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Optimising the location of antenatal classes

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ABSTRACT

Objectives: To combine microsimulation and location-allocation techniques to determine antenatal class locations which minimise the distance travelled from home by potential users.
Design: Microsimulation modeling and location-allocation modeling.
Setting: City of Leeds, UK.
Participants: Potential users of antenatal classes.
Methods: An individual-level microsimulation model was built to estimate the number of births for small areas by combining data from the UK Census 2001 and the Health Survey for England 2006. Using this model as a proxy for service demand, we then used a location-allocation model to optimize locations.
Findings: Different scenarios show the advantage of combining these methods to optimize (re)locating antenatal classes and therefore reduce inequalities in accessing services for pregnant women.
Key Conclusions: Use of these techniques should lead to better use of resources by allowing planners to identify optimal locations of antenatal classes which minimise women's travel.
Implications for practice: These results are especially important for health-care planners tasked with the difficult issue of targeting scarce resources in a cost-efficient, but also effective or accessible, manner. (169 words).

Introduction

The aim of this paper is to offer a methodology to help reduce inequalities in accessing antenatal classes. Historically classes have been offered to prepare parents-to-be for childbirth and issues following birth such as advice on infant feeding. McMillan et al. (2009) provide more detail of the types of service provided by antenatal classes in the comprehensive review of antenatal education '*Birth and beyond: a review of the evidence about antenatal education*'. For example, access to classes can provide improved health benefits in terms of promoting breast feeding, especially for low income mothers. In addition to advice and support, antenatal classes help to increase the confidence of parents-to-be and can produce new social networks.

In 2004, the UK Department of Health (DoH) published the 'National Service Framework for Children, Young People and Maternity Services', which offered guidelines for the provision of maternity services of the 'highest standards' to meet the needs of pregnant women and mothers (Department of Health, 2004). It was argued that pregnant women need access to antenatal classes to prepare them for labour and birth. However, at the same time, antenatal classes in certain parts of the UK have been withdrawn, or the number of classes cut, due to financial problems (Clift-Matthews, 2007). This came at a time when UK Government policy was trying to encourage more community based services at the expense of centralised hospital treatment. The White Paper 'Our Health, Our Care, Our Say: a New Direction for Community Services' (Department of Health, 2006) outlined the aim of bringing maternity services (along with other health services) more into the community to provide better access to maternity care. A more recent White Paper 'Maternity Matters' (Department of Health, 2007) aimed to ensure that women have high quality, safe and accessible services and the choice of where to give birth. Therefore locations where antenatal services are offered should

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be women-focused and family-centred. The emphasis has again been placed on community maternity care to improve access and hence encourage a higher uptake of services.

The study area for this paper is Leeds, a city in West Yorkshire, UK with a population of around 750,000 people. In Leeds, in addition to the standard antenatal classes, services are also offered for different ethnic groups, such as ethnic minority communities (for example the 'Haamla Service'). Teenagers also get a separate 'parentcraft' package, which is incorporated into their care pathway. Specially trained midwives give teenagers one-to-one sessions rather than group sessions (as is the case for standard antenatal classes). The focus for Leeds Teaching Hospitals in recent years and local service commissioners has been to reduce health inequalities and improve access to services (Making Leeds Better, 2005). This paper focuses on the locations of standard antenatal classes and offers a methodology for comparing these to optimal locations based on the number of small-area births.

The rest of the paper is structured as follows. Firstly, we briefly review the key literature in the field including a short overview of the proposed methods and their application in health related areas. In the section 'Methods', we examine the problem of how to estimate birth rates for small geographical areas. We argue that taking one key demographic factor alone (age, social class, and ethnic status) can lead to very different estimates at the small-area level. Therefore, we introduce the modelling method of *microsimulation*, a technique, which enables us to estimate the number of small-area births based on a combination of demographic characteristics and *location-allocation* models, which can be used to locate classes 'optimally' in relation to the estimates of demand generated from the microsimulation process. In the section 'Findings', a number of scenarios regarding alternative policy options are given. In the final section, we offer some concluding comments.

Literature review

Inequalities in the uptake of antenatal classes are apparent for different population groups. For example, Hirst and Eisner (1999) noted that women from disadvantaged areas were least likely to access such services. Similarly, a study by Hamlyn et al. (2000) showed that there were variations in access rates to antenatal classes by women from different occupational groups. Their survey found that 82% of mothers in higher paid occupations attended antenatal classes in comparison to 54% from lower paid occupations. The lowest attendance rate (27%) was found for mothers who had never worked or who were long term unemployed. Women holding a university degree were almost eight times more likely to attend a class in comparison to mothers with a 'minimum' level of education. A recent study by Redshaw and Heikkila (2010) showed that the offer of antenatal classes was higher to first time mothers (87%) than mothers who have already given birth (50%). Further, the study showed that classes were more often offered to younger women aged less than 19 (80%) in comparison to older women aged 40 or more (65%) whereas Asian and Black women were least offered antenatal classes in comparison to White women. A key question, which then emerges is how to increase attendance rates, especially for disadvantaged mothers. One approach is to improve accessibility to services. The location of individual classes is important, especially when women are dependent on public transport (Cliff and Deery, 1997). Although the National Health Service (NHS) provides classes free of charge, a shortage of staff and resources means a limited universal provision of such services. This makes it more difficult for women in certain parts of cities or regions to access antenatal classes. Factors such as language differences may also prevent certain ethnic groups making use of services. Although some women may feel accessing education and support services are not as important as attending for antenatal checks and investigations, McMillan et al. (2009) report the importance of antenatal classes for helping prevent complications within pregnancy and that classes are highly supportive for preparing mothers-to-be for labour and birth and gaining access to good social support networks. Therefore, making services more accessible, and focusing on certain population groups, could potentially increase the uptake of antenatal classes.

In order to locate classes optimally, it is important to be able to estimate the likely distribution of women giving birth across spatial areas. This is especially necessary if facilities are to be located within communities rather than in central locations such as major hospitals. In the UK (as in many other countries), data on the residential location of pregnant women are difficult to obtain. Thus it is useful to employ modelling approaches (microsimulation in this case) that will estimate the likely number of births at the household level, which can then be aggregated into small zones such as Census output areas (effectively 2439 small community areas in Leeds). If this data can be provided or estimated, it will allow a much better spatial targeting of antenatal class locations. In the UK, the number of births is available from time to time at the Census ward level. In Leeds, this gives data for only 33 areas, and a number of these are very large, heterogeneous areas in terms of population characteristics. Nevertheless, this data are useful for this project as it allows us to test the results of the model—ensuring that when aggregated, the total number of births is close to the known Census ward level data.

Redshaw and Heikkila (2010) showed that in England most antenatal classes were offered in North-East (73%) and least classes were offered in the East Midlands (62%). Further, the attendance rate varied between 37% and 45%. The majority attended antenatal classes at the start of the third trimester and 12% of women preferred private and voluntary sector paid-for courses where women have to pay a contribution as these classes are not offered for free. These are non-profit charity organisations, which have to cover their expenses to exist. Such classes were less common for women aged below 30, women living in more deprived areas or women whose ethnic background are Black or who are from Minority Ethnic groups. The report by TNS (TNS, 2005) showed that antenatal classes are the maternity service least accessed by pregnant women, with only a 37% attendance rate (58% for first time mothers). Non-attendees stated that they believed such classes were not important or useful. In addition, only 53% of mothers who attended antenatal classes were satisfied with the choice offered of where and when the class took place. Further, the survey detected some differences within different population groups in accessing classes. Women in lower socio-economic groups attended antenatal classes less often than women in higher socio-economic groups. Since women in lower socio-economic groups tend not to have the resources to attend privately funded classes this may mean that they do not attend a class at all. Further, single women were less likely to attend a class in comparison to married women. In terms of ethnicity, Madhok et al. (1998) analysed satisfaction with health services among Pakistani women in Middlesbrough, UK. Their findings showed that, in general, Pakistani women claimed to be satisfied with health services, although only a few attended antenatal classes. In fact, only two pregnant women out of the 39 surveyed accessed classes, with a frequent complaint voiced around the difficulties of language barriers. The 37 non-attendees listed reasons that they 'were not aware of the service', which they 'did not have time to attend', there were 'language problems' and a minority reported that they simply 'did not bother'.

The time and day of antenatal classes are an important factor in studying access but also the locations of the classes are crucial, especially when places are limited and/or there are not enough midwives available. Cliff and Deery (1997) highlighted that pregnant women in the UK do not attend antenatal classes when the location and timing of the service are not convenient for them. When they are dependent on public transport then the situation is even more difficult. The importance of increasing accessibility to services (including longer opening hours) has encouraged new debates concerning alternative forms of location for classes. A thoughtful planning of both location and time for classes is necessary to meet the need of particular population groups, such as mothers from different social classes or ethnic backgrounds.

Although the literature supports the hypothesis that there are many reasons why women may not attend antenatal classes, there is evidence in the literature cited above that location and access are important factors. If access to service locations can be improved then we believe this provides a useful starting point for improving antenatal services to the community. In the following section of this paper we demonstrate the modelling approach using the case study of antenatal classes in the City of Leeds, UK.

Methods

Spatial microsimulation and location-allocation models

Spatial microsimulation is a novel approach to estimate small area data to support policy makers in their decisions. Microsimulation originated in the 1950s for fiscal planning, analysing how policy changes in relation to Government tax or benefits would affect certain population groups. Spatial microsimulation, however, does not only consider the impacts on certain population groups but also where these impacts occur: i.e. what communities are most impacted. There is a limited but growing number of spatial microsimulation applications in the area of health-care planning. Recent applications have focused on obesity (Edwards and Clarke, 2009), smoking (Tomintz et al., 2009; Smith et al., 2011), and diabetes (Smith et al., 2007). These are all areas where data at the small-area has been hard to obtain directly.

Location-allocation models are designed to allocate demand to supply points given the distance (or time taken) between the two. Their aim is to locate supply points 'optimally' in order to minimise the total distance travelled by all consumers of a service within a given location (i.e. a town or city). As demand for any service is not evenly distributed across a region, so the locations suggested by these models are highly skewed towards the main areas of demand. At the same time, however, the models also ensure that all consumers of that service have some access to supply points. Cromley and McLafferty (2002) provide a good overview how location-allocation can be used to locate health service optimal depending on the service activity. Location-allocation models have been applied for health location planning in the developed and developing world (see Tanser et al., 2010).

Estimating small-area birth rates

Although data for births in the UK are available at the Census ward level (33 wards in Leeds) there are no routinely published data available for smaller geographical units. As noted above, this is deemed important if we are to search for optimal locations for antenatal classes within different communities in the city.

The aim in this section is to estimate the number of births at the Census output area (OA) level. OAs are the smallest geographical units where demographic and socio-economic data can be accessed in the UK. To estimate births, it is important to consider variables such as age, marital status, socio-economic class and ethnicity. The national birth rates are summarised in Table 1. We show estimates based on each of these in turn and visualise the results in form of maps using equal intervals for four categories (Figs. 1–4). The darker the colour, the higher the birth rate which helps to identify areas of low and high birth rates more easily. The analysis is based on output area geography but we also show the ward boundaries and names.

Table 1
National birth rates.
Source: www.statistics.gov.uk, 2005.

Categories	Rates (%)
Age	
16–24	4.7
25–29	7.9
30–34	8.0
35–39	3.5
40–49	0.4
Marital status	
Outside marriage	3.2
Inside marriage	6.3
Ethnicity	
Bangladeshi, Asian/Asian British	4.2
Indian, Asian/Asian British	5.8
Pakistani, Asian/Asian British	9.6
African, Black/Black British	6.0
Caribbean, Black/Black British	9.8
White British	4.5
White Other	4.3
All other ethnic groups	5.4
Socio-economic status	
Large employers and higher managerial	2.3
Higher professional	3.8
Lower managerial and professional	3.6
Intermediate	4.7
Small employers and own-account workers	4.5
Lower supervisory and technical	4.0
Semi-routine	6.2
Routine	6.9

Firstly, it is useful to examine birth rates by age group. The UK Vital Statistics database provides data on different age groups in Leeds: the age groups are 16–24, 25–29, 30–34, 35–39, and 40–49. To estimate the number of births by age, the number of individual women from the Census 2001 has been aggregated to the five age groups listed above. Small-area birth rates can then be calculated based on UK national birth rates by age (see Table 1). To estimate the number of births at the OA level we can thus take the number of females in each age category and multiply them by the UK age-related birth rates. The results of this estimation procedure are shown in Fig. 1. It can be seen that the birth rates are estimated to vary between 1.4% and 6.6%, where the highest rates (the darkest shading) are found in the inner areas and also to the south of the city centre (less affluent neighbourhoods comprising of large public housing estates). The lowest rates are mainly in the more affluent northern and eastern suburbs of Leeds.

Secondly, births can also be estimated based on a different census variable: marital status, based on the number of births either outside marriage or within marriage. When UK national birth rates (Table 1) are applied to the local Census data for each OA in Leeds the estimates of birth rates vary between 3.2% and 5.7%, with higher birth rates in the suburban areas of Leeds where more married people reside. The spatial variations in these results are shown in Fig. 2 where darker shades again mean higher birth rates. The different spatial patterns are immediately evident when compared to the birth rates estimated by age shown in Fig. 1.

Fig. 1. Birth rates (%) using age as the predictive variable (OA level for Leeds).

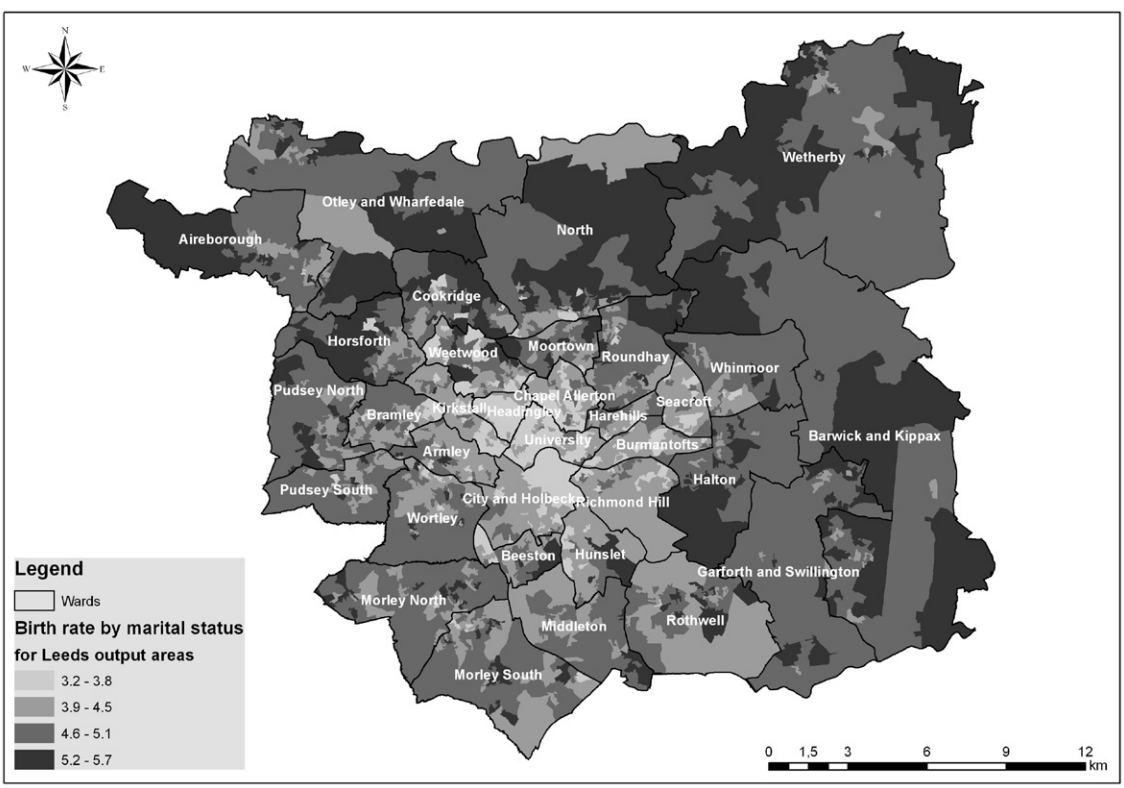

Fig. 2. Birth rates (%) using marital status as the predictive variable (OA level for Leeds).

Thirdly, births can be estimated by examining variations in birth rates by socio-economic status. The information of birth rates based on socio-economic status is only provided by male head of household and can ignore single female households. The UK national rates for England and Wales are also only based on a 10% sample (see Table 1). These national rates were applied to

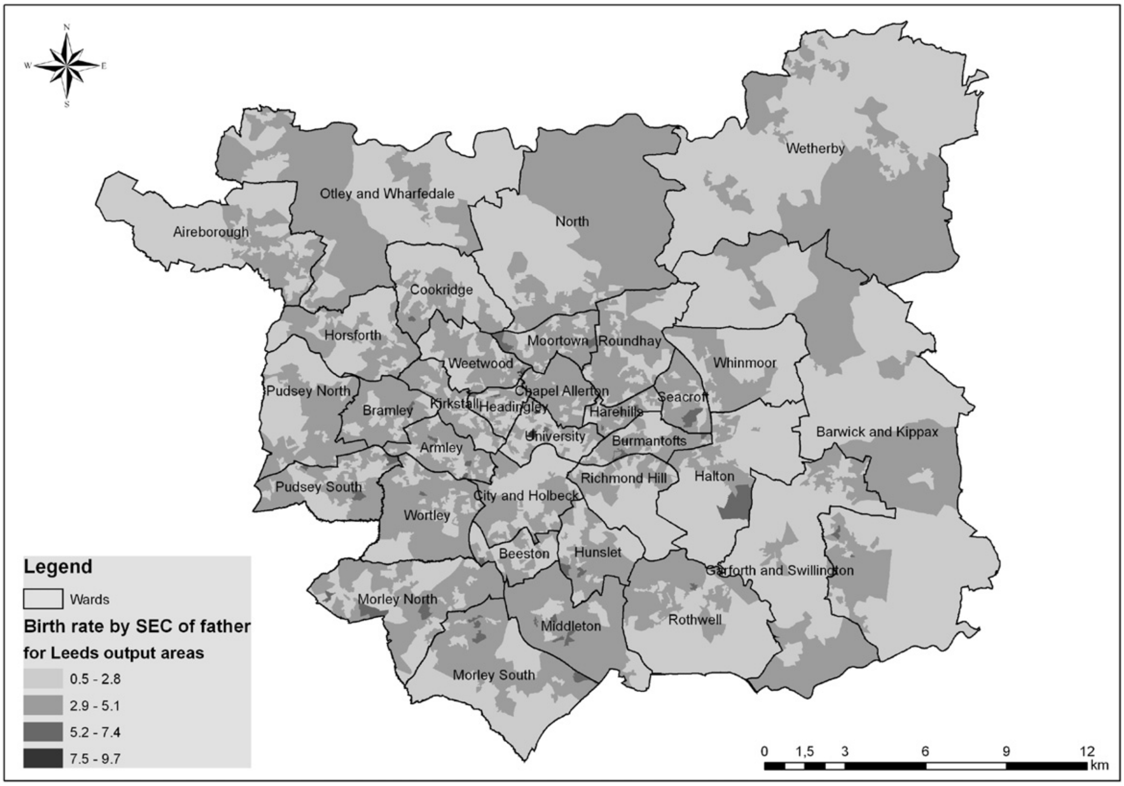

Fig. 3. Birth rates (%) using socio-economic status as the predictive variable (OA level for Leeds).

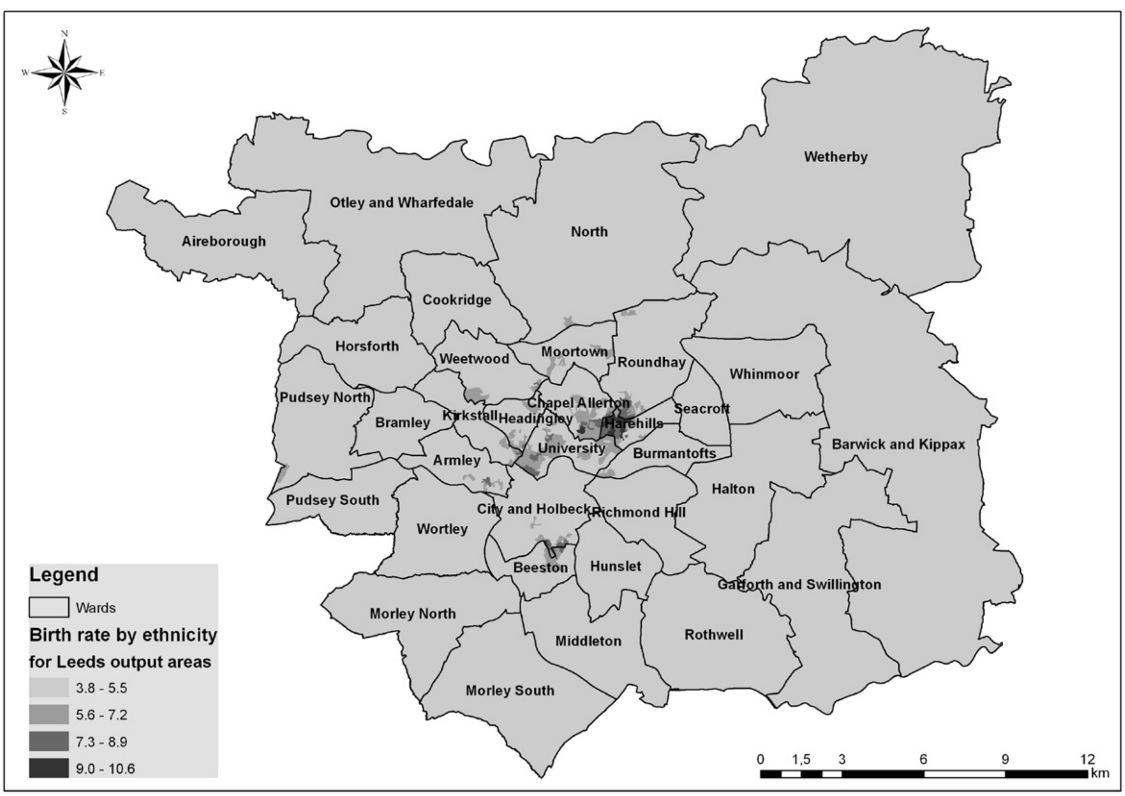

Fig. 4. Birth rates (%) using ethnicity as the predictive variable (OA level for Leeds).

OAs in Leeds to explore the likely spatial variations, and the results are shown in Fig. 3 where again darker shades show higher values of birth rates. The average birth rate here is 3.2% and the range is 0.5–9.7%. Again, these results are very different to Figs. 1 and 2.

Finally, it is possible to estimate the number of births using ethnic status as the main driver of the variations. National births data by ethnic status have been published by the UK Office of National Statistics (for 2005); see Table 1. This is the first time that such data have been published for England and Wales. When these national rates are applied to match the ethnic population within each Leeds OA, this produces an estimate of an average birth rate for Leeds of 4.4% and a range from 3.8% to 10.6% (Fig. 4). The results show that highest rates (darker shades) occur in Harehills, Chapel Allerton, University and Beeston, which are associated with the higher birth rate of the Pakistani population in particular.

The maps above show clearly that estimations based on different socio-economic attributes will provide very different spatial patterns across the city. This makes it difficult for health-care planners to decide where to locate new services: which map is most 'accurate'? To overcome this problem we need to be able to combine estimates of giving birth based on age, marital status, social class and ethnicity. The methodology we adopt here to do this is *spatial microsimulation*. This modelling technique is first briefly described below, and then applied to the estimation of birth rates.

Birth rates based on spatial microsimulation

Spatial microsimulation is a technique used to create synthetic individuals or households in a city or region. These individuals or households are populated with a set of attributes that make them resemble, as closely as possible, the real individuals or households in that city or region (see Ballas et al., 2005 for more technical details). In this paper we wish to build a set of individuals in Leeds who have all the different attributes necessary to estimate births. As seen above, however, estimating births based on only one key demographic (age, social class, ethnicity) provides different small-area patterns (Figs. 1–4). To help overcome this problem, a spatial microsimulation model is employed to reweight survey data which contains *all* these variables for individuals or households and, in this case, the key variable 'giving birth'. For the spatial microsimulation model, attributes associated with pregnant women are therefore required. A useful data source is the Health Survey for England (HSE). The HSE is an annually conducted, cross-sectional survey collecting individual and household data on demographic, socio-economic and health issues at the regional or national level. The HSE in 2006 consisted of 21,399 cases and contained 1,831 variables. From the HSE, we can see the kinds of households with women being pregnant or women having a new-born child as well as the attributes such as age, ethnicity, etc. that we are interested in for our model. The microsimulation procedure now matches these households (or individuals) to households (or individuals) which are similar within OAs in Leeds: i.e. it effectively 'clones' these types of individuals in the HSE and assigns the behaviour of those individuals to individuals with the same attributes at the small-area level (the matched variables being provided by the UK Census). Thus, these two data sets are combined through the spatial microsimulation model to obtain an estimate of the number of pregnant women for OAs in Leeds. Variables used in the model are age, socio-economic class, marital status, ethnicity and economic class. The final collection of sub-categories is shown in Table 2.

To calibrate, or fit this model, we can aggregate the estimates of the number of births at OA level to the Census ward level where actual data exists. Having done this, the initial run of the models seemed to under-estimate the number of births in the most deprived areas. This is often the case with microsimulation models as not enough very deprived (or indeed very affluent households) are surveyed in typical household surveys such as the HSE. As these types of surveys have more middle income households the modelled distributions can look a little 'flat' in areas of high disadvantage or high affluence. One response to this is to add an additional deprivation score into the models to weight the number of births further by socio-economic group

Table 2
Variables and categories used in the birth simulation model.

Age	**5 categories**
	16–24
	25–29
	30–34
	35–39
	40–49
Socio-economic class	**3 categories**
	Managerial and professional occupations
	Intermediate occupations
	Routine and manual occupations
Marital status	**2 categories**
	Single
	Married
Ethnicity	**3 categories**
	White
	Asian/Black
	Mixed/other ethnicities
Economic class	**2 categories**
	Employed
	Unemployed

Table 3
Estimated vs. actual number of births aggregated to the Census ward level.

Ward code	Ward name	Real counts mid 2000–mid-2006	Simulation	Difference	Per cent difference
00DAFA	Aireborough	254	249	−5	−2.0
00DAFB	Armley	287	293	6	2.1
00DAFC	Barwick and Kippax	260	235	−25	−9.6
00DAFD	Beeston	253	213	−40	−15.8
00DAFE	Bramley	286	362	−24	−8.4
00DAFF	Burmantofts	270	249	−21	−7.8
00DAFG	Chapel Allerton	294	318	24	8.2
00DAFH	City and Holbeck	340	295	−45	−13.2
00DAFJ	Cookridge	201	190	−11	−5.5
00DAFK	Garforth and Swillington	221	224	3	1.4
00DAFL	Halton	187	195	8	4.3
00DAFM	Harehills	471	433	−38	−8.1
00DAFN	Headingley	103	124	21	20.4
00DAFP	Horsforth	197	196	−1	−0.5
00DAFQ	Hunslet	227	236	9	4.0
00DAFR	Kirkstall	186	238	52	28.0
00DAFS	Middleton	315	288	−27	−8.6
00DAFT	Moortown	238	251	13	5.5
00DAFU	Morley North	257	256	−1	−0.4
00DAFW	Morley South	352	336	−16	−4.5
00DAFX	North	214	213	−1	−0.5
00DAFY	Otley and Wharfedale	240	220	−20	−8.3
00DAFZ	Pudsey North	241	256	15	6.2
00DAGA	Pudsey South	229	235	6	2.6
00DAGB	Richmond Hill	272	247	−25	−9.2
00DAGC	Rothwell	225	212	−13	−5.8
00DAGD	Roundhay	242	247	5	2.1
00DAGE	Seacroft	272	268	−4	−1.5
00DAGF	University	227	266	39	17.2
00DAGG	Weetwood	174	210	36	20.7
00DAGH	Wetherby	227	194	−33	−14.5
00DAGJ	Whinmoor	165	186	21	12.7
00DAGK	Wortley	287	265	−22	−7.7

(Smith et al., 2009; Birkin and Clarke, 2011). The same applies to student areas, where the number of births tends to be over-predicted (in Leeds these are Census wards such as Headingley, University, Kirkstall or Weetwood). This is because of the presence of many females aged 18 to 21 and the high fertility rate of this group as a whole across the UK. One solution is simply to add a student weighting factor, which has the opposite impact of the socio-economic weighting factor which gives extra births. Table 3 shows the final simulated results at the Census ward level in Leeds (not taking multiple births into account). The third column shows the average numbers of real counted births in the time period between 2000 and 2006 and the fourth column shows the simulated births after adjustment for high levels of deprivation and students. The fifth column presents the difference between the real and simulated counts and the sixth column shows the same in percentage terms. It can be seen that the model is now capable of estimating actual Census ward totals very well (given the difficulty of making single year predictions when the number of births is never constant from year to year). The final results of the microsimulation model are mapped at OA level (Fig. 5) where it can be seen that highest birth rates are simulated in the west of Harehills, Seacroft and Burmantofts and lowest rates are in Headingley, parts of University and Wetherby. Further, the map shows that birth rates vary considerable within Census wards and therefore it is useful to simulate births at the smallest geographical level if we are to target service points for antenatal classes most effectively.

We would argue that this 'final' map is a better estimate of small-area demand for antenatal classes than taking a single Census variable only (age, marital status, social class, and ethnicity; see Figs. 1–4).

Location-allocation models

As briefly noted above, the basic concept of location-allocation models is to allocate demand (e.g. pregnant women) to facilities (e.g. services for antenatal classes) using an accessibility measurement (which can either be straight line distance or distance along a road network) under predefined criteria or rules. With such models it is possible to understand complex relationships between residential locations and facility locations and the variations over space and time (Nemet and Bailey, 2000).

The method to be adopted for this paper is the p-median problem which aims to minimise the total distance persons have to travel (Cooper, 1963). The choice of this model is premised on the basis that people are most likely to choose to attend their nearest service. Hence we aim to minimise the costs or time taken for people to travel to the services providing antenatal classes, as it is assumed that with an increase in travel costs there will be a decrease in the uptake of a service. It is most likely that longer travel distances result in higher travel costs and, as for many public or private services, when the costs of travel (or time) reach a certain critical threshold people are less likely to use the service. This emphasises the importance of geography or distance-decay effects. In the model used here, accessibility is based on travel distance along the road network. The model was run using ESRI ArcInfo which is a commercial geographical information software that can handle complex spatial models, analysis and visualisation.

Locations where antenatal classes are held in Leeds were obtained from the Leeds Teaching Hospital NHS Trust for two time periods. Firstly, the venues for December 2007 (including street names and postcodes) were geocoded making it possible to map these service location points. From this dataset it was found that 17 locations provide antenatal classes, including the two major hospitals in Leeds, St. James Hospital and Leeds General Infirmary. The second dataset was provided in July 2008 with additional information on service closure or suspension pending re-alignment of services following the changes to the local Sure Start projects and the transition to local Children Centres. This left only 13 service locations offering antenatal classes.

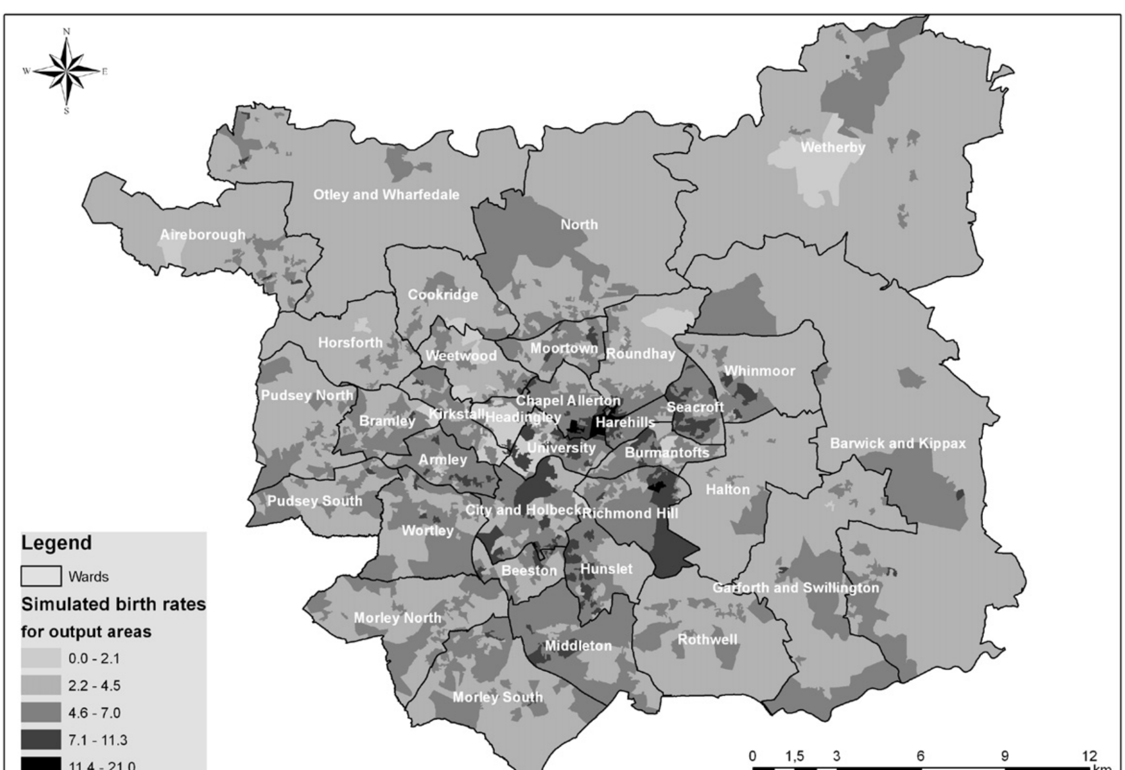

Fig. 5. Model-based estimates of birth rates (%) at OA level for Leeds using a combination of Census variables.

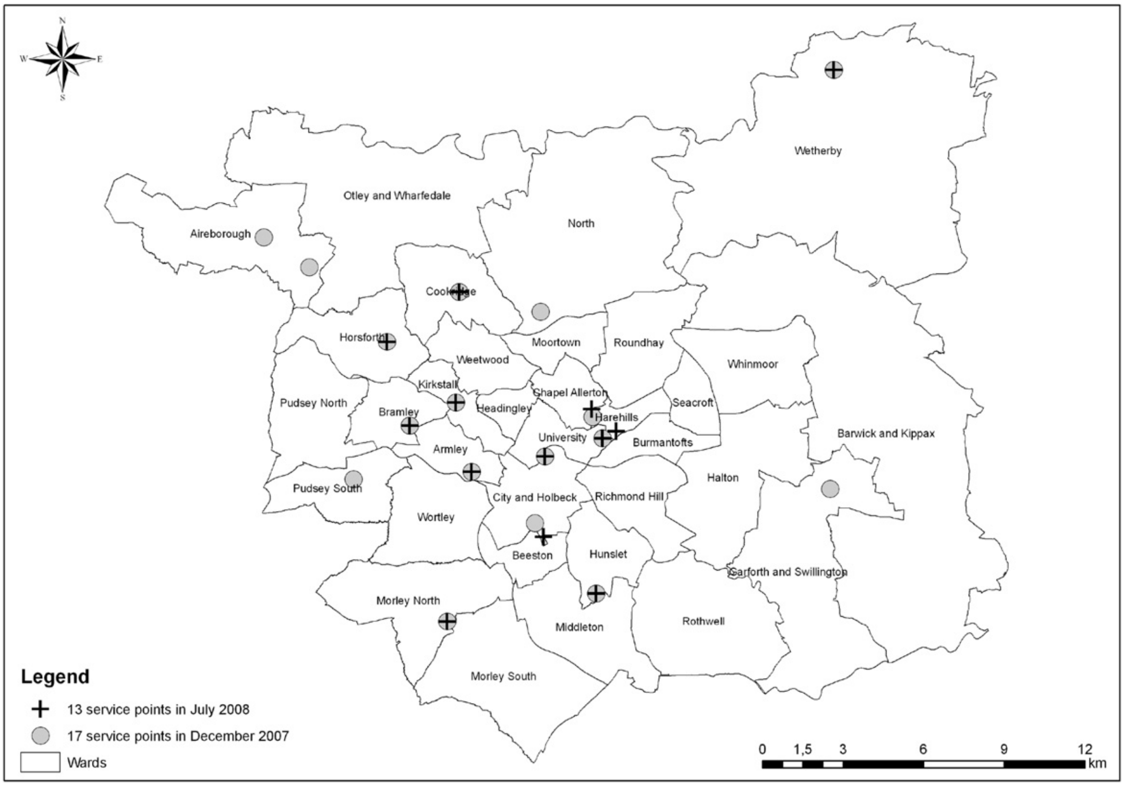

Fig. 6. Service points for antenatal classes in December 2007 and July 2008.

Fig. 6 shows the locations where antenatal classes were held in December 2007 (grey dots) and in July 2008 (black crosses). It can be seen that some service points remained in the same locations including Wetherby, Cookridge, Horsforth, Kirkstall, Armley, University (where both hospitals are located), Morley North and Hunslet. However, it should be noted that not all services surviving in July 2008 provide weekly courses. For instance, the service points in Horsforth and Cookridge alternate antenatal classes each month. Further, it can be noted that no antenatal classes were offered in some of the very deprived areas in Leeds during these time periods, such as Seacroft and Richmond Hill.

Given the discussion above, it is useful to try to locate services in such a way that pregnant women have the best opportunities to access services. With the help of location-allocation models, it is possible to model different scenarios to see where antenatal classes should be provided based on demand (see the next section).

Findings

Best locations for 13 service points of antenatal classes

The first run of the location-allocation model located thirteen service points aiming to minimise the travel distance for all pregnant women based on the Leeds road network. Results are shown in Fig. 7 where the grey dots are the existing locations (in July 2008) and the centres of the grey 'spiders' are the modelled optimal locations for antenatal classes. The areas reached by each of the 'spider's legs' are the output areas which are assigned to this centre. It can be seen that four existing locations match very well with the optimal ones, but based on the model demand estimates services need to also be located in Aireborough, Pudsey North, Moortown, Seacroft, Middleton, and between Barwick and Kippax and Garforth and Swillington. When locating services based on this location-allocation model then the average distance for women to travel would be reduced from 3.6 km to 2.3 km and the furthest distance women would need to travel would be reduced from 16.6 km to 10 km.

Impact on accessing a service location when closing more service points

The next scenario explores the impact on service provision given the possibility that more services have to close. As mentioned earlier, the Leeds Teaching Hospital NHS Trust has reduced the number of classes from 17 to 13. In addition, there are four existing classes which only operate occasionally and they are clearly under threat also. These service points are located in Horsforth, south of Armley, Hunslet, and Morley North and these are now removed from the model to explore the impact such closure would have on accessing services.

Fig. 8 shows the best locations for only nine service locations (the centre of the grey spider plots indicating the optimal locations) whereas the grey dots are the actual nine service locations. It can be seen that services would need to be offered not only in central Leeds (where a higher population density exists) but also in the suburbs including the north-east and north-west, the east, south and west of Leeds. The larger 'spiders' reflect the fact that these service locations now need to cover a larger geographical area (such as the west of Leeds) and hence more pregnant women than were seen for the 13 locations in Fig. 7.

Estimating pregnant women in lower socio-economic groups

The final scenario shows an example of how to target services based on a specific group of pregnant women. As a key UK Government aim is to give more attention to 'hard to reach'

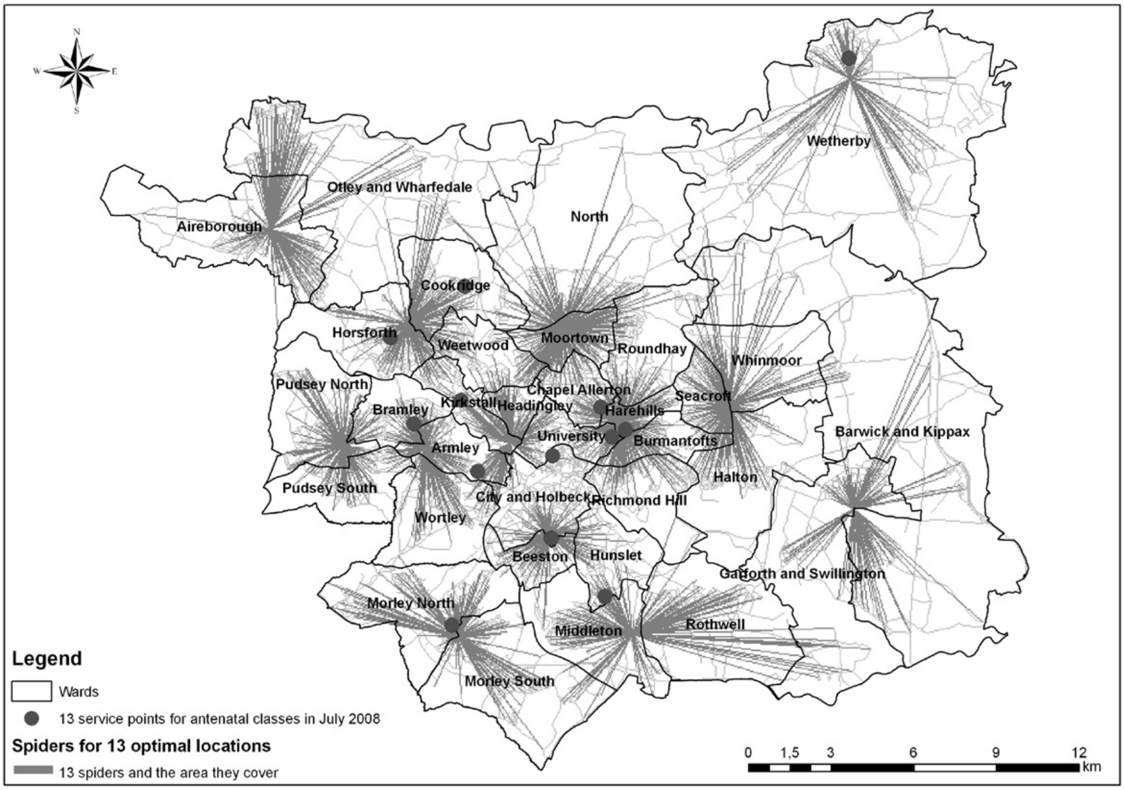

Fig. 7. 'Optimal' service points for thirteen antenatal classes to minimise the travel distance for pregnant women in Leeds.

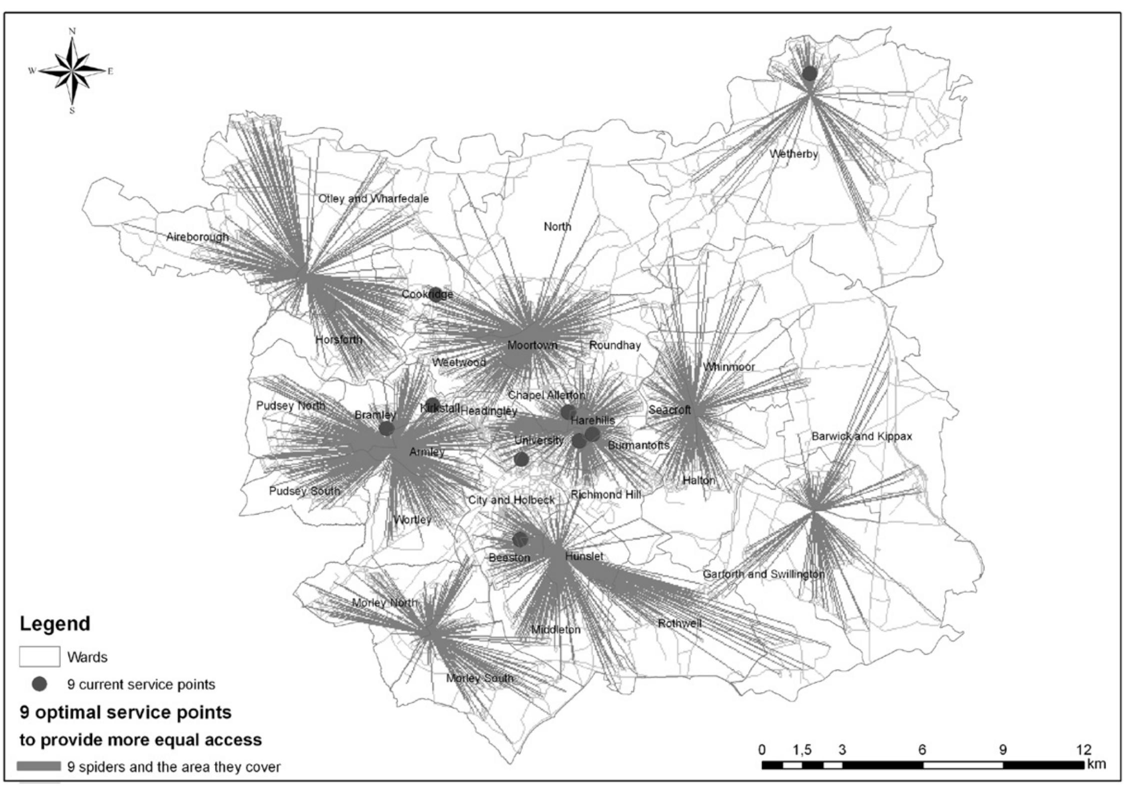

Fig. 8. Nine 'optimal' locations where antenatal classes could be held to provide more equal access for pregnant women.

groups, the numbers of pregnant women from lower socio-economic groups are estimated using the spatial microsimulation model. The outcome variable of the microsimulation model is now adjusted (which is one main advantage of this method) so that only pregnant women that belong to the socio-economic group 'routine and manual occupations' are estimated. The results that are obtained are shown in Fig. 9 for OAs. As expected, higher numbers of births can be found in more deprived areas including

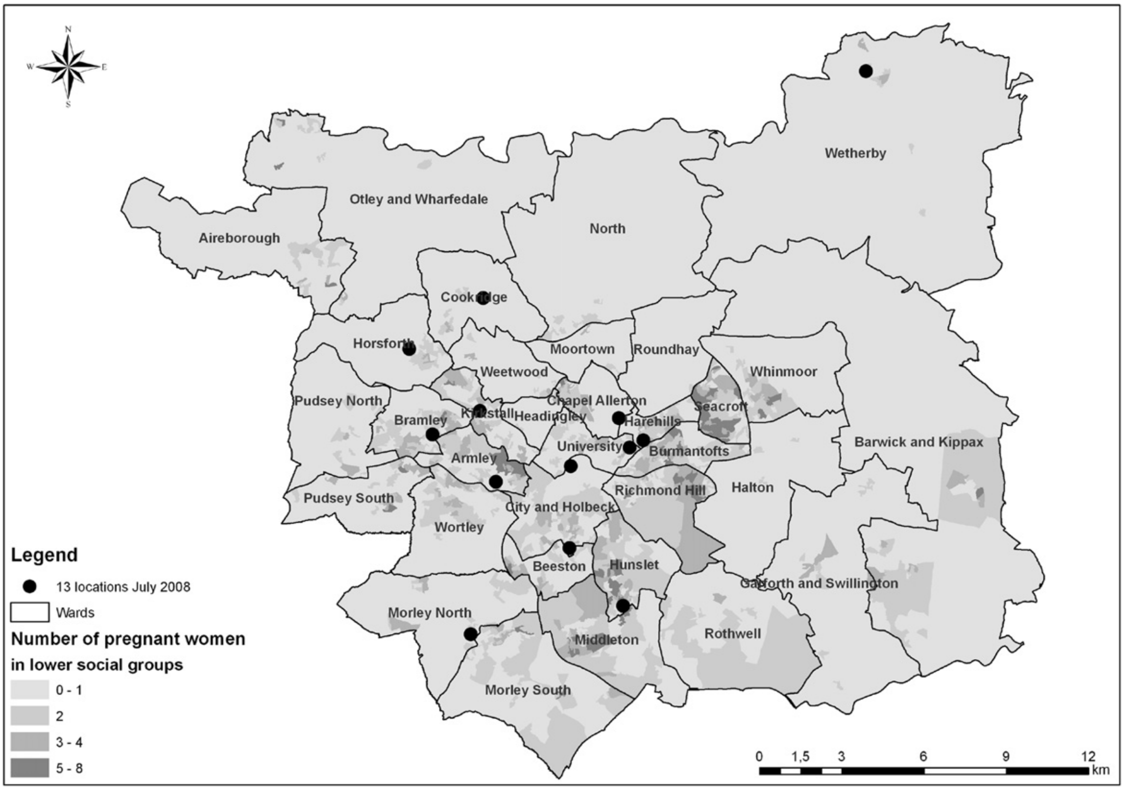

Fig. 9. Estimated number of pregnant women who are from lower socio-economic groups with 13 existing services.

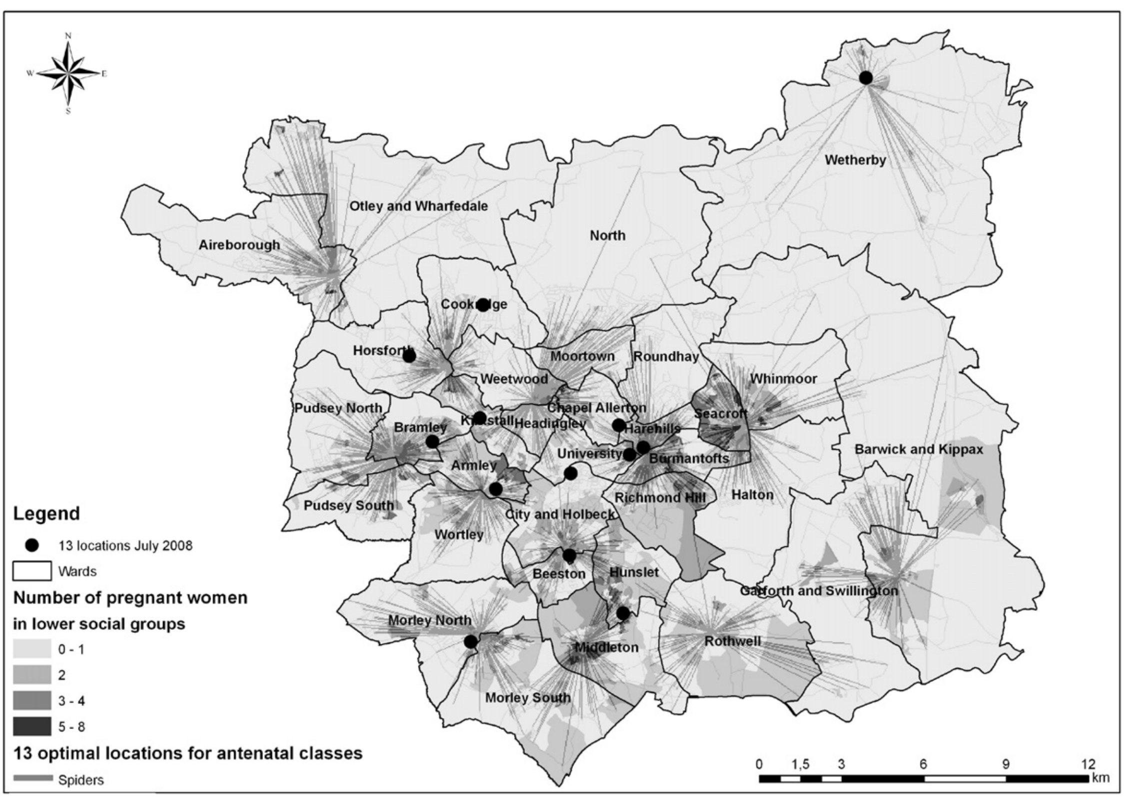

Fig. 10. Estimated numbers of pregnant women who are from lower socio-economic groups in combination with 13 'optimal' service points for this target group.

Seacroft, Harehills, Burmantofts, Hunslet, Middleton, and Armley. Therefore, the provision of antenatal classes in these areas would be desirable to give women with lower incomes the possibility to attend antenatal classes without needing to travel long distances. A combination of long opening times, good locations and better promotion of services should help to target this population group more effectively.

The results from Fig. 9 are now used as the demand variable in the location-allocation model. Fig. 10 shows the 13 best locations for antenatal classes to support pregnant women from this lower social class background (to have more equal access to services). Areas with high estimations of the target group are found in Seacroft (especially in the west of Seacroft) where a location for antenatal classes would certainly be required. Further high demand is found in Harehills, Burmantofts, Richmond Hill, Middleton, and Armley where the model now locates more services in these areas.

Discussion and conclusions

A key UK government aim is to provide more health services within communities to reduce inequalities in access to services. However, challenges due to increasing birth rates, shortages of staff and lack of resources for new facilities can provide a barrier to access. When antenatal classes have to close, or are withdrawn due to a lack of staff, pregnant women who want to attend a service have either to travel further distances or they have to pay to attend private and voluntary sector paid-for classes. Unfortunately, this has most impact on more deprived women who do not have the income to pay for antenatal classes and therefore the risk occurs that pregnant women from lower income communities may not attend antenatal classes at all.

The results presented in this paper highlight that it is possible to plan the location of antenatal classes more effectively by increasing physical access to a set of more decentralised facilities and thus, it is hoped, increasing the attendance rate. Although we provide a case study of Leeds, UK, this type of analysis could be reproduced for any region. It was shown that the applied models are powerful for demonstrating different scenarios concerning where to locate service points based on different criteria. The analysis was based on demand assigned to Census output areas and the accessibility measure was based on a road network. There are a number of limitations in this analysis. Firstly, we did not include public transport networks in detail. This will be an issue in more disadvantaged areas where people are less likely to own a car. Another layer of analysis to include this would be useful in future research. Secondly, we have assumed that all nodes on the road network are possible locations for a service point. In reality, certain areas may simply not be feasible as no opportune sites could be found. Third, different types of services (Children's Centres, Teenage classes, etc.), opening hours and capacity are not considered in detail in the model, although again could form part of future research to sophisticate the analysis further. Another limitation is that we assume that women travel from their home location to their nearest antenatal class. However, especially in early stages of pregnancy women often still work and therefore could use the nearest location from their workplace instead of home place to visit antenatal classes. Incorporating flows from work locations is another future research strategy. Finally, we note that, at the time of the study, the monitoring of antenatal attendance rates was ad-hoc and cannot be used to draw on the levels of access. To have detailed information from all service points would be valuable as further analysis could then be undertaken to explore variations in actual catchment area size and shape, and on the geodemographics of non-attendees (based on age, social class, etc.).

Despite those limitations, we believe the spatial microsimulation approach, provides a useful modelling methodology for estimating births by small area, which are otherwise not available or accessible. Further, the outcome variable (births by demographic group) can be altered based on the area of policy application. For instance, the number of total births by women can be simulated but so too can the numbers of births by different age groups or socio-economic groups. The analysis in this paper shows the potential of combining microsimulation estimates of the number of births with location-allocation models to find optimal locations for providing antenatal classes (by minimising the distance to travel for the target group) which was not done before in this context. The findings of this paper can effectively inform service providers and commissioners with their decisions on managing and operationalising antenatal classes.

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