

How scale affects environmental impact assessment

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Abstract

This paper evaluates the influence of geographical scale on the outcomes of Environmental Impact Assessments (EIAs). The paper presents results obtained by using spatial data with different scales for an EIA for a proposed road bypass in Southeast England (the Hastings Bypass). Scale effects were measured separately for spatial extent and spatial detail, and were measured both *quantitatively* using a Geographical Information System (GIS) and *qualitatively* using the judgement of EIA experts. The study found that changes in scale could affect the results of EIAs. For example, the impact significance and the number of houses affected by air pollution from the road varied according to the scale used. These observed scale-dependent changes suggest that scale choice can have important repercussions for the accuracy of an EIA study. This situation is made more serious when it is recognized that many environmental impact statements (EIS) fail to mention in explicit terms the scale used. The paper concludes with recommendations for future practice on how best to control the quality of EIAs in relation to scale choice.

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1. Introduction

This paper investigates to what extent the choice of scale can affect the outcomes of Environmental Impact Assessments (EIAs). In other words, is it possible that EIA results are more an artefact of the scale of the data used rather than the situation in the real world being studied? If that was the case, and the scale effects were ignored, then there could be serious repercussions for EIA accuracy and quality. To date, EIA practitioners and researchers have largely ignored this topic. This study puts scale under the spotlight to stimulate a debate about this important issue.

In this paper the word ‘scale’ is considered to have two key interrelated meanings relevant to EIAs: scale as *spatial extent* of the assessment; and scale as amount of *geographical detail* or granularity. The two are, however, related, as the spatial extent of the assessment will usually affect how detailed the assessment will be, i.e., an EIA of a larger area cannot afford the same amount of detail as a local assessment. This suggests the existence of a ‘ratio’ between extent and detail that constrains the data volume that is reasonable to analyse for a particular project (Goodchild and Quattrochi, 1997). The notion of scale can be applied both to temporal and spatial aspects, and both are important to EIAs. The research presented in this paper, however, concentrates on the spatial scale only.

Scale is a key research topic in many disciplines, such as hydrology, archaeology and ecology, and much has been written describing the problem of scale and the methods for studying scaling (e.g., Levin, 1992; Quattrochi and Goodchild, 1997; Tate and Atkinson, 2001; Turner and Gardner, 1991; Wiens, 1989). But at the same time scale remains a complex and misunderstood issue. ‘Scale is one of the most fundamental yet poorly understood and confusing concepts underlying research involving geographic information’ (Montello and Golledge, 1999, p. 3). The importance of scale issues has even led some researchers to propose a new *science of scale* (Goodchild and Quattrochi, 1997; Meentemeyer and Box, 1987). Goodchild and Quattrochi (1997) suggested that a full science of scale would include: which measures or properties are invariant with respect to scale; methods to change scale; measures of the impact of scale change; scale as a parameter in process models; and implementation of multiscale approaches. In this paper, the emphasis is on measuring the *impact* of scale change.

Despite its importance, scale has long been a ‘Cinderella topic’ within EIAs. EIA literature only very rarely addresses the issue of scale and how it can affect the outcomes of impact assessments. When it does so, it is often couched in the vaguest of terms. For example, the Canadian Environmental Assessment Agency briefly commented on the difficulty of identifying spatial boundaries: ‘If large boundaries are defined, only superficial assessment may be possible and uncertainty will increase. If the boundaries are small, a more detailed examination may be feasible but an understanding of the broad context may be sacrificed. Proponents may perceive assessments with large boundaries as onerous or unfeasible, whereas the public may think small boundaries do not adequately encompass all of the project’s environmental effects’ (Canadian Environmental Assessment Agency, 1996, p.

13). This paper aims to redress this neglect by focusing exclusively on scale and EIAs.

Besides a review of academic literature, this study also investigated the importance of scale issues within EIAs by obtaining information directly from environmental impact statements (EIS) and from the views of EIA practitioners themselves. Given the nature of EIAs, where one of the written products is the EIS itself rather than an academic paper, and where practitioners might not always express in writing their thoughts on scale issues and EIAs, it was felt that an exclusive review of academic papers on EIAs would be insufficient. Forty-two UK EIS were reviewed to find any explicit mentions of scale—none were found. Also, internet-based discussions with EIA practitioners were established that tapped into a wide range of EIA expertise from different countries and backgrounds. In total, during the course of this research, more than 230 research contacts were established. The review of EIS, and the discussions with practitioners worldwide, found that EIS, although they cannot escape dealing with scale, often do not state the scale used *explicitly*. This is another symptom of the neglect of scale in EIAs. ‘In my experience, geographical scale is an issue that receives inadequate attention in the majority of EIS, and in many cases can represent a fundamental limitation to the production of an effective EIS that provides a defensible basis for the identification of potentially significant environmental impacts’ (David Broom, SGS United Kingdom, 1999, personal communication). If scale is not explicitly included, readers must guess and arbitrarily apply a scale of their own (Allen and Starr, 1982). As a consequence, and because different scaled models define entities differently, results using apparently identical models will appear inconsistent.

There is, however, literature on the specific effects of scale on disciplines related to EIAs, such as water quality (Osterkamp, 1995), landscape studies (Meentemeyer and Box, 1987), ecology (Fernandes et al., 1999), archaeology (Stein and Linse, 1993), soils studies (Julien and Frenette, 1986), and hydrology (Sposito, 1998). In a study on land degradation, Gray (1999, p. 330) found that ‘one’s conclusions about whether land is degraded are influenced by the scope and scale of the analysis. For example, if we examined changes at the local or regional scale using aerial photographs, we would most likely arrive at a different conclusion than if we examined soils at the farm scale. The scale at which studies are undertaken affects the conclusion because processes and parameters important at one scale may not be important or predictive at another scale.’

Given the importance of scale in these disciplines it is unlikely in the extreme that EIAs would be immune from the effects of scale. This is especially relevant, given that most EIAs are done under strict budgetary and time constraints: ‘In practice, budgets and schedules often get in the way of using sufficient detail’ (Ron Bass, Jones and Stokes Associates, USA, 1998, personal communication) and ‘Unfortunately, scale is often directly related to funding. Although the overall boundary of investigation may be less affected, the detail of investigation will be’ (Tim Huntington, MacAlister Elliott and Partners UK, 1999, personal communication). If budget and time allows, studies are done with more detail or for larger

spatial extent (ironically, this study has found that this is probably more likely to happen for small-sized projects with generally fewer impacts). This begs the question of how many projects are done without sufficient detail and large enough spatial extent, and how this is affecting the quality of EIA work.

The potential effect that scale might have on the outcomes of EIAs (e.g., by influencing the type of impacts found, their magnitude and significance, the type of mitigation measures recommended, and ultimately the end decision regarding the proposal) means that it is essential to try to quantify scale effects in EIAs. This paper describes the results of such a study using an EIA of a controversial road project. The paper starts by describing the methods used and the results of the empirical study on the effects of scale on EIAs. The paper concludes with suggestions on how best to control the quality of scale choice in EIAs.

2. Methods used in the empirical study on the effects of scale on EIAs

For the empirical study, parts of an existing EIA of a *road bypass* project were redone using data at different scales to discover how the results differed. Scale effects were measured separately for extent and detail. In order to measure changes due to the amount of detail, areas of the same size but different detail were compared, while to measure scale effects due to changes in spatial extent, areas with the same detail but different spatial extent were used.

The empirical study consisted of two different but complementary approaches: one study based on quantitative measurements using a Geographical Information System (GIS) and a parallel study based on a qualitative analysis by EIA experts. The inclusion of the qualitative judgements of EIA experts was important because one of the most common EIA methodologies for evaluating impacts is ‘expert opinion.’ An exclusively quantitative study of the effects of scale, therefore, would have only offered a limited view of how scale can affect EIAs.

Through a preliminary investigation of possible UK case studies involving road projects, seven road EIAs were shortlisted. Of these, the A259 Hastings Eastern Bypass (6.2 km) was selected (see Fig. 1 for its location in Southeast England). Two other proposed schemes were related to the Hastings Eastern Bypass: the Bexhill and Hastings Western Bypass (14.7 km) and the Pevensey to Bexhill Improvement (4 km) (also seen in Fig. 1). Together these three projects were nearly 25 km long, which made them one of the longest, and most controversial, road projects in the UK at the time.¹

¹ In July 2001, after the research described in this paper was concluded, the proposed Hastings Bypass was cancelled. This was because of the controversy and strong environmental impacts of the road project. The UK government reached this decision by using a new ‘multimodal approach’ that looked at all the alternatives considering all the different modes of transport. This was the first time in the UK that decisions regarding a road proposal were guided by the new multimodal methodology.

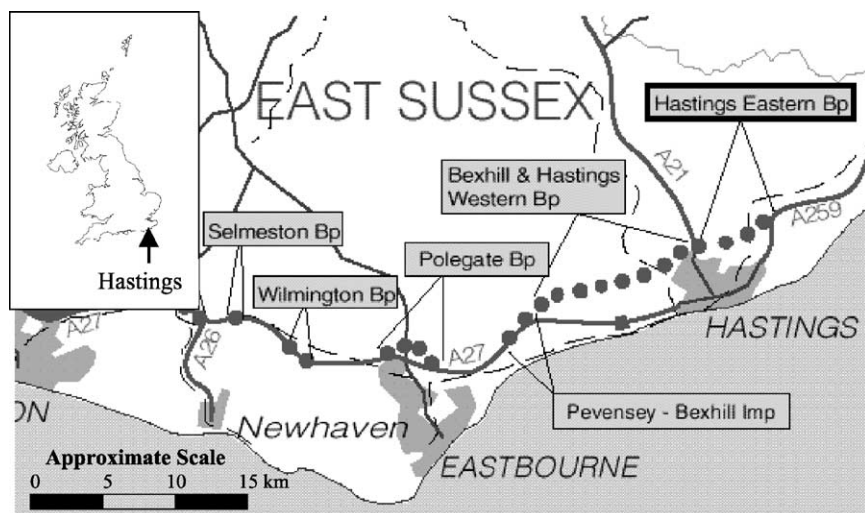


Fig. 1. Location in Southeast England of the proposed A259 Hastings Eastern Bypass (6.2 km) (modified from DETR, 1998), and inset showing location of the town of Hastings in the south coast of the UK.

There were three main reasons why a road bypass project was selected for this research, rather than another type of development such as a new factory. The first reason had to do with the spatial aspects of road projects. Due to their linear nature, and potential long length, roads pose interesting challenges related to the choice of the spatial extent and detail of the study. The second reason was because roads exert impacts at a range of scales: from localised, direct impacts on particular areas, through to impacts affecting whole regions due, for example, to habitat fragmentation and severance of human and wildlife communities. The final reason had to do with the availability of EIA guidelines. Road projects are one of the very few types of EIAs for which guidelines exist to advise on the scale to use. These include the UK Design Manual for Roads and Bridges (Highways Agency, 1998), and the World Bank publication on roads and the environment (Tsunokawa and Hoban, 1997).

Data for the Hastings Eastern Bypass case study were obtained by digitising different source-scale maps and by obtaining data directly from the Ordnance Survey, the national mapping agency of Great Britain. Table 1 summarizes the different data sources used for this research. Project EIA is usually done using very detailed map data, and often culminates with fieldwork. For this reason very detailed source scales were chosen: 1:10 000 and 1:25 000. For the 1:10 000 scale map, 1 mm in the map represents 10 m in the terrain, while for the 1:25 000 scale map 1 mm in the map represents 25 m. The review of EIS carried out (see Section 1) found that both of these scales are the most common scales used for the EIA of

Table 1

Data sources for the empirical study on measuring scale effects on EIA

Data	Source and scale
Major environmental features (e.g., ancient woodland, ponds with nature conservation value, etc.)	1:25 000 source scale map. Digitised by the author directly from the mapped information contained in the Environmental Impact Statement (EIS) of the Hastings Eastern Bypass (covering one A3 sheet). ^a
Major environmental features (e.g., ancient woodland, ponds with nature conservation value, etc.)	1:10 000 source scale map (complemented by fieldwork carried out for the EIA). Digitised by the author directly from the mapped information contained in the EIS of the Hastings Eastern Bypass (covering four A3 sheets). ^a
No. of buildings within 200 and 1000 m of the Hastings Eastern Bypass ^b	1:25 000 Ordnance Survey paper map (1997).
No. of buildings within 200, 1000 and 2000 m of the Hastings Eastern Bypass	Land-Line Digital Data from the Ordnance Survey (Feb 1999)—based on 1:1250, 1:2500 and 1:10 000 source scales. ^c
No. of addresses within 200, 1000 and 2000 m of the Hastings Eastern Bypass	Address-Point Dataset from the Ordnance Survey (Oct. 1999). ^d

^a Date of publication of the EIS: September 1994.^b Buildings had to be counted by hand. Because this was so time consuming, it was not done for the 2000-m buffer.^c Land-Line—is the family name for a range of Ordnance Survey Digital Data products, surveyed to a high degree of accuracy, that provide detailed information about the topography of Great Britain such as buildings, kerb-lines, hedges and fences, areas of woodland and even garages and telephone kiosks (www.ordnancesurvey.co.uk/land-line/) (Ordnance Survey, 1997, 2001).^d Address-Point—is a dataset product that uniquely defines and locates residential, business and public postal addresses in Great Britain. It is created by matching information from Ordnance Survey digital map databases with more than 25 million addresses recorded in the Royal Mail Postcode Address File (Ordnance Survey, 2001).

projects by environmental consultancies in the UK. These two scales are also the main scales recommended by the UK Highways Agency for the determination of road impacts (Highways Agency, 1998).

By definition, the two source scale maps portray different amounts of detail or resolution. The 1:25 000 scale map is a *generalised* version of the 1:10 000 scale map. This means that many geographical features of the 1:25 000 scale map would have been displaced, enlarged, amalgamated or even eliminated (see João, 1998). Other features would have been simplified, i.e., their representation will be smoother and less sinuous. This means that the same river at the scale 1:25 000 might be straighter, and therefore shorter, than at the scale 1:10 000. It is worth pointing out, of course, that even the more detailed 1:10 000 is also a generalization of reality. For example, the Ordnance Survey guidelines for the depiction of water detail for the 1:10 000 scale map state that ‘ponds smaller than 1 mm² [on the map]

will be omitted unless they are in an area where there is little other water detail, in which case they will be enlarged to the minimum size (i.e., 1 mm²)' (Ordnance Survey, 1989). The omission of these water bodies takes no account of their *ecological* importance, and this sort of generalisation is a strong argument for the use of multiple scales and fieldwork in EIA studies.

Data on major environmental features from both 1:10 000 and 1:25 000 scales were digitised directly from the information provided by the EIS of the road bypass. The 1:10 000 scale data contained in the EIS, covering four A3 sheets, included field work data (such as a classification of ponds according to their nature conservation interest) and that information was also digitised. In addition, Ordnance Survey's Land-Line and Address-Point data (for a description of this data, see [footnotes of Table 1](#)) were used for the air pollution impacts. Using ARC/INFO and ArcView these digitised data were then used to measure scale effects in EIAs. The measurements looked at changes in the number of features, differences in measured lengths and areas, and displacement in the position of features. Although the quantitative measurements were done using a GIS for accuracy and convenience, the results of this study are not only relevant to the use of GIS in EIAs. The results are relevant to the general use of spatial data in EIAs, with or without the application of GIS.

Coupled with the above quantitative analysis, a qualitative analysis using structured face-to-face interviews of EIA experts was also carried out. Twenty-one EIA experts, familiar with the environmental assessment of road impacts, from eight well-respected environmental consultancies were asked how their impact evaluation changed when an area was looked at in more detail or when a larger area was considered. The structured interviews were focused on five different maps showing either different detail or different extent of the key environmental constraints of the Hastings Eastern Bypass. However, and in order not to bias their analysis, at the start of the interview the experts were only told that it was a 6.2-km road bypass project and they were not informed that it was the Hastings Eastern Bypass until the end of the interview.

The experts were first shown a map of the major environmental features for a corridor only 100 m from the road centreline (within which most road construction impacts are usually felt), with data taken from the 1:25 000 scale source map. This first map was the one with the least detail and the narrowest extent. The experts were asked what was their impression about the main impacts caused by the road bypass from this first map. The experiment then tried to determine how this judgement changed as more detail and more context was revealed. The experts were shown a second map of the major environmental features for the same spatial extent, but using the more detailed 1:10 000 scale map. These two maps were followed by: a 500-m road buffer zone from the 1:25 000 scale map; a 500-m road buffer zone from the 1:10 000 scale map; and lastly, a 1500-m road buffer zone from the 1:25 000 scale map (see Appendix A for the five maps shown to the experts). Finally, they were told where and what the road project was, and again were asked how they evaluation changed. For the last question the experts were

asked, overall, what affected their judgement the most—was it the lack of detail or was it the lack of extent?

3. Results of the empirical study that measured scale effects on EIAs

The changes to the EIAs caused by using maps with different amount of geographical detail and those caused by maps with varying spatial extent were measured separately. This section concentrates on the results from that study. Firstly, the scale effects due to changes in the amount of detail (measured quantitatively with a GIS) are presented. Secondly, the results of the scale effects due to changes in spatial extent are shown. The section concludes with the results from the study where the human experts analysed the five impact maps with different spatial extent and different spatial detail.

3.1. *Scale effects due to changes in the amount of detail*

Scale effects due to changes in the amount of detail of the maps fell into three main categories: (a) changes in the *number* of features; (b) difference in measured *lengths* and *areas* and; (c) displacement in the *position* of features. As much as possible the study concentrated on changes in features that were of environmental significance, and the ramifications of these changes to the EIAs were made explicit.

3.1.1. *Changes in the numbers of features*

When all maps are generalised a large number of features can go missing (see João, 1998 for numerous examples). The maps used for the Hastings Eastern Bypass were no exception. In the cases of the category ‘recent woodland,’ 14 small individual areas occupying 4.3 ha in the 1:10 000 scale map (corresponding to 8% of the total area occupied by recent woodland), were absent from the 1:25 000 scale map (within 500 m of road centerline). In some case whole feature classes disappeared. The 1:10 000 scale map had nine extra classes (e.g., ponds and hedges) that were not present in the less detailed 1:25 000 scale map. The effects that the elimination of these features had in the evaluation of impacts are covered in the human experts’ Section 3.3.

In the original Hastings EIS report, the most quantitative analysis was carried out on potential air pollution. Because this was the environmental impact that relied most on direct map measurements it was chosen as the key quantitative variable on which to study the elimination of features. According to the UK [Highways Agency \(1998, Section 3, part 1, page 6/1\)](#), in order to assess air quality ‘mark on a map of a scale in the range 1:25 000 to 1:10 000 all buildings or areas where people might possibly be subjected to a change in air quality. Only properties or areas within 200 m of the route or corridor need to be considered.’ This method advocated by the Highways Agency, and used by most UK environmental consultancies when conducting an EIA of road projects, requires that the number of properties be used

Table 2

Number of buildings for different scales when measuring air pollution within 200 m of the Hastings Eastern Bypass (6.2 km long)

	1:25 000 paper map	OS Land-Line digital data (based on 1:1250, 1:2500 and 1:10 000 scales)	Address-point seeds
No. of buildings within 200 m of the Hastings Eastern Bypass	56	160	58

as a surrogate for population. It is assumed by the UK Highways Agency that beyond 200 m the contribution of vehicle emissions is not significant because air pollutants return to background levels.

The process used for the assessment of air-quality impacts was therefore a powerful way of studying how specific changes in the number of features could affect an EIA. Table 2 shows the results of calculating the number of buildings for the two map scales recommended by the Highways Agency (1998) method. Because more buildings are found when using the Land-Line data, air-pollution impacts look more serious when using this data source than when using the 1:25 000 scale map. So, depending on which one of these two scales is used, different alternative routes might be selected in order to reduce air pollution impacts caused by the road.

In addition to the 1:10 000 and 1:25 000 scale data, the table also shows the results when using postcode addresses. This last data source was used because it is considered by many researchers to be a more accurate way of estimating population than using maps (Raper et al., 1992). Surprisingly, the number of address point seeds was less than the number of buildings in the very detailed Land-Line data. Because there are multiple addresses in high-rise buildings, the opposite was expected, i.e., that there would be more addresses than there were buildings. This unexpected result was due to the way ‘building seeds’ are classified in the Land-Line digital data. It covers all buildings with a minimum dimension of 5 m but this includes uninhabited buildings such as greenhouses, detached monuments, cooling towers and water tanks! Counterintuitively, in this example, the less detailed 1:25 000 scale map (where less important buildings have been eliminated or amalgamated) was therefore more accurate than the 1:10 000 scale data for calculating the population exposed to air pollution from the new road. This result is useful in highlighting the importance of data quality for analysis, especially when fieldwork is not available to corroborate the true meaning of map features.

3.1.2. Difference in measured lengths and areas

The quantitative analysis of key environmental linear and areal features also demonstrated extensive changes for maps of different geographical detail. In order to compare changes in lengths and areas, only features that were common to both scales were used. For linear features, the length of the boundary of the Area of

Outstanding Natural Beauty (AONB) was 14% shorter in the less detailed map as the line was simplified and therefore made less sinuous. However, the very straight Roman road increased in length by 23% on the 1:25 000 scale map, due mainly to the EIS extending the length of the line to the wrong point.

For areal features there was very large variation in the changes in size (see Fig. 2). Of the 37 individual features common to both maps, 24 increased in area and 13 decreased in area. In general, areas got larger as the outline of areas got less convoluted (see Fig. 3, which shows how an area of ancient woodland increased from 22.9 to 26 ha) or small areas were exaggerated. The most dramatic increase in areas (for example, feature 20 in Fig. 2, a recent woodland, nearly tripled in size) were all due to very small features being enlarged in the less detailed map so that they would not be eliminated. This is a common effect of map generalisation—see the Ordnance Survey example on the guidelines for the depiction of water detail in Section 2. The four areal features that increased the most (features 10, 17, 20 and 26

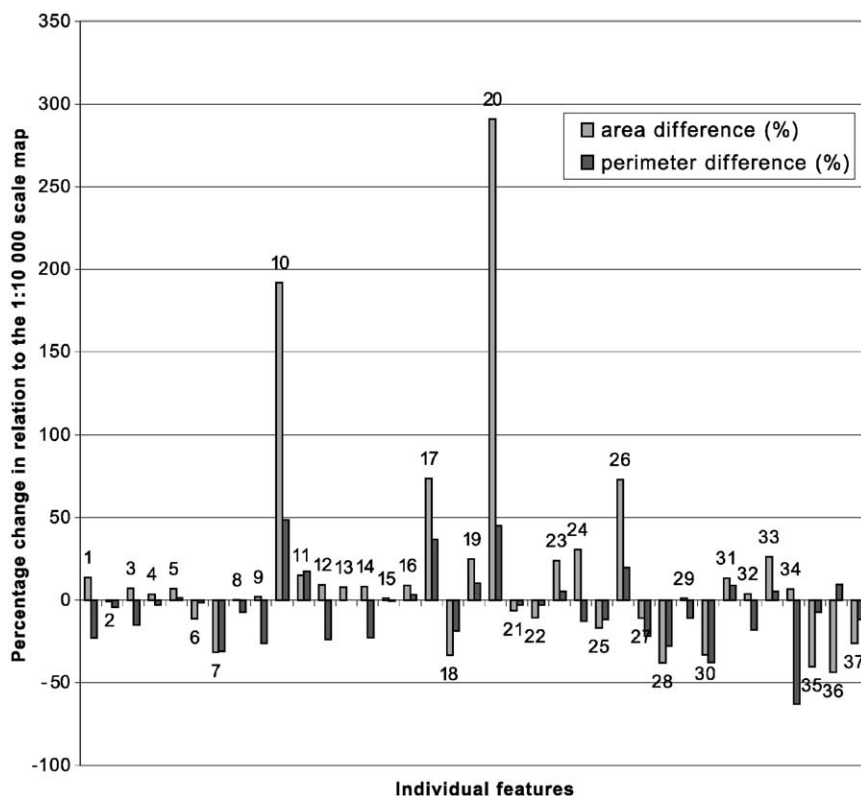


Fig. 2. Percentage change of area and perimeter for the 37 individual areas common to both 1:10000 and 1:25000 scales, for the zone 500 m from the proposed road centreline. The graph shows the change in the features in the 1:25000-scale map in relation to the 1:10000 scale.

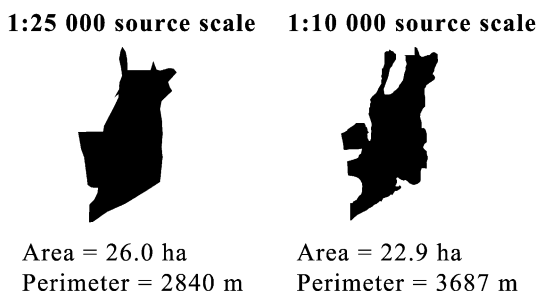


Fig. 3. An area of ancient woodland measured using different source scale maps (although displayed here at the same scale)—the feature labelled 1 in Fig. 2.

in Fig. 2) were the four smallest features. The cases where areas got smaller were usually due to small or narrow peninsula-type shapes and small sections disappearing on the less detailed scale.

One of the key impacts of the Hastings bypass was on the important ancient woodland present along the route of the proposed road. Depending on the scale used, the area of the woodland affected would vary. For example, the area of ancient woodland within 500 m of the road using the 1:25 000 scale map was 91.2 ha, while for the 1:10 000 scale map the area was 87.5 ha. This means that the impacts of the destruction and potential disturbance of ancient woodland for the proposed Hastings road bypass could be found to be slightly more serious when measured using the less detailed 1:25 000 scale map. While the absolute difference is small, if there was a threshold involved then the difference in areas could play a crucial role.

3.1.3. Displacement of features

Displacement of features means that the features are not in the same geographical position in the two maps and this introduces errors of positional accuracy and affects any subsequent spatial analysis. For example, it may affect which features fall in or out of an impact zone and it can strongly alter the results of a map overlay to determine, for example, the areas that will suffer the most cumulative impacts (see João, 1998). In this study, there were several instances when displacement in the position of features was observed between the two scales. The 14 listed buildings (common to all maps) suffered, on average, 23.4 m displacement (ranging from 9.4 to 42.8 m), while the Roman road had a maximum displacement of 90.5 m and the boundary of the AONB had a maximum displacement of 51.1 m (for a definition of maximum vector displacement see McMaster, 1987).

Displacement can lead to either finding false relationships between the data or lead to a failure in finding important relationships that matter. In one case, because of the close proximity between the Roman road and five listed buildings, an environmental consultant interviewed judged that there could be a possible archaeological relationship between the Roman road and the

buildings, indicating an important archaeological area. However, that relationship was no longer evident at the 1:10 000 scale due to the different relative positions of the features (see Fig. 4). This meant that at the scale 1:25 000 the area was considered more important archaeologically and, as a consequence, the impacts of the road bypass would be found to be more serious than if the study had been done at the 1:10 000 scale.

3.2. Scale effects due to changes in spatial extent

In order to measure scale effects due to changes in spatial extent, areas with the same detail but different spatial extent were compared. The main effect on EIAs is how it influences the determination of the level of impact significance, i.e., how important the impact is deemed to be. If only a small spatial extent is considered, and a particular resource is widely available within that small extent, then it would be assumed that losing part of that locally abundant resource is not very important. If, however, a wider area is studied and it is found that this resource is rare at a regional or national level, then the same amount of resource loss would have a relatively greater importance and the impact significance is deemed to be high.

This can be expressed quantitatively using the example in Table 3. In this case, as the extent increases and more urban areas are included, the percentage of population affected by air pollution decreases, and the impacts therefore appear to take on less importance (when the study area is 1000 m

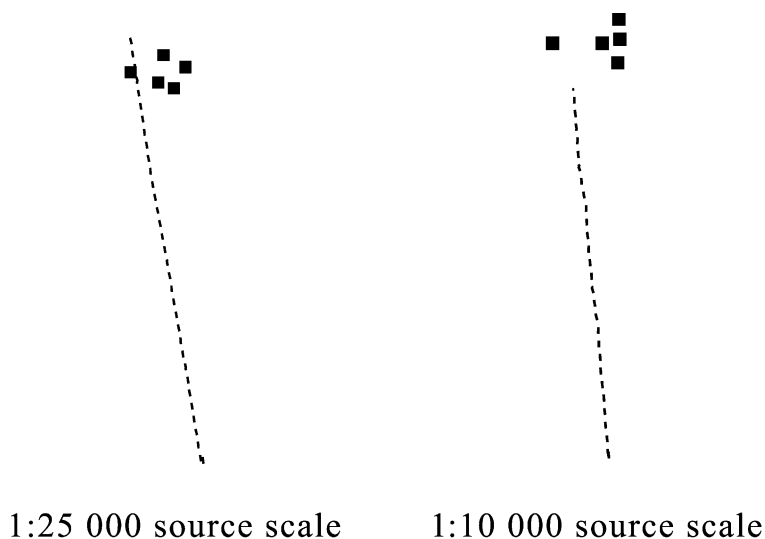


Fig. 4. Change in the position of five listed buildings (the black squares) and the Roman road (the dashed line) for two different source scale maps (although displayed here at the same scale).

Table 3

Percentage of addresses, of different-sized study areas, affected by air pollution caused by the Hastings Eastern Bypass

	No. of address-point seeds	% affected by air pollution
Area within 200 m of road centreline	58	100
Area within 1000 m of road centreline	1653	3.5
Area within 2000 m of road centreline	7101	0.8

Note: It is assumed that only addresses within 200 m of the road centreline are affected by air pollution.

from the road centreline 3.5% of the population is affected by air pollution, but when the study area is increased to 2000 m from the road centreline only 0.8% of the study population is affected by air pollution). The opposite could also happen—the impacts could look more serious if fewer urban areas were included when the area looked at was increased. Therefore, the homogeneity of the study area has a role to play—if the area was completely homogeneous, then no such difference would occur.

This relationship means that it is possible to manipulate the results according to the size of the area studied. Ross (1998, p. 271) noted this in relation to cumulative effects assessment (CEA):

The greater the area assessed for CEA, the smaller will be the percentage of impacts caused by the project, because more other sources of impact get captured in the analysis. While I would not suggest this happens on purpose (a proponent wishing to have it appear that a project causes only a small portion of the impact), it is an interesting feature of this and other regionally based CEAs.

The possibility of cynical manipulation of results according to the detail used or the size of the area studied is obviously of crucial importance. A solution to this problem might be to set up guidelines or rules that give advice on suitable scales for analysis (see Section 4). The Inter-American Development Bank, for example, started to demand the use of particular scales in the ‘terms of reference’ both for analysis and for presentation of the results, and as a consequence noted an improvement in the quality of the EIA work (Luis Miglino, Inter-American Development Bank, USA, 1998, personal communication). This was prompted by the case of corrupt enterprises in Brazil that were using maps of poor detail to help them get work commissioned—bearing in mind that the criteria of selection is often to minimise cost and producing, say, a geologic map at the 1:50 000 scale is more expensive than at 1:500 000 scale.

3.3. Study on the effects of scale on EIAs using human experts

Coupled with the above quantitative measurements, EIA experts were asked to evaluate road impacts by analysing five different maps (see

Appendix A) to see how their evaluation changed for different size areas and areas with different detail. As more detail and greater spatial extent were provided, a wider range of features and issues appeared. Most experts felt that the impacts looked more serious both with increased detail and with increased extent. The new features that appear with each new map can be seen in [Table 4](#). With the exception of the 500-m buffer zone using the 1:10 000 source

Table 4

Features that appeared when more detail or more extent was given to the EIA experts

Sequence of maps given to experts	Initial features	New features that had not appeared before on any of the maps
Map 1: 100-m buffer zone, 1:25 000 source scale map	1. Ancient woodland 2. Recent woodland 3. Copses and shaws—possible ancient woodland 4. Conjectured Roman road	
Map 2: 100-m buffer zone, 1:10 000 source scale map		1. Grassland of nature conservation interest 2. Pond of nature conservation interest 3. Archaeological find-scatter, identified from field walking 4. Line of trees 5. Hedges 6. Public footpath 7. Archaeological earthworks 8. Archaeological site 9. Archaeological find-spot
Map 3: 500-m buffer zone, 1:25 000 source scale map		1. Public open space/recreation area 2. Archaeological significant area 3. Southern boundary of the Area of Outstanding Natural Beauty (AONB) ^a 4. Listed building 5. Sites from 'Sites and Monuments Record'
Map 4: 500-m buffer zone, 1:10 000 source scale map		
Map 5: 1500-m buffer zone, 1:25 000 source scale map		1. Sites of Special Scientific Interest (SSSI) ^b 2. Scheduled ancient monument

^a The primary purpose of the AONB designation is to conserve natural beauty. Since 1949, 14% of the countryside of England and Wales has been given AONB status. AONB are of national as well as local importance.

^b SSSI are the finest sites for wildlife and natural features in England (covering approximately 8% of England), supporting many characteristic, rare and endangered species, habitats and natural features. SSSI are areas of national or international importance.

scale map, all maps presented the expert with some new information. Particularly noteworthy, as observed by most experts were: the hedges, footpaths and features of conservation interest that only appear on the 1:10000 scale map; the southern boundary of the AONB that only appears with the 500-m buffer; and the two Sites of Special Scientific Interest (SSSI) that only appear with the 1500-m buffer zone.

Overall the experts felt that it was the lack of spatial extent, rather than lack of detail, that affected their judgement more. ‘In terms of EIA, context is everything’ (Ruth Kelly, Environmental Resources Management, UK, 1999, personal communication). As the consultants explained, they are accustomed to evaluating sites with very limited data: ‘you can sort the detail in your mind very quickly but what you can’t do is form any view of where it is and what is the context you’re dealing with’ (Jon Grantham, Land Use Consultants, UK, 2000, personal communication). It was even suggested by one of the experts that information provided by using wider spatial extent could be used to complement detail. For example, the existence of archaeological sites within a wider extent (as wide as a 1-km buffer zone) can be used to conjecture whether there might be archaeologically significant areas within the narrow corridor of 100 m. This finding indicates that it is necessary to assess environmental impacts with sufficient extent, otherwise the real importance of a site might be disguised. Widening the study area supports the recommendation by English Nature to have all proposed roads evaluated with a minimum buffer of 500 m and a maximum of 2000 m, on each side of the road (Bina et al., 1995). An area this size is considerably larger than the recommendation by the UK Highways Agency of using a 100-m buffer zone as the maximum distance needed to calculate disruption due to construction.

Presented with the 100-m buffer most experts felt very uncomfortable and stated that they could not do a fair judgement with such a narrow extent. Some expressed how it was problematic to evaluate the significance of the impacts. For example, it was not possible to determine the percentage of woodland areas affected. It was also impossible to know if the road was passing through the middle of an area of ancient woodland or if it was merely cutting an edge of the woodland. It was also difficult to evaluate alternatives with such a narrow corridor. ‘Can’t do any evaluation with just 100 m buffer—woodlands might only be 100 m wide—if so then you could go around them’ (Philip Cumming, Dames and Moore, UK, 2000, personal communication).

Although less so than in relation to lack of extent, some experts also felt uncomfortable with the lack of the detail. With more detail, the majority of experts felt that the impacts looked more problematic than before. ‘A key issue in EIA is that the more you look, the more you find. This means that a site that is looked at in more detail might appear more precious than other sites’ (Jon Grantham, Land Use Consultants, UK, 2000, personal communication). With increasing detail, it looked as if the road would have potential impacts along its

whole route while previously only the west area seemed problematic. ‘My first impressions were wrong. I originally assumed that only the first two kilometres of the road were vulnerable to impacts. With the extra detail it became obvious that the whole length of road was an issue’ (Ana Teresa Chinita, PROCESL, Portugal, 1999, personal communication).

The experts’ analysis on the seriousness of impacts caused by the proposed new road was affected by both different spatial extent and different geographical detail. This finding, coupled with the quantitative measurement of scale effects in EIAs, strongly supports the need for improved practice regarding how scale issues are currently taken into account in EIAs.

4. Conclusions and recommendations for future practice

To the author’s knowledge, this was the first time an empirical study had been carried out specifically to determine whether scale could affect the accuracy of impact prediction. Parts of an existing EIA of a road project (the Hastings Eastern Bypass in Southeast England) were redone at different scales to discover how the results differed. Two complementary approaches were used: one study based on measurements using a GIS, and a parallel study based on analysis by EIA experts. Both aspects of the study found that changes in scale, in terms of detail *and* spatial extent, can have important repercussions on the results of EIAs, such as in the determination of impact significance and the measurement of environmental parameters.

The ultimate consequence of the changes in EIA results, according to scale, is that the *outcomes* of EIAs can be altered. A different EIA outcome might be, for example, how much longer the road would need to be to avoid sensitive or protected features apparent at one scale and not another. This means that, according to the scale used, different decisions might be taken regarding the proposal, or different alternatives might be chosen, or different mitigation measures might be implemented. This is the ultimate ‘impact’ of scale in EIA. It is impossible to know for sure whether the EIA of the Hastings Bypass would have come to a widely differing conclusion overall if different scales had been used. However, this study has demonstrated important scale effects such as in the area of woodland affected, the importance of archaeological sites, and the number of buildings affected by air pollution. The impact that these scale effects would then have on the final outcome of the EIA would depend on the methodology used for deciding on alternatives or what mitigation measures should be applied. A quantitative methodology based on thresholds would be more sensitive even to small changes in the determined values of impact significance or the measured environmental parameters.

It may be argued that for most project EIAs, fieldwork would complement and correct any incomplete or wrong information given in mapped data. If this were always the case, scale effects might not manifest themselves as

seriously. For example, the number of houses within 200 m of a road might be counted one by one in the field. This, however, would only apply to scale effects caused by changes in detail and would not apply to the scale effects caused by changes in spatial extent. It can also be argued that scale effects (for both detail and spatial extent) will always be relevant in that (a) the field study might not cover all areas; (b) scale influences the desk study, which in turn affects the design of fieldwork; (c) the fieldwork itself is carried out using a map (either paper copy or a digital copy on the computer screen) as a base, with information added directly to the map in the field (such as in the case of the 1:10000 source data used in this study); and (d) spatial scale will always affect assessments that rely strongly on mapped information, such as very large projects, cumulative effects assessment, and strategic environmental assessment. Above all, it is crucial that practitioners are aware of the dangers of ignoring scale effects in EIA or of being uncritical in relation to the choice of scale. ‘Spatial scale is a last consideration in many studies, yet scale often selects the nature of the results’ (Meentemeyer and Box, 1987, p. 22).

This research has discovered that scale, in terms of both detail and extent, is an important issue that, to date, has been largely neglected in EIA. For this reason, it is necessary to devise ways of improving existing environmental assessments by taking scale into account. A key recommendation for future practice is that the choice of scale in EIA should be public and transparent. ‘Scale is not a property of nature alone but, rather, is something associated with observation and analysis’ (Allen and Hoekstra, 1991, p. 48). This means that the chosen scale is one part of the observer bias, and therefore it is fundamental to define the scale of observation. In other words, scale choice should be explained, justified and explicitly stated in all EIS. Otherwise one cannot accurately compare different environmental impact assessments or even choose between them when they differ.

Another recommendation is that it is necessary to investigate the need for new EIA guidelines on scale. These guidelines could be of three different types: general qualitative recommendations (e.g., ‘Terms of reference should consider scale issues explicitly’); specific quantitative guidelines linked to processes (when possible) (e.g., ‘In reporting landscape pattern, grain should be two to five times smaller than the spatial features of interest,’ O’Neill *et al.*, 1996, p. 169); and, ‘scale warnings’ indicating scales to be avoided (e.g., ‘Map scales of less detail than 1:250000 should be avoided for baseline studies of project EIA’). Where it is not possible or sensible to impose strict rules like ‘100 m either side of a road,’ the scale guidelines could be procedural rather than prescriptive.

A key aspect of these guidelines is the realisation that there isn’t necessarily one ‘right’ scale but that there are instead multiple or a range of scales appropriate for the description of a system. Although it might be unclear as to the ‘right’ set of scales to use, it may be known which scales should be avoided. ‘That there is no single correct scale or level at which to describe a system does not mean that

all scales serve equally well or that there are not scaling laws' (Levin, 1992, p. 1960). What is fundamental is to recognise that, because change is taking place on many scales, multiscale approaches might be required, and that we need 'to understand the consequences of suppressing or incorporating detail' (Levin, 1992, p. 1947).

Future research will investigate multiscale approaches in EIAs and will propose new scale guidelines in EIAs for both spatial and temporal aspects. Another major line of research is the need to compare scale issues for project EIAs with strategic environmental assessment (SEA). If SEA is defined prior to the EIAs of individual projects, ensuring the SEA is as accurate as possible can be argued to be at least as important (if not more).

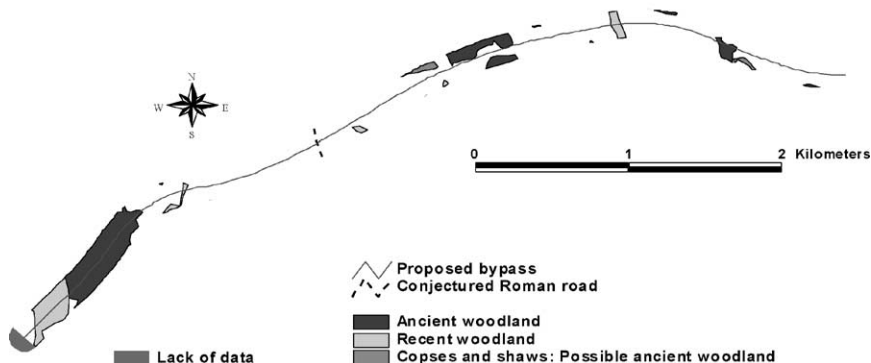
Acknowledgments

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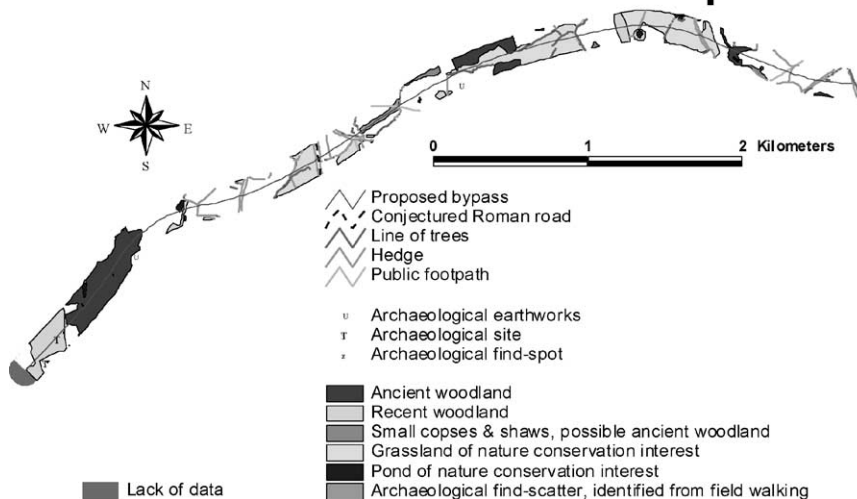
Appendix A. The five maps shown in sequence to the EIA experts

Note: Colour versions of these maps can be found in <http://www.geog.gla.ac.uk/~ejoao/maps.pdf>

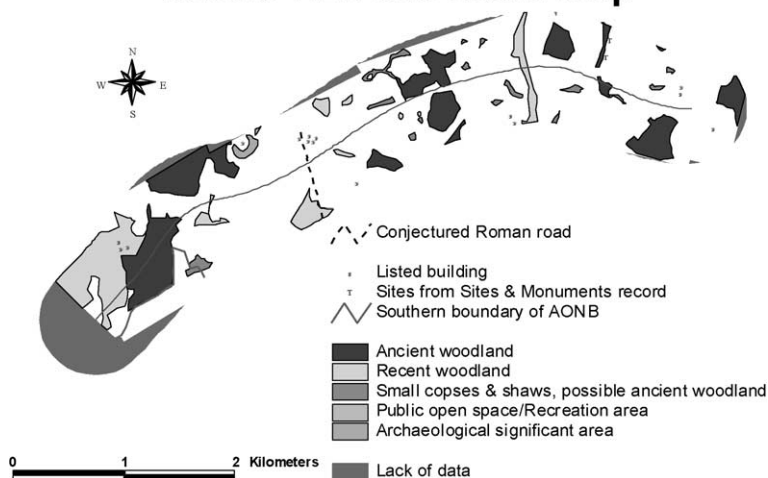
Buffer 100 metres from road centreline based 1:25 000 scale map



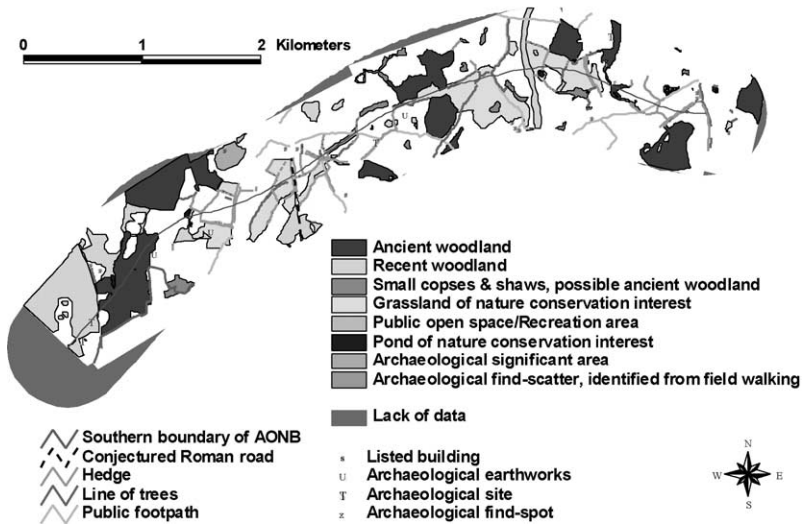
Buffer 100 metres from road centreline based 1:10 000 scale map



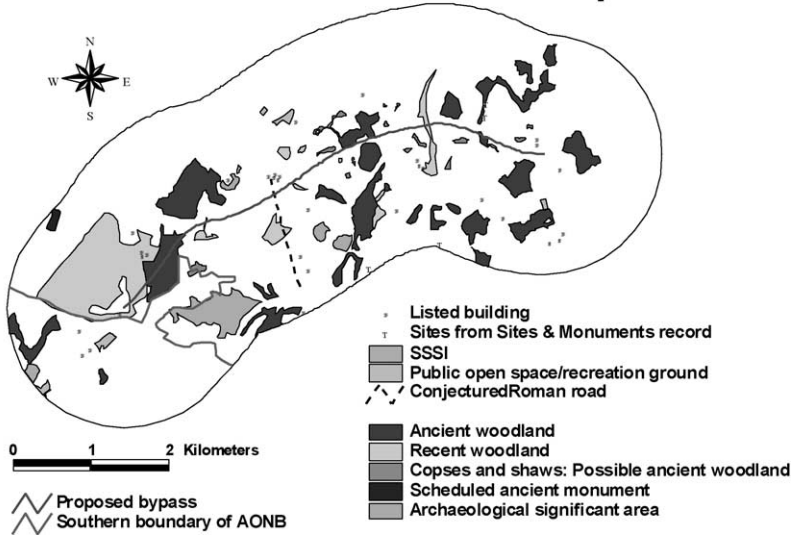
Buffer 500 metres from road centreline based 1:25 000 scale map



**Buffer 500 metres from road centreline
based 1:10 000 scale map**



**Buffer 1500 metres from road centreline
based 1:25 000 scale map**



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