J Geograph Syst (2004) 6:117–132
DOI: 10.1007/s10109-004-0128-1

Journal of Geographical Systems

Democratic input into the nuclear waste disposal problem: The influence of geographical data on decision making examined through a Web-based GIS

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Abstract. This paper elucidates the manner in which users of an online decision support system respond to spatially distributed data when assessing the solution to environmental risks, specifically, nuclear waste disposal. It presents tests for revealing whether users are responding to geographical data and whether they are influenced by their home location (*Not in My Back Yard* – style behavior). The tests specifically cope with problems associated with testing home-to-risk distances where both locations are constrained by the shape of the landmass available. In addition, we detail the users' wider feelings towards such a system, and reflect upon the possibilities such systems offer for participatory democracy initiatives.

Key words: democracy, Web, participation, risk, NIMBY

JEL Classification: C8, Data collection and data estimation methodology; Computer programs

1 Introduction

This paper evaluates the effectiveness of Geographical Information Systems (GIS), in particular Web-based GIS, as a medium for gathering stakeholder decisions on environmental problems with a spatial component. The issue of radioactive waste management and disposal is used as an example, with individuals from outside the industry being asked to choose a site for a nuclear waste repository using a Web-based decision support system. Plainly, how the public interacts with a problem once spatial data is introduced is of particular relevance to radioactive waste management where "Not In My Back Yard" (NIMBY) influences may act (Luloff et al. 1998). Nuclear waste

The authors would like to thank the two anonymous referees for their helpful and generous comments.

is perceived to have a risk associated with it that may, consciously or otherwise, lead people to suggest sites away from the areas where they live. Previous research (Kingston et al. 2001) suggests that peoples' attitudes to this decision problem can change markedly when information is made available in map form. These findings follow current thinking in risk perception research that suggests people will respond to increased information by changing their views (Adams 1995; Douglas 1994). This paper directly examines the effects of geographical information on the process of assessing risks, and also examines how users interact with a system that allows decision-making on the basis of such spatial information. Evaluation of these issues is carried out by studying changes in user behavior when maps of potential nuclear waste repository sites are made available through the system, and by user profiling.

In particular, this study aims to answer questions about the quality and flow of information between stakeholders and decision makers when dealing with spatially-based risk problems. The specific questions are:

- How do stakeholders respond to the inclusion of spatial concepts and data?
- Can we tell when stakeholders are making a decision reasoned on the basis of spatial data?
- Can we tell whether we are encouraging a bias in stakeholders' responses by adding a spatial element to the risk assessment?
- How do stakeholders respond to the opportunity for participation?

2 The system

A Web-based system (http://www.geog.leeds.ac.uk/projects/atomic/) has been developed to explore how stakeholders respond to, and use, digital information relevant to the spatial and non-spatial aspects of radioactive waste management. The foundation for this is based on previous work within Web-based decision-making environments (see Carver et al. 1997; Kingston et al. 2001). The basic system elements include:

- a hierarchical information system to provide users with information in a manner which gives them a baseline understanding, but also allows them to explore particular issues down to the level of consultancy reports and raw data;
- a sequence of increasingly complex questions and tasks concerning radioactive waste management and the siting of storage/disposal facilities designed to measure users' responses to information, the methods of presentation and option choice behavior;
- a feedback form to garner users' knowledge of radioactive waste management issues and provide further user feedback about information needs, system design and other issues raised.

In particular, users work through a GIS system that allows them to input where they believe a national nuclear waste repository would best be located within the mainland of Britain together with its islands, including the Western Isles, the Shetlands and Orkneys. Users can experiment with issues that may be important when making such a decision by constructing a site suitability map. On this map they can limit the suitable locations by switching on a series of constraints (for example, that it should not be within designated conservation areas) and by weighting certain factors relative to each other using scrollbars (for example, weighting the distance from populous areas as highly important but distance from roads as less important). These constraints and factors are listed in Table 1.

The critical feature of the system is that users are asked to quantify their feelings on the constraints and factors before seeing a map that shows the most suitable locations generated on the basis of these choices. They then

Table 1. Constraints and factors chosen by the users. All datasets were at a per pixel resolution of $4km^2$

Binary constraints: On-off variables	**Explanation**
Deep geology	A suitable geology is important for deep underground repositories if they are to survive without maintenance. Taking into account factors like the type of rock, depth and faulting, this constraint limits sites to highly suitable deep rock areas.
Surface geology	Limits sites to soft surface rock areas that might be suitable for a shallow disposal facility such as currently used at Drigg near Sellafield. These rocks include certain types of clays and mudstones that restrict the movement of water.
High population density	Areas with a high population density may be considered to present too great a risk-benefit ratio. This constraint limits sites to areas with less than 490 people per km^2.
Conservation areas	Excludes sites from: National Parks; Areas of Outstanding Natural Beauty; Heritage Coasts; Environmentally Sensitive Areas; National Scenic Areas; Regional Parks.
Within 10 km of coastline	Limits repository to within 10 km of the coast. Offshore stores with an entrance near the coast are less likely to contaminate the land/populated areas.
Factors: Graded variables	
Population density	Population density map, as above, but with no imposed threshold.
Population Accessibility	Any repository is likely to provide work, during both construction and its operational life. This data is derived from the population density map and describes how close each place on the mainland/islands is to a suitable work force.
Strategic access	This is used to describe the costs/risks associated with transporting radioactive waste from source sites to disposal sites. The dataset is based on straight line distances from major waste producing sites to each point on the mainland/islands.
Road access	Waste can be transported by road. This dataset is the distance to the nearest road.
Rail access	Waste can be transported by rail. This dataset is the distance to the nearest railway.
Distance from conservation areas	Distance to the nearest of the conservation areas listed above from each place on the mainland/islands.

have the opportunity to change their constraints and weightings and see the map dynamically update to reflect their new criteria. Once they are satisfied with their proposed "suitable sites" map, they then make a second submission of their weights/constraints. This allows an investigation into how user responses change when faced with the geography of the problem. A major part of the second submission is the choice of one specific favored site from the map. As part of the user profile, users are asked to fill in their home postcode (zipcode) so that their changes and sites can be compared with their postcodes to examine potential NIMBY-type behavior.

The results presented in this paper are derived from a pilot group of individuals invited to participate as a test cohort for the system. Specifically, the system was advertised within the authors' University. Planned future work will evaluate the changes associated with demographic groups once the system has been more publicly disseminated. The demographic characteristics of the users are given in Table 2. In order to encourage a suitable level of risk appreciation, the users were told that the submissions they made would be collated in research that would be passed on to the institutions responsible for nuclear waste disposal in the UK.

There were a total of 167 users, though some used the system more than once, giving 217 total responses (see below for details of how repeats were dealt with). Table 2 shows a strong bias towards highly educated twenty-year olds with affluent backgrounds. There is no reason to believe that this group has any greater understanding of the issues of nuclear waste disposal than other groups. Indeed, it might be argued that as most of the group were not

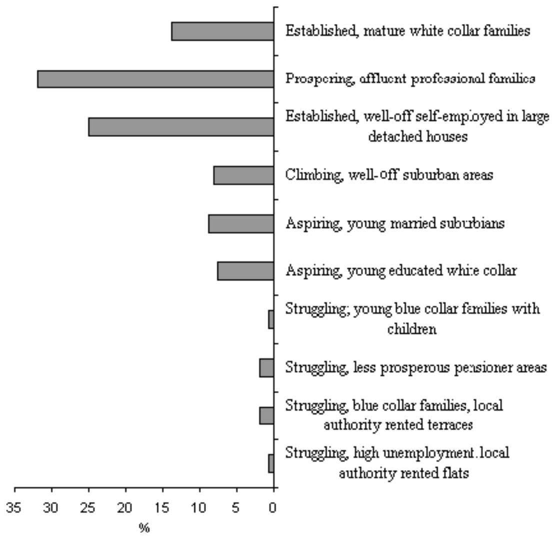
Table 2. Demographic profile of users. The socioeconomic groups have been derived using home postcodes and the LGAS system (Openshaw and See 1998). For students the postcode asked for was where they lived outside of term time, and therefore the socioeconomic grouping will in many cases be parental

Age
- 17–25: 96%
- 25–35: 3%
- 35–50: 1%

Gender
- Male: 54%
- Female: 46%

Education level
- Currently at high school: 1%
- Currently undergraduate: 93%
- Currently masters: 3%
- Currently PhD: 1%
- Finished PhD: 2%

Socioeconomic groups



born at the height of the anti-nuclear protests and would have been very young at the time of the Chernobyl accident they may, on average, be slightly less aware of nuclear issues than the general population. A survey of undergraduates conducted at the same time as this study revealed that 53% thought they “knew a little” about nuclear waste, while 24% felt they knew “not much”. Only 12% felt they were well informed. The group may have a slightly higher than average familiarity with computers, but with some 44% of the population in the UK currently having access to the Internet at home (Economist 2003), they probably only fall in the upper half of the population.

3 Responses

Users were first asked to weight factors and turn on criteria they felt were important without seeing a map of the potential sites these choices produced. Where users had repeatedly tried the system, only the first set of these geographically uninformed choices were taken, as a complete run through of the system allows users to view and experiment with the maps. The combined map generated from all users’ geographically uninformed choices is given in Fig. 1A.

After the users have submitted their geographically uninformed choices, they were then presented with a map of the most suitable sites on the basis of these choices, and allowed to alter the weights and criteria as many times as necessary and see the map dynamically alter to reflect these changes. The maps were generated by multiplying a suitability surface for each factor by the weight the user had chosen for each. The weighted suitability surfaces were then summed and normalized by the maximum possible combined weights. This gave a new, combined, suitability surface showing the suitability of each point on the basis of the variables the users chose and their weightings. The areas under the various constraints were then set to zero suitability. When they were satisfied with the choices they had made, they could then resubmit them. Where users have used the system several times, their last submission of this data was taken as their most

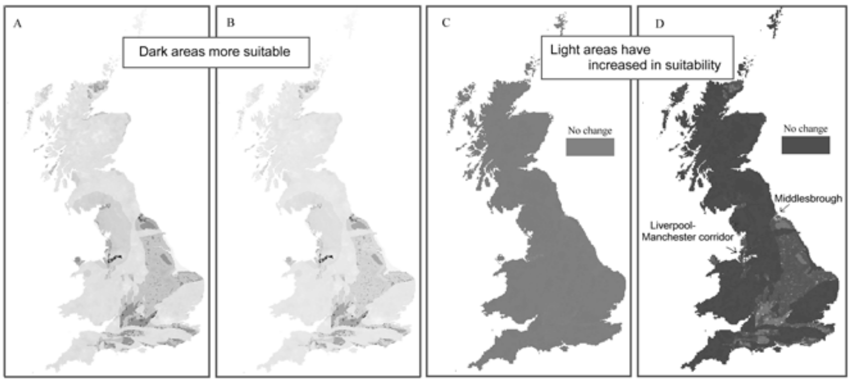


Fig. 1. **A**. Geographically uninformed suitabilities. **B**. Geographically informed suitabilities. **C**. Difference between the two maps. **D**. Map C with a stretched scale

geographically-informed set of choices. Note that this is in contrast with their geographically-*uninformed* choices, where the first of their repeated attempts was collected as the most appropriate.

The combined map from all the users' geographically informed choices is given in Fig. 1B. The changes to the variables are shown in Table 3. The percentage factor change shown is for the full range, not relative to the original value of individual weights. Two-tailed Mann-Whitney significance levels are shown that were generated when comparing the weights given before and after seeing the spatial nature of the data. In addition, two-tailed Chi-squared significances for the changes in constraints are shown. In both tests anything with a significance level less than 0.05 is considered a significant change.

In addition, users were offered the chance to choose a specific location on their final map that they considered most appropriate for a nuclear waste repository, having assessed the evidence. Figure 2A shows the locations chosen by the 64 users who also used a weighting system and gave a full postcode. Figure 2B shows their home location on the basis of the postcodes.

All genuine UK postcodes were accepted and, though there was no attempt in this pilot to collect addresses or any other personal information for cross checking, the derived locations were checked for residential potential. Some users plainly typed in random postcodes that were not viable postcodes. To check whether a user could randomly generate a viable UK postcode a small experiment was completed. 100 postcodes were randomly generated in the correct character-number format (50 six character and 50 seven character). Of the 100, only one was a viable postcode, suggesting that the chance of a user entering a postcode with which they were not at least familiar was limited.

Table 3. Binary constraints and relative factors offered to the users as important in siting nuclear waste repositories

Constraints (can be on or off)	Changes after geography seen			
	On → off	Same	Off → on	Significance
Deep geology	3.3%	87.8%	8.9%	0.168
Surface geology	8.9%	80%	11.1%	0.672
High population density	10%	71.1%	18.9%	0.08
Conservation areas	8.9%	78.9%	12.2%	0.447
With 10 km of coastline	10%	73.3%	16.7%	0.206

Factors (can be weighted relative to each other)	Changes after geography seen		
	Average change	Standard deviation of % changes	Significance
Population density	+1.9%	33.4	0.946
Population accessibility	+6.5%	26.9	0.384
Strategic access	+17.2%	37.9	0.03
Road access	+20.3%	32.4	< 0.01
Rail access	+21.6%	35.9	< 0.01
Distance from conservation areas	+21.9%	39.3	< 0.01

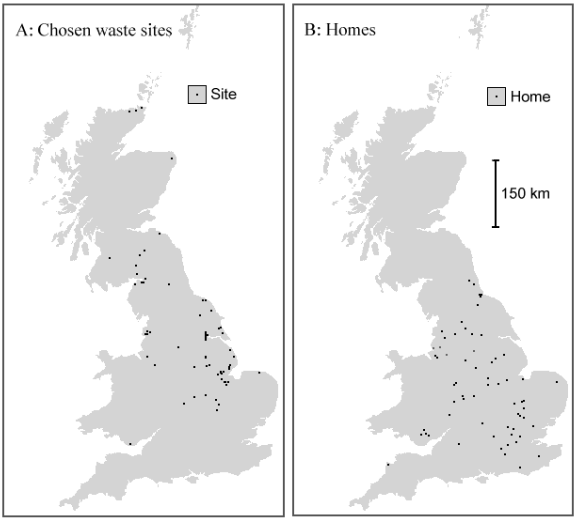


Fig. 2. A. User picked sites for a nuclear repository. **B**. User home locations

4 Analysis

The following analysis elucidates the effect that spatial data has on the users. In particular it examines NIMBY-style behavior by looking at the distances between the locations of users' homes and the waste repository sites they picked (denoted the 'home-to-risk' distance below). In order to examine NIMBY-style behavior we need to answer several related questions. Can we tell the difference between random and informed answers? Can we identify geographically informed choice? Can we tell when people are selecting on the basis of their home locations? The analysis below suggests several tests that answer these questions to reveal the level of geographical influence on the users. The tests, and their significance levels, are outlined in Table 4. The random and quasi-random data was generated using a small application developed to produce geographically constrained randomness (Evans 2003).

4.1 Are the users making random choices?

A simple plot of the distances between users' homes and their chosen waste repository sites suggests there is a distinct peak in these home-to-risk lengths (Figure 3A). However the distances possible or likely to occur will be skewed by the shape of the available landmasses on the map and the location of the homes. For example, given the length of landmass available, if we imagined all the users lived in the centre of the map, distances over 500 km would never occur. The effect of the landmass shape can be seen if we randomly generate points within the areas of land on the map and link pairs of them (Fig. 3B). The significant difference between such a sample of geographically constrained randomness and our data (Table 4, Test 1) indicates that our

Table 4. Two-tailed Mann-Whitney significance levels when comparing the distribution of user generated choices with various modelled choices

Test	Significance (< 0.05 is a significant difference)
1) Distances between random points on the land compared with user generated home-to-risk distances.	< 0.001
2) Distances between random points and user homes compared with user generated home-to-risk distances.	< 0.001
3) Distances between homes generated probabilistically on the basis of population density and random points, compared with distances taken between users' homes and random points.	< 0.001
4) Site suitability scores at waste sites chosen by users compared with suitability at random points on their maps.	< 0.001
5) Distances taken by randomly connecting user chosen waste sites with user homes, compared with user generated home-to-risk distances.	0.631
6) Average distances from users' homes to most suitable waste site locations on their weighted maps compared with user generated home-to-risk distances.	0.525
7) Suitability scores at user home locations before the users see and experiment with the geographical nature of the data, compared with afterwards.	0.709
8) Average distance from the most suitable waste site locations to user homes before the users see and experiment with the geographical nature of the data, compared with afterwards.	0.605

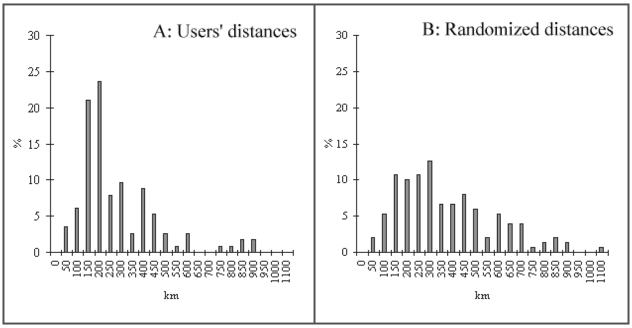


Fig. 3. A. Frequency of distances between users' homes and their chosen waste site locations as a percentage of total users. **B**. Frequency of distances between random points within the map area as a percentage of total users

user data distribution is not simply due to the constraints of the shape of mainland Britain – there are additional factors at work.

One such factor will be the position of the users' homes within the possible land areas. When the randomized distances are constrained so they link between each user's home and a random point on the land, there is still a significant difference when compared with the user home-to-risk data (Table 4, Test 2). There are, again, additional factors at work. The comparison shows that the relationship between home locations and waste sites chosen is not geographically random. The waste sites are being picked from geographically constrained areas even when we ignore the constraining effects of the shape of the land areas and the location of people's homes on the potential home-to-risk distances generated. That is, the users are not randomly picking waste sites from just anywhere on the map; they are making an informed choice of some type. This is important to determine in Internet based studies, in which disinterested or uninformed "click through" might be raised as a possible behavior. Note, though, that the geographical relationship contained in the home-to-risk distance need not be either causal or psychologically significant. Users may be basing their waste site choices on the geography of the variables offered, uninformed by the geographical relationship with their homes. Imagine, for example, a scenario in which there is only one "good" location for a waste site, and most people live in one place 200 km from it. The home-to-risk distances would be the same, even if users were only picking the most suitable site.

4.2 Is the sample of citizens representative of the population as a whole?

In order to examine the question of whether the sample of citizens is representative of the population as a whole, distances were generated by taking users' home points and randomly linking them with points over the whole country. These were then compared with similar data for home positions generated on the basis of the population distribution in the UK. These distances were generated by probabilistically taking random home positions such that there were more homes in areas of higher population density. These quasi-random home positions were then linked to totally random points. The real home-to-random and generated home-to-random distances were then compared. The two datasets are significantly different (Table 4, Test 3), suggesting the potential distances generated from our group's homes are not those of the general populous. This is a firm measure which allows us to determine when our sample population is diverse enough geographically to justify treating it as a *geographically* representative sample of the whole population, that is, one with which we could examine distance biases generally. In our case it is not and we must confine ourselves to discussion of our sample alone when it comes to NIMBY-style analysis.

4.3 Is the geographical information affecting where the users are picking sites?

We have already seen that users are picking waste sites from geographically constrained areas, however, we need to determine whether these are being picked on the basis of the weighted map they have each generated. To test this, each user's weighted map was reproduced and the suitability score at the user's chosen waste site noted. At the same time, a random point was taken on the map and the suitability score recorded as well. The combined samples for all the users' chosen waste sites and the random points were then compared (Table 4, Test 4). As is indicated, there is a significant difference that suggests users are strongly influenced by the geographical distribution of suitable sites on their maps. The average suitability for the users' waste sites was 83.7 out of a possible 100, compared with 37.0 for the random points. That is, user-picked waste sites are more suitable by 50.7% of the total range. It is, of course, possible that users are manipulating the weights to drive up suitability scores in the areas they want sites, and tests for this are given below.

4.4 Are the locations of the users' homes affecting their site choices?

We have seen that the users are picking waste sites that are more suitable than might be expected from random choices. However, we need to examine whether these waste sites are actually the most suitable, or whether users are picking sites with a slightly lower suitability score further away from their home locations because of the perceived risks. A simple test that might examine this effect is to take distances generated by randomly connecting user picked waste sites with other users' home locations, and to compare these distances with the users' genuine home-to-risk distances (Table 4, Test 5). Such a test examines the distances between two sets of geographically constrained points: the homes and picked waste sites. A significant difference here would tell us, in combination with the above results, that users were definitely picking waste site locations that were related to the distance from their homes. However, the lack of significance obtained does not confirm the inverse argument. To show why, consider the following scenario. Imagine that all the users live in one location, and they all pick the waste repository location with the maximum possible distance from their home. Plainly our test would still give no significant difference between the randomly linked and actually linked areas, as both would be identical. Having a significant result would guarantee this wasn't the case. If our sample more closely resembled the distances possible for the general population we might have an argument for comparing our data with distances derived by probabilistically generating households and linking them with user picked waste locations. However, as we have seen, we cannot have this confidence in our data.

Given the negative results of this simple test, we proceed to examine the data directly. We regenerate each user's weighted map, and note the distance from the most suitable waste repository site/s to the user's home. The "most suitable" sites are defined as the site or sites with the highest suitability score on each user's weighted map. In the case of more than one site sharing the highest score, an average distance is used. This dataset is then compared with the user generated home-to-risk distances (Table 4, Test 6; Fig. 4A; B). As can be seen, there is little difference in the distances between the users' homes and their chosen sites, and their homes and the most suitable sites. Despite the 4.7% of the users who picked the 700–900 km distance category, a category not represented in the distances to the most suitable waste sites, there is no overall significant difference to the distributions, suggesting that by-and-large the users were acting without significant self-regard. As we have already seen that the users are not acting randomly, we are left with the conclusion that they are acting altruistically, for the benefit of society. Figure 4B represents the per-user differences in the two measures, and therefore gives a visualization of the level of this altruism: those acting with NIMBY-style self-regard would

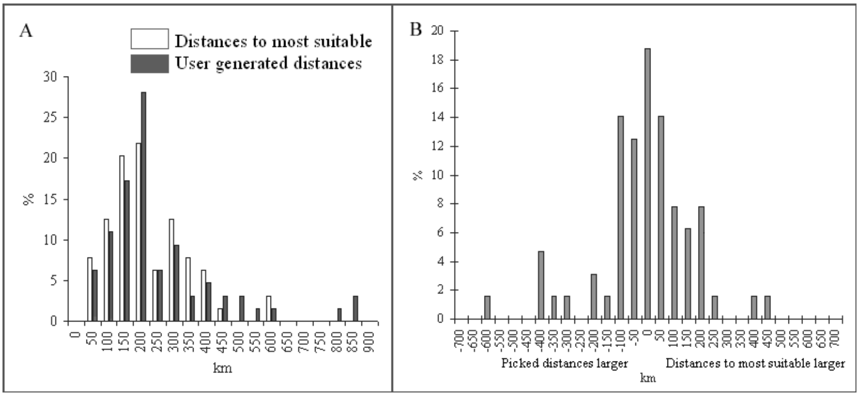


Fig. 4. **A**. Frequency of user generated home-to-risk distances and the average distances from users' homes to the most suitable waste site locations. Both are shown as a percentage of total users. **B**. Frequency of differences between each user's home-to-risk and home-to-most suitable site distances as a percentage of total users

probably be expected to pick sites further from their homes than nearer, more suitable, sites. It is plain that as well as some users picking less suitable repository sites further from their homes, just as many users appear to have made less suitable choices nearer their homes. Both may actually reflect the choice of potential waste disposal sites in areas where the scores are nearly the best but the suitable area is larger than the area with the maximum score. Users may have considered such areas a better location for a waste site if the most suitable area is small and a long way from other partly suitable regions. It should be possible to investigate this possibility using suitability-weighted lengths in the distance calculations, though we have not done so here.

4.5 How do the factors and constraints that users feel are important change after they have seen their geography?

The difference between Fig. 1A (the geographically uninformed combined map) and Fig. 1B (the geographically informed map) is shown in Fig. 1C/D. The statistical significance of the changes for individual variables is shown in Table 3. Most of the areas that become more important are controlled by constraints: as these are either 100% 'on' or 'off' they have a disproportionately large effect on the combined maps compared with the weighting factors. The constraints tended to be added by users when the geography is presented to them. Despite this influence, there are two notable details in the changes. The first is that users have a tendency to misunderstand the system. The absolute values assigned to their weighting factors all tend to increase after the geography is seen, despite the fact that ultimately the map is produced by weighting each of these values relative to each other. This relative weighting means that setting high values for all the factors produces the same map as setting low values for all the factors. This misunderstanding seems to suggest that users rate all factors more importantly after they have seen the geography associated with them. The second notable, and surprising, change is that population density becomes a less important factor, and accessibility becomes more important. This is not to say that population is unimportant, but that other factors have risen in importance relative to it. This explains the rise in waste site suitability of very small areas like the Liverpool-Manchester corridor and Middlesbrough: these are areas where the general region is suitable, but population levels reduced their suitability in the geographically uninformed map.

4.6 Are the locations of the users' homes affecting how they choose their factors and constraints?

We have seen that users are not picking sites preferentially further from their home locations than the most suitable points generated by their weighted maps. However, it is possible that some users are weighting their maps to drive suitable areas away from their homes. Certain factors mitigate against this: while the users know their responses are being recorded, the choosing of the site location is highlighted to them as the major step, not experimentation with the factors. In addition it takes some effort to alter the factors to consciously drive suitable locations away from a specific point. However, it is still possible this behavior may be expressed in the data. To test this, we examined the suitability scores at the home location before and after the users have seen the map and been allowed to experiment (Table 4, Test 7). It could be argued that the score at the home location may not be representative of the surrounding area, so we also test the average distance between the home and most suitable sites before and after the users become geographically informed as well (Table 4, Test 8). In neither case is there any significant difference, suggesting the home location is not driving the weighting or constraining of different variables via the map.

4.7 Did users understand the system?

We have already seen evidence that the users misinterpreted how the system worked to a minor degree. However, we have also seen that they have used the maps to inform their choices. Whether they understood the weighting system that produced the suitability map or not is largely irrelevant when they based their choices on the visual output. User feedback (Table 5) through multiple-choice questions at the end of the system suggests that 87.9% of those who responded felt the system was easy, or mostly easy to use. However, some 32.5% found the GIS component the most difficult to deal with. Possibly of more concern are the 7.3% who found Web links hard to deal with, and 4.9% who found the introductory Web pages difficult, as the system has been through several design iterations influenced by a broad lay audience.

4.8 Were users turned into active participants?

The users were asked questions aimed at elucidating how informed they felt, and whether they felt there was a need for the public to be allowed more of a

Table 5. Feebback answers from users garnered at the end of using the system

System questions	Answers	%
Did you find the system easy to use?	Yes	54.4
	Mostly	33.5
	Partly	10.2
	No	1.0
Which parts of the system (if any) did you find the most difficult?	Introductions to issues.	4.9
	The profile pages	16.5
	Links to other web sites	7.3
	The on-line GIS	32.5
Understanding and participation questions	The Help and Information system	10.7
Do you feel that you are better informed about nuclear waste management?	Yes	53.9
	Partly	40.8
	No	5.3
Compared to the current system how much information do you want about nuclear waste management issues?	More	75.7
	About the same	23.3
	Less	0.5
Should the public be given access to more information about nuclear waste management?	Yes	96.1
	No	2.4
Should the public be given the opportunity to be more involved in the debate about nuclear waste management?	Yes	91.3
	No	8.7
Should the public be given the opportunity to be more involved in the decision-making process concerning nuclear waste management?	Yes	65.0
	No	34.0
Method questions		
Which of the following methods do you feel are appropriate for helping the public participate in nuclear waste management?	Face-to-face public meetings	59.2
	Paper-based consultation documents	48.1
	Political lobbying (e.g. through local MPs)	47.1
	Media information (newspapers, TV and radio)	77.2
	The Internet	65.0
Do you feel that such a system could be used to help facilitate public participation in nuclear waste management and other issues?	Yes	65.0
	Partly	25.2
	No	7.3
	Don't know	2.4

say in the disposal of nuclear waste. While we have no definitive statement of their beliefs before using the system, their answers suggest they felt the system had given them some additional understanding of the issues (94.7% said they were better or partly better informed) but that they were keen to learn more (75.7%) and thought they had a right to (96.1%). In addition they believed the public had a right to be involved in the debate (91.3%), though substantially less trusted the public to actually be more involved in the decision-making (65%). This is perhaps reflected in the fact that the mechanism most people chose as the best method for the public to be involved was the, largely passive, mass media (77.2%). The Internet was respondents' second choice as a mechanism (65%), and most found the system to some degree useful (90.2% thought the system potentially useful or partly useful).

5 Discussion

The analysis above suggests that the users of the system were making choices informed by the spatial data and their experiments in dynamically generating suitability maps. The system collects how important users' feel various variables are, their picked repository sites and their postcodes. This combination allows us to determine, as a group, whether they are making random "click through" choices, whether their choices have been influenced by the spatial data, and whether they have biased their results on the basis of home locations. Recording user variable preferences as well as their final site choice has allowed us to cross-check their decisions for biases and added richness to our understanding of their concerns. In addition, we can test whether this group's voice is geographically representative of a more general population we might hope to sample, or whether there might be inherent geographical biases present because of their home locations.

It is clear that users' attitudes underwent a significant change when they were exposed to the spatial component of the data. It is also clear that these changes were not related to the location of their homes, despite the nature of the decisions being made. In fact, users seem to have chosen with an altruistic rationality. One ramification of this would appear to be that the use of spatial data and Geographical Information Systems in the process of stakeholder dialog is of considerable importance. While no attempt was made in this study to quantify the change of understanding in the people who had used the system, or to compare the individual locations chosen with such a test, it is apparent that users are responding to the geographical information and using it when making their decisions. The analysis revealed a tendency for users to increase the level of all variables once their distribution was understood. While this is a misunderstanding of the way the system works, it is none-theless an interesting result. It is suggested that this reflects an additional regard for the importance of the problem and the data once the geography is presented, and it would be informative to formally investigate this with the users. The tests on the home-to-risk distances certainly suggest this is not due to personal anxiety caused by the spatial data, and this is backed up by user feedback on the experience, which suggests the system was viewed as a positive contribution and to be encouraged.

6 Conclusions

There are two arguments that are commonly raised against participatory, as opposed to representative, democracy. The first, and oldest, is that if the people are given direct control, they will make decisions which are at the best irrational, and at the worst self-interested. The solution, so the argument goes, is to elect rational agents that will protect the people from themselves while representing their true, rather than professed, interests. The second argument, which drives the current debates on associative democracy (that is, approximately, activism) and media reproval after poor electoral turnouts, is that the people are not interested in participating, and that allowing it therefore simply opens the door to extremist groups.

This paper suggests neither argument has any validity for the people we have examined. We have found that, far from making irrational decisions, they have made informed choices based on the data presented to them. Further to this, rather than acting in a self interested manner, the significant majority have made decisions indistinguishably matching the most rational choices based on the data, in a highly altruistic manner. In addition, feedback suggests that the majority of those who went through the system want to learn more about the issues, and participate in the decision-making process. Indeed, when compared with the actions of successive UK governments who appear to have put off making a decision for fear it would be an "election loosing issue", the people seem positively enlightened in their response and beatific in their selflessness. Whether such results would be generated in a real participatory event making a concrete decision at the national scale remains to be seen. But we have reason to hope – if for no other reason than that this study suggests that nuclear waste disposal does not engender NIMBY-style behavior when regarded at a national level by at least one broad section of the populous.

In short, when such systems provide an environment in which users can learn about issues and experiment with the ramifications of their choices, they tend to make informed and well-reasoned decisions. While the consequence of extending such systems is likely to be a debate as to who constructs the knowledge within them and who controls the possible solutions offered, such a debate is entirely healthy in a developed democracy, and is likely to drive the systems towards greater flexibility and public input. It would seem that to have the input of a broad and interested (but not self-interested) group of people into the decision making process is to the benefit of all responsible for managing the public's environment and risks, and would enhance public interest in the democratic and decision making processes.

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