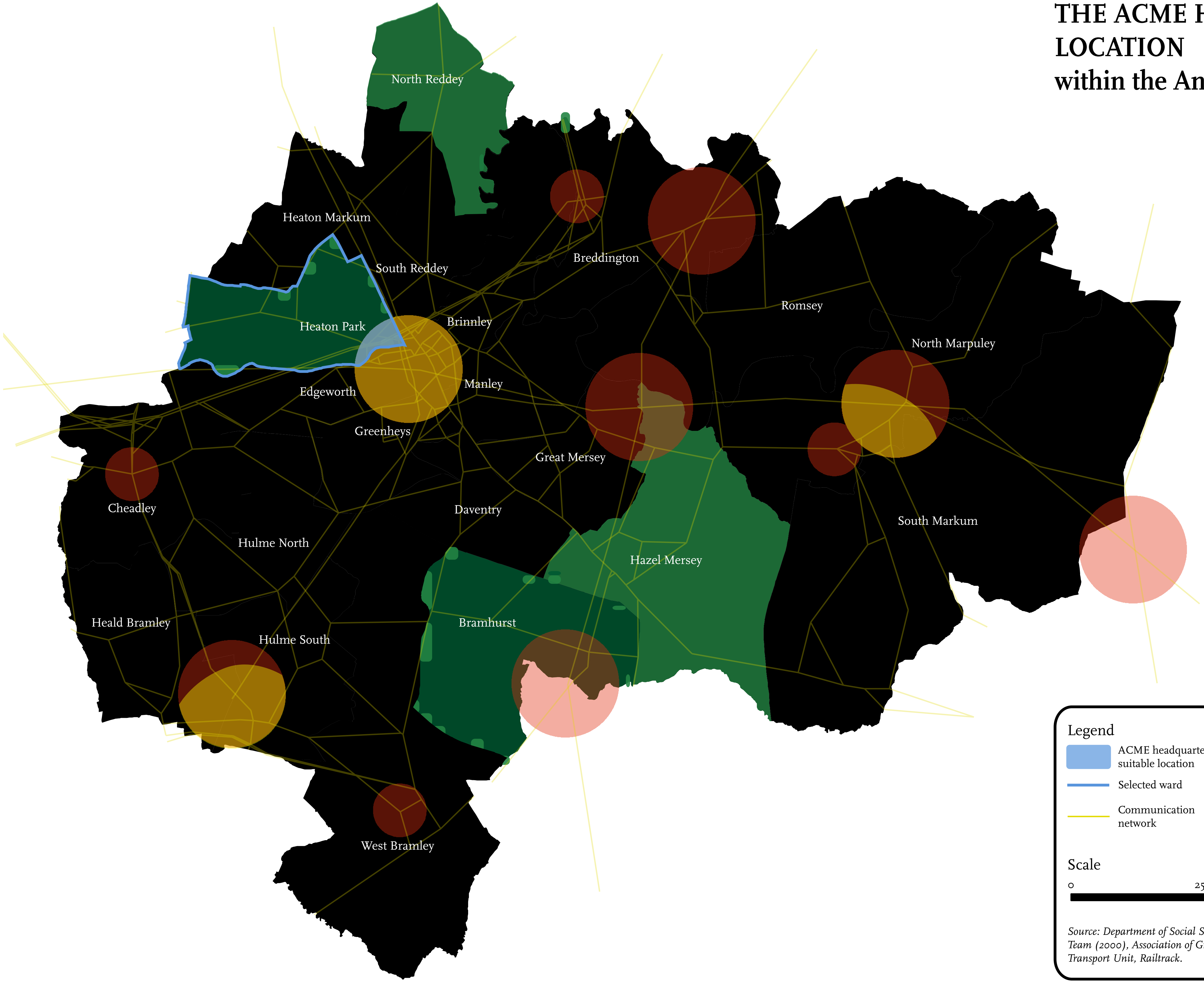
As previously stated, the suitable location for ACME's headquarters results from the three ACME criteria previously analyzed. An appropriate location should have a good connectivity to the communication network, accessibility to public transport and proximity to sizeable potential workforce. Therefore, a solution for the ACME headquarters location problem can be found by intersecting areas which are found suitable according to these specified criteria.

As stated before, in the Anytown region there are three areas with good communication network connectivity – resulting from the road and railway network good-connectivity locations. These areas are situated in the center, southwest and east of Anytown region **[Map 5, p. 23]**. The other sectors are not relevant in the choice of the suitable location for the ACME industries and are rejected because they are not connected to both road and railway networks. The public transport accessibility criterion analysis shows ten suitable locations, each with different characteristics , with the most accessible locations in the east and center of Anytown region where bus and train stations are in close proximity. Areas within train stations catchment are also relevant to be considered in the search for the ACME headquarters location, but bus station catchments are too small to be considered. The sizeable potential workforce criterion analysis highlighted four (part of) wards suitable for the implantation of the ACME headquarters. Two are located in the southern periphery of Anytown, one in the northern part and the last in proximity of the center.

The comparison of the two transportation criteria limit the choice of a suitable ward and shows that the center of Anytown – between Brinnley, Edgeworth, Greenheys, Heaton Park, Manley and South Reddey – is the best connected to road and railway networks, therefore accessible by bus and train. A part of this area, located southeast of Heaton Park, presents the best sizeable potential workforce location. According to the three ACME location criteria the most appropriate headquarters position is, therefore, within an area of about 170'000 m2 located at the southeast part of the Heaton Park ward.

[Map 5]

THE ACME HEADQUARTERS LOCATION
within the Anytown region



Legend

- ACME headquarters suitable location
- Selected ward
- Communication network
- Sizeable potential workforce proximity
- Public transport good accessibility
- Comunication network good connectivity

Scale

0 2500 5000 Meters

Source: Department of Social Security Information Centre (1998), Oxford Index Team (2000), Association of Greater Anytown Authorities, Greater Anytown Municipal Transport Unit, Railtrack.

CONCLUSIONS

The aim of this assignment was to explore the use of GIS as a spatial decision-making tool by applying a spatial analysis process to the ACME headquarters location case study. Returning to the initial problem, it is now possible to affirm that, through the different stages of spatial analysis, it is possible to effectively investigate and identify ACME's location criteria and suggest a suitable site for their headquarters, finally located in the southeast part of Heaton Park ward.

In order to reach this conclusion, an iterative process has been followed, starting from a review of the existing data and selection of its more relevant parts. This stage is fundamental in the determination of an approach to the case study and the whole process of spatial analysis. The quality of the provided datasets strongly limited the extensiveness of the analysis. Concerning vector datasets, the lack of comprehensive attributes of the road and railway network and bus and train stations has limited the ability to perform a detailed analysis of the communication network connectivity and public transport accessibility criteria. The raster datasets were at low resolution and therefore restricted the precision of the spatial analysis. The values' scales were heterogeneous and impossible to compare and analyze without a homogenization to ranking scales.

The methodological approach to the communication network connectivity and public transport accessibility was based on methods widely used in planning and transportation literature (Victoria Transport Policy Institute, 2011; Curtis and Scheurer, 2010; Andersen and Landex, 2008). Because of the poor quality of the data recieved and the lack of time for further research, it has not been possible to develop more complex methods of analysis. The sizeable potential workforce criterion analysis method has been developed more by necessity than by choice. Although necessary for considerations of precision, the reduction of raster datasets to simple ranks limited the range of methods to a simple analysis of dataset summed ranks. It is also necessary to mention that weighting methods are not unanimously welcomed in the scientific community (Frohlich *et al.*, 2001).

The spatial analysis itself was based on a cartographic modeling method, emphasizing the use the GIS-package ESRI ArcMap. The main strength of this method lies in the capacity of GIS to assess multi-criteria problems through a chain of spatial operations on different datasets, in order to extract and create useful information (Tomlin, 1990). Here, a wide range of GIS operations have been employed, such as: network analysis, filtering and raster queries and overlay. Although the employment of these tools seems easy and immediate, they are in fact quite complex, and it is necessary to understand the logic behind these operations in order to use the appropriate settings. For this reason, default settings values have been employed in the spatial analysis.

The previous paragraph provides an answer to the second question raised in the introduction: whether GIS is an effective decision-making tool in this spatial analysis case study. The answer is obviously affirmative but, as previously shown, a successful spatial analysis does not depends solely on GIS software, but on various components such as data quality and appropriate methods.

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