Prediction of the visual impact of motorways using GIS

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Abstract

Large scale transportation projects can adversely affect the visual perception of environmental quality and require adequate visual impact assessment. In this study, we investigated the effects of the characteristics of the road project and the character of the existing landscape on the perceived visual impact of motorways, and developed a GIS-based prediction model based on the findings. An online survey using computer-visualised scenes of different motorway and landscape scenarios were carried out to obtain perception-based judgements on the visual impact. Motorway scenarios simulated included the baseline scenario without road, original motorway, motorways with timber noise barriers, transparent noise barriers and tree screen; different landscape scenarios were created by changing land cover of buildings and trees in three distance zones. The landscape content of each scene was measured in GIS. The result shows that presence of a motorway especially with the timber barrier significantly decreases the visual quality of the view. The resulted visual impact tends to be lower where it is less visually pleasant with more buildings in the view, and can be slightly reduced by the visual absorption effect of the scattered trees between the motorway and the viewpoint. Based on the survey result, eleven predictors were identified for the visual impact prediction model which was applied in GIS to generate maps of visual impact of motorways in different scenarios. The proposed prediction model can be used to achieve efficient and reliable assessment of visual impact of motorways.

Keywords
Visual impact; motorway; landscape; GIS; perception-based approach

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1. Introduction

Visual impact is one of the major environmental impacts of motorway projects that need to be assessed and considered for decision making (Federal Highway Administration, 1988; Highways Agency, 2010). In current practice, the assessment of visual impact of motorway projects largely draws on approaches proposed by relevant government agencies (e.g., Bureau of Land Management, 1984; Federal Highway Administration, 1988; Highways Agency, 2010; Roads and Traffic Authority, 2009; U.S. Forest Service, 1974 & 1995). By these approaches the assessment is carried out with respect to certain assumption or design criteria which are relevant to visual landscape quality, and the obtaining of judgement for steps of these approaches is very often expert-based (Daniel, 2001). Expert-based assessment is efficient (Lothian, 1999), but is criticised for the inadequate level of reliability and precision, as the assessment is typically made by a single person and only gives very rough classifications of the impact level (Daniel, 2001).

On the other hand, a considerable amount of research studies on visual landscape assessment have drawn on perception-based approach to obtain more precise and reliable judgement (e.g., Anderson & Schroeder, 1983; Bishop & Miller, 2007; Buhyoff, & Leuschner, 1978; Louise, 1977; Schroeder & Daniel, 1981; Shafer, 1969). This approach, usually by the mean of a preference survey, derives visual quality of the landscape or visual impact on it as perceived by a sample of actual or potential viewers on site or via surrogate media (Daniel, 2001). Perception-based approach is relatively time-consuming and expensive, but the results have a capability of being used for prediction (Lothian, 1999), if the sample viewers are representative for a wider or targeted population. While some studies found differences between viewer groups, e.g., by cultural background (Zube & Pitt, 1981); by landscape expertise and knowledge (Hunziker et al., 2008; Tveit 2009), many show substantial agreement between diverse groups in visual landscape assessment (e.g., Anderson & Schroeder, 1983; Daniel & Boster, 1976; Kearney et al., 2008; Ode et al., 2009; Wherrett, 2000; Zube, 1974).

Attempts to study the visual impact of road projects and the possible predictive factors using perception-based approach has been made in the 1970s. Based on visual judgement made by respondents on site, Hopkinson & Watson (1974) found that the increases of the visibility of the road and the number of dwellings in the view detracted from the visual quality of the view while the amount of visible sky enhanced it. Using colour-slides, prints and cine films, Huddart (1978) obtained visual pleasantness ratings from local residents and visitors to study the visual impact of roads in the Lake District, UK, and concluded that the ratings decreased as road construction became more visible and the decrease rate was probably affected by the character of the background landscape.

However, this type of research on visual impact of road projects is very limited in literature. Moreover, the existing studies have a limitation that they only investigated view-based predictive factors, and their results could only be applied for the assessment of circumscribe views rather than the whole affected areas (Bishop & Hulse, 1994). To achieve area-wide assessment, some visual landscape studies integrated the prediction models derived from the preference surveys into a geographic information system (GIS) by using map-based measures as predictive factors (e.g., Bishop & Hulse, 1994; Grêt-Regamey et al., 2007; Schirpke et al., 2013). With the increased availability and manipulability of geographic data, the results of these studies can be applied to assess visual quality or visual effect of landscape changes from viewpoints covering the whole area in interest with efficiency and reliability.

Early examples of using GIS for road project visual assessment can be found in Federal Highway Administration (1988). Landscape features visible from the road were mapped and classified to indicate the quality of views from the road. The impact of roads on views to the road, which is the issue addressed in this paper, was assessed by mapping the viewshed of the road and weighting the viewer sensitivity inferred from land use. In recent research, Garré et al. (2009) calculated three morphological metrics of the visible landscape from random viewpoints using GIS, and compared the results from the on-road viewpoints with those off-road, to investigate the visual access to the landscape offered by roads. Chamberlain & Meitner (2013) analysed route-based visual magnitude of DTM cells for views from a tourist highway, to demonstrate a more advanced GIS application for planning. However, no attempt seems to have been made to predict human-perceived visual impact of road projects in GIS. It is still difficult to achieve reliable assessment for the whole affected area instead of a limited number of selected key views along the long corridor of a large scale road project like a motorway project.

Therefore, the aim of this study is to investigate how factors of project development and existing landscape contribute to the perceived visual impact of motorways, and consequently to develop a GIS-based model to predict the impact. In this study, factors of project development of interest include the appearance of roadways, noise barriers, and tree screen, as they are the main motorway features that are potentially predictive for the visual impact assessment at a large scale. The potential impact of moving traffic is not investigated at the stage of this study. Factors of existing landscape considered are map-based measures of land covers and landform, as visual landscape is mainly defined by land cover and landform (Daniel, 2001). It is also aimed to use predictors that are readily derivable from the general planning data for the prediction model. With human preference for computer-visualised scenes of different motorway and landscape scenarios obtained via an online survey, the specific steps and objectives of this study are: (1) investigate the effect of the appearance of roadways, noise barriers, and tree screen on the perceived visual impact; (2) explore the relationship between map-based measures of the existing land covers and landform and the perceived visual impact; (3) predict the perceived visual impact using the derived model in GIS.

2. Methods

This study used computer-based visualisation for the preference survey, and visual impact was calculated as reduction in mean visual pleasantness ratings given to the same view without and with motorways. Tree screen, timber and transparent noise barriers were simulated in addition to the original motorway to study the effect of the characteristics of the motorway project on the perceived visual impact. Different landscape scenarios varying in land cover of buildings and trees in three distance zones were created to study the effect of the existing landscape. In total 120 images captured from 10 viewpoints were rendered and used for the preference survey which was carried out online. Based on the result of the preference survey, a regression model was developed and applied to a grid of viewpoints in GIS to map the predicted visual impact.

2.1. Visualisation

2.1.1. The advantage and validity of computer-based visualisation

Computer-based visualisation is more advantageous than photographs, which have been commonly used as a surrogate of the actual environment for visual landscape preference surveys (Palmer & Hoffman, 2001), in terms of scenario creation and variable control (Bishop & Miller, 2007; Ode et al., 2009), as well as links between 2D and 3D data (Ode et al., 2009) which is of particular importance for GIS-based analysis. The validity and realism of computer-based visualisation for visual landscape assessment has been examined by research studies (e.g., Appleton & Lovett, 2003; Bishop & Rohrmann, 2003; Lange, 2001; Oh 1994). The results of these studies indicated that although computer-based visualisation could not be used with full confidence to represent the actual landscape for visual perception or assessment, generally reliable judgments could be obtained and its use was supported. They also showed that increasing the level of simulated details could enhance the degree of reality, and some specific landscape features, e.g., foreground vegetation and ground surface (Appleton & Lovett, 2003), were more important than others and would require more realistic presentation. Sophisticated use of visualisation can provide powerful tools for communicating with different interest groups and obtaining public landscape preferences (Lange & Hehl-Lange, 2005; Lange et al, 2008; Wissen et al 2008; Smith et al 2012).

2.1.2. Base site modelling

A segment of the M1 motorway near Ecclesfield (Sheffield), UK was chosen as the base site for visualisation, covering an area of 2500m × 2500m (Figure 1). It was not intended to study the visual impact of the specific motorway on the specific site, rather, it was just to get a typical motorway project that can be seen in the actual world. The selection is based on the ideas that the site should be a typical UK rural or semi-rural area where motorway corridors are usually located, slightly varying in land cover and landform, and it should be an open area so the existing road would have been built without too much earth work, which ensures that the modelling of the without-road baseline scenarios can be made without too much transformation of the land. The road on the selected site is a dual 3-lane motorway with asphalt surface. The dimensions of cross-section components for rural motorway mainline provided by Highways Agency (2005) was used for modelling. Detailed information can be found in Figure 2.

With terrain data of the site obtained from Ordnance Survey, the motorway was modelled in AutoCAD Civil 3D, and then imported into Autodesk 3ds Max Design to add further road structures, vehicles, land cover, and to apply materials and daylight for rendering. modelled land cover features include trees and buildings, of which the geo-data was obtained from

Ordnance Survey's MasterMap. Most of the trees were modelled 12m in height and 8m in diameter, a few shorter trees were set 6m in height and 4m in diameter. A random 50%-150% variation in scale was applied to all the trees. Most of the buildings on the site are 2-story semi-detached houses and the height was set as 8m. The heights of other buildings were estimated on site. All the buildings were site-typically textured using images captured from Google Street View. For each camera view (see Section 2.1.2), the land surface behind the road was draped with satellite imagery to make the scene more realistic; the land surface between the viewpoint and the road was textured with a bitmap of grassland since the draped image blurs when getting close to the camera. The weather and daylight condition was set as sunny June midday in the UK and was kept the same for all the renderings.

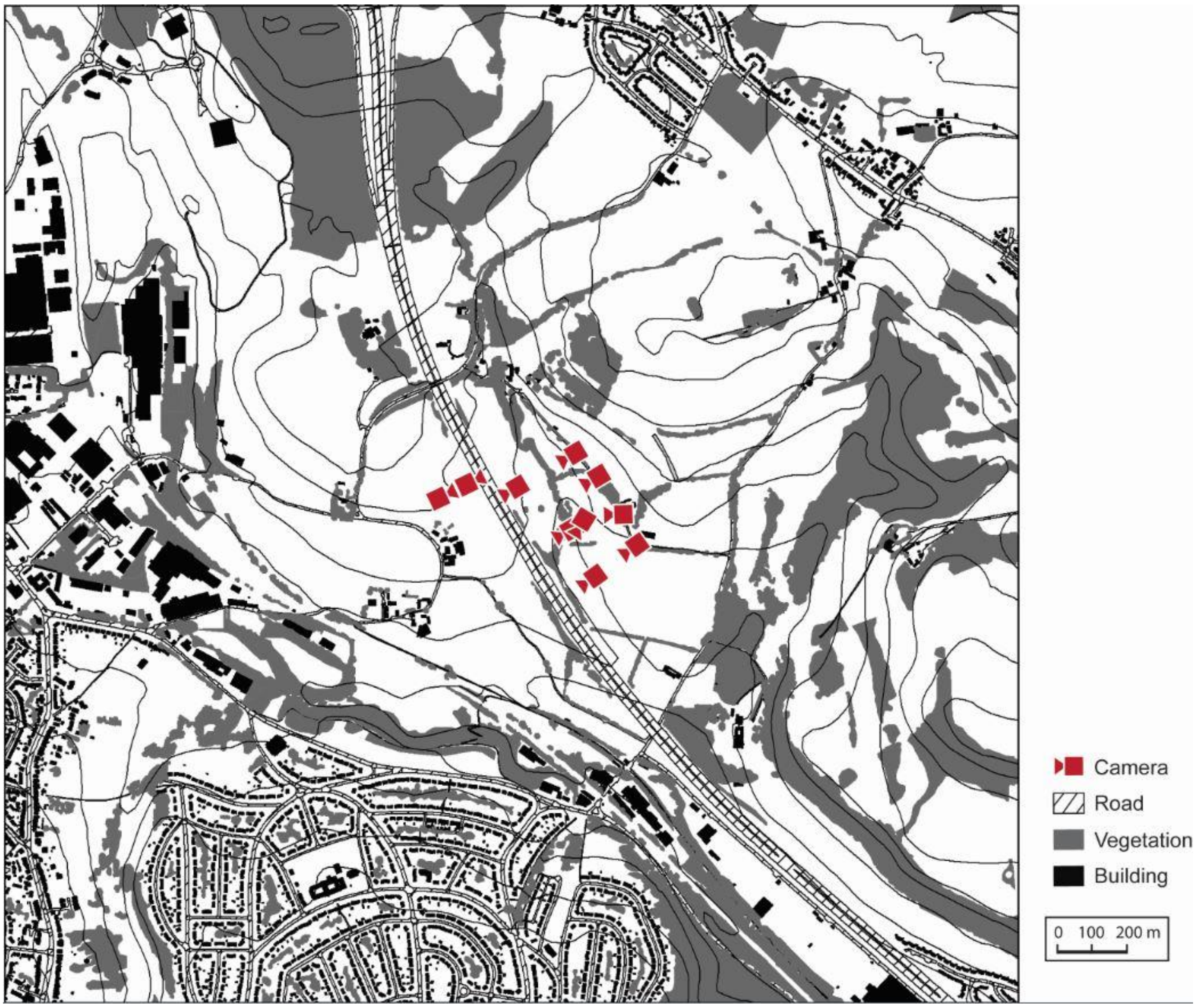


Figure 1 The base site and the location and direction of the cameras (reproduced based on Ordnance Survey MasterMap).

2.1.3. Viewpoints and cameras

Ten viewpoints, covering distances to road (horizontal distance to road central line) from 53m to 286m, were chosen to start scene creation. Only viewpoints accessible on site were considered so field assessment of their suitability was allowed. The chosen criteria were to have various land covers and landforms at the starting point. The distance to road was limited within 300m as on-site observation suggested that the visibility of the motorway from approximately this distance has declined to a low level that it only forms a relatively small element at ground level in the view. It was aimed to study visual impact in the most affected area, so short distances within 300m were thought to be suitable. However, it should be kept in mind that possible visual impact can reach much further distances (Federal Highway Administration, 1988; Highways Agency, 1993) and should still be considered in practice.

The camera for each viewpoint was set 1.6m above the ground and with a horizontal viewing angle ranging from 60° to 90° to the motorway. Figure 1 shows the location and direction of the ten cameras. To ensure that the motorway was vertically in the middle of each view, the target of each camera was set at the same height as the targeted road surface. So the vertical viewing angles of the viewpoints varied depending on their relative elevations to the road surface. Horizontal field of view of 72°, which is wider than that of a standard lens, was chosen for this study to convey the breadth of visual information required for road project which extends transversely in the view (Landscape Institute, 2011). To avoid distortion of distance perception, the vertical field of view was kept at 27°, which is close to that of a standard lens. The resulted aspect of the captured images was 3:1. Photographs taken at accessible viewpoints on-site were used to compare and calibrate the base site simulation.

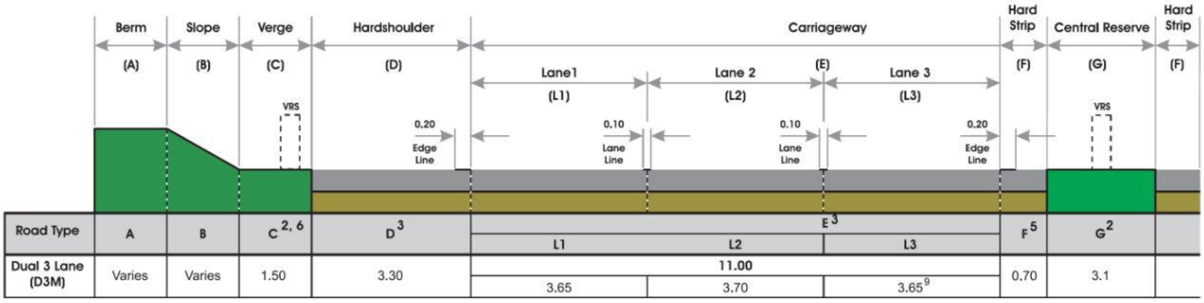


Figure 2 Dimensions of cross-section components for the simulated motorway (reproduced based on the Figure 4-1a in Highways Agency (2005)).

2.1.4. Visual feature design

Variations in visual features from each viewpoint were designed to create different but controlled motorway and landscape scenarios for the purpose of this study. For the motorway scenarios, tree screen and two types of noise barriers: timber barrier and transparent barrier, were introduced in addition to the original roadway. The height of the tree screen was set 9m with a little variation; the heights of the two barriers were both 5m. Apart from the original dual 3-lane scenario, a dual 2-lane scenario was also considered. However, the two scenarios looked almost identical at ground level with the viewing angles nearly perpendicular to the road. So the dual 2-lane scenario was abandoned. To create the baseline scenarios, the modelled motorway was deleted and the land was draped with a photoshopped satellite image in which the existing motorway was masked by grassland.

Different landscape scenarios for each viewpoint were created based on the original settings of the base site by adding and/or removing buildings and/or trees, which are the two typical types of land cover apart from grassland in this area. Since research has shown that the same landscape elements at different distances from the viewpoint will have different effect on visual judgment (Shafer, 1969; Steinitz, 1979), three distance zones were defined: 0-300m (foreground); 300-900m (midground); and greater than 900m (background), and buildings and trees were added and/or removed in each of the distances zones to ensure that there were changes in land cover at each distance from the viewpoint. Scattered trees between the motorway and the viewpoints were added to or removed from some of the scenes to create counterpart scenes for the comparison of the effect of their presence, as research has shown that landscape elements between the viewer and the project object has a strong influence on visual assessment (Hadrian et al., 1988). No modification in landform was made and the original landform which varied slightly from the ten viewpoints was used to represent changes in landform for investigation, for the reasons that landform along a typical motorway corridor usually changes less dramatically than land cover and any modification in landform will make data preparation for GIS analysis very complicated.

2.1.5. Output images

The resolution of the rendering output images was 1200 × 400 pixels. Overall, 120 images, including 88 images with road and 32 images for the corresponding baseline scenes, were rendered. Figure 3 shows a set of 24 images used in one of the questionnaires (see Section 2.3 for questionnaire design).

Figure 3 A set of 24 images used in one of the questionnaires.

2.2. Scene content measurement

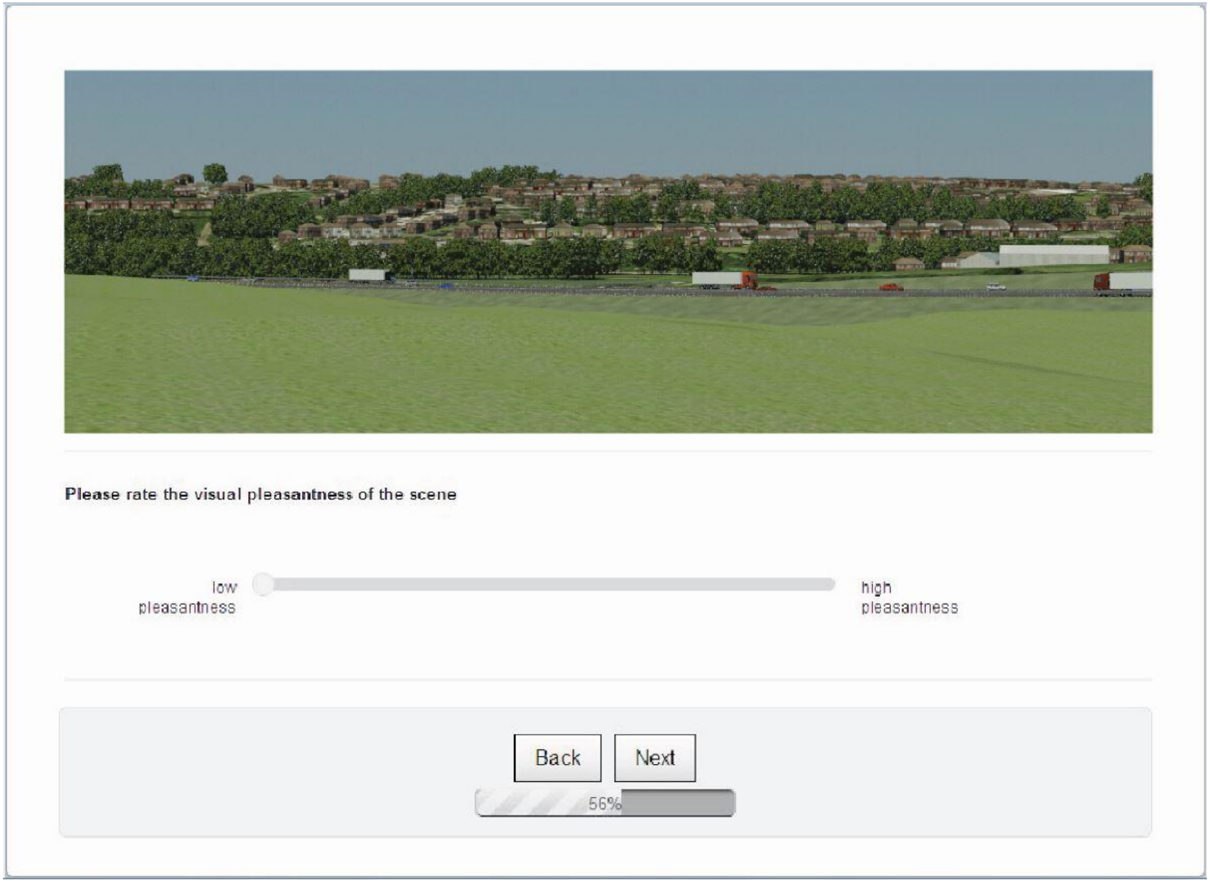
The scene content shown in each image was dummy-coded or measured, and 24 variables were derived for study (Table 1). For each landscape scenario at each viewpoint, visible buildings and trees in each distance zone were measured by cell count in GIS based on baseline landscape without motorway. To achieve this, a 5m × 5m raster digital terrain model (DTM) of the site was built in ArcGIS 10.1 with terrain data obtained from Ordnance Survey. For each landscape scenario, another raster of the same cell size recording the height of buildings and trees was superimposed onto the DTM to generate a digital surface model (DSM). With the DSMs, viewshed analysis was performed in ArcGIS to calculate visible cells from each viewpoint of which the attributes were set consistent to the corresponding camera in Autodesk 3ds Max Design. Numbers of cells representing buildings and trees in the three distance zones were then counted within the viewshed by overlaying the viewshed onto corresponding land cover raster. Average slope and standard deviation of the slopes of the visible DTM cells from each viewpoint were also calculated in ArcGIS.

Table 1 Dummy-coded and measured variables

	Variable		All the 120 images				88 with-road images		
		Mean	Min	Max	S.D.	Mean	Min	Max	S.D.
Motorway Characteristics	Original road	0.26	0 (no)	1 (yes)	-	-	-	-	-
	Road with timber barrier	0.18	0 (no)	1 (yes)	-	0.25	0 (no)	1 (yes)	-
	Road with transparent barrier	0.18	0 (no)	1 (yes)	-	0.25	0 (no)	1 (yes)	-
	Road with tree screen	0.11	0 (no)	1 (yes)	-	0.15	0 (no)	1 (yes)	-
	Distance to road	-	-	-	-	173	53	286	73
Existing Landscape Character	Scattered trees between road and viewpoint	0.34	0 (no)	1 (yes)	-	0.32	0 (no)	1 (yes)	-
	Amount of buildings in the viewshed (AB)	773	0	1744	561.83	791	0	1744	560
	Amount of buildings in the viewshed in foreground (ABF)	7	0	27	10.94	7	0	27	11
	Amount of buildings in the viewshed in midground (ABM)	170	0	552	172.49	169	0	552	170
	Amount of buildings in the viewshed in background (ABB)	696	0	1504	460.42	615	0	1504	462
	Amount of trees in the viewshed (AT)	1054	42	2256	615.99	1047	42	2256	613
	Amount of trees in the viewshed in foreground (ATF)	37	0	243	57.03	34	0	243	52
	Amount of trees in the viewshed in midground (ATM)	351	10	1200	286.85	341	10	1200	276
	Amount of trees in the viewshed in background (ATB)	665	5	1313	430.15	671	5	1313	432
	Percentage of buildings in the viewshed (PB)	18	0	40	10.01	18	0	40	9.64
	Percentage of buildings in the viewshed in foreground (PBF)	1	0	7	1.82	1	0	7	1.79
	Percentage of buildings in the viewshed in midground (PBM)	18	0	58	16.47	18	0	58	16.17
	Percentage of buildings in the viewshed in background (PBB)	37	0	90	15.17	37	0	90	13.88
	Percentage of trees in the viewshed (PT)	25	4	61	12.22	24	4	61	11.45
	Percentage of trees in the viewshed in foreground (PTF)	7	0	84	14.96	6	0	84	12.74
	Percentage of trees in the viewshed in midground (PTM)	30	5	67	18.33	29	5	67	18.24
	Percentage of trees in the viewshed in background (PTB)	44	10	100	15.60	43	10	100	14.33
	Average slop of visible land (SLPavg)	5.0°	4.1°	8.2°	0.91	4.9°	4.1°	8.2°	0.81
	Standard deviation of the slops of visible land (SLPstdv)	2.74	1.78	3.44	0.44	2.72	1.78	3.44	0.44

2.3. Online preference survey

The preference survey was carried out online. Since assessing 120 images would take too long for an online survey and leads to a high drop-out rate, it was decided that each participant only needed to assess 24 images out of the 120 which would take no more than 5 minutes in total. However, simply dividing the 120 images into 5 groups of 24 images to be assessed by 5 different groups of participants will induce biased responses, since not only different people have different judging criteria, but also people’s judgement of each image can be influenced by the presentation of the other images in the same group (Gescheider, 1997). To minimise the potential bias, 100 questionnaires were designed and the 120 images were distributed across them such that each questionnaire contained a unique combination of 24 images and each image was shown in a unique set of 20 questionnaires (see Appendix A). Thus, all the 120 images were treated equally. To minimise the sequential effect on judgement, the 120 images were ranked in a random order before distributed to the 100 questionnaires, and within each questionnaire, the 24 images were further randomised. Each questionnaire should be answered by the same number of participants.



Please rate the visual pleasantness of the scene

Figure 4 The online survey interface

The online survey consisted of five parts: introduction, participant and device information collection, image assessment, daily commute information collection, and a word of thanks. Participants were only informed that the study was about visual landscape assessment, the exact purpose of studying the visual impact of motorways was not mentioned, and questions about living area, car ownership and daily commute were asked only after the image assessment. In the image assessment part, which was laid out with one image per page, participants were asked to rate the visual pleasantness of each image using visual analogue scale, that is, by moving the slider on a bar which was set 0 to 100 but only had “low pleasantness” and “high pleasantness” labelled at the two ends (Figure 4). The slider (visual analogue scale) was favoured over the more commonly used Likert scale as research has shown possible difference in results from using these two scales (Cowley & Youngblood, 2009) and visual analogue scale gives continuous measures which are more suitable for the statistical analysis that would be used for this study. The term “pleasantness” was used since Landscape Institute and Institute of Environmental Management and Assessment (2013, p158) defined visual amenity of the landscape as “the overall pleasantness of the views people enjoy of their surroundings”. The use of “pleasantness” was also found in some other studies involving subjective visual evaluations (e.g., Day, 1967; Ruddell et al., 1989). Participants were informed at the beginning of the image assessment part that visual pleasantness in this study could be understood as visual landscape quality or scenic quality of the scenes, and there were no clear criteria for the rating, and they could draw upon whatever value judgements they deemed necessary.

The survey was broadcasted via university email lists, Facebook, QQ groups, and receivers were encouraged to forward the survey invitation to others. While there were 100 different questionnaires, only one unique URL was used for the survey, and participants were randomly directed to one of the questionnaires upon starting the image assessment part. To balance the number of responses received for each questionnaire, the survey was monitored and questionnaires receiving more responses than others were deactivated. The survey was online for one week and received 253 completed responses and 74 partial responses (dropout rate: 22.6%). 200 of the 253 completed responses, two for each questionnaire, which means each of the 120 images received 40 judgements, were used for analysis.

2.4. Data analysis and visual impact prediction

Forced-entry regression analysis was used to test the effect of participant groups on image ratings. The *t*-test was applied to analyse reductions in visual pleasantness of scenes when the motorway was introduced, as well as to compare visual pleasantness and impact ratings in scenarios with and without scattered trees between the motorway and the viewpoint. Correlation analysis was used to study the relationship between visual impact and measures of land cover and landform. To predict the perceived visual impact, a regression model was chosen from four tested models, and applied on a grid of viewpoints to map the predicted impact in GIS. To verify the prediction, predicted visual impacts at three typical viewpoints were compared to empirical results collected in a supplementary online survey (N = 58) using photos taken on-site and their edited copies as visual stimulus. The supplementary survey used the same template as the main survey as shown in Figure 4.

3. Results and discussion

3.1. Analysis of responses

Figure 5 shows the distribution of demographic, transport and device groups of the 200 participants whose responses were used for analysis. Among the 200 participants, 83 were male and 117 were female. The majority of them were young people in the age groups of 18-24 (62%) and 25-34 (26.5%), implying that most of the participants were university students. Approximately half of the participants (52.5%) chose UK as their home country, while 11.5% from China which made up the second largest group. The rest of the participants were from 30 other countries across the world. 88.5% of the 200 participants were living in the UK when answering the survey. In terms of living areas, 52.5% of the participants were living in urban area and 39% in suburban area, only 8.5% in rural area. In terms of transport, 29% of the 200 participants had one or more motor vehicles, but only 10.5% drove for their daily commute. Most of the participants (65.5%) chose walk as the form of their daily commute.

Most of the rest used public transport. The devices that participants used to answer the survey were mainly personal computers (88.5%), followed by tablets (5.5%) and smart phones (5%). Various sizes of screens were used, with the majority of them were 10”-15” (27%), 15”-23” (32.5%), and 23”-30” (10%).

The respondent sample skewed to be more representative of the UK university students. However, given the large amount of research that has shown the minor effect of participant groups for landscape assessment (e.g., Anderson & Schroeder, 1983; Daniel & Boster, 1976; Kearney et al., 2008; Ode et al., 2009; Wherrett, 2000; Zube, 1974), there is still confidence to generalise the result to give useful information. The effect of participant groups in this particular study was also tested.

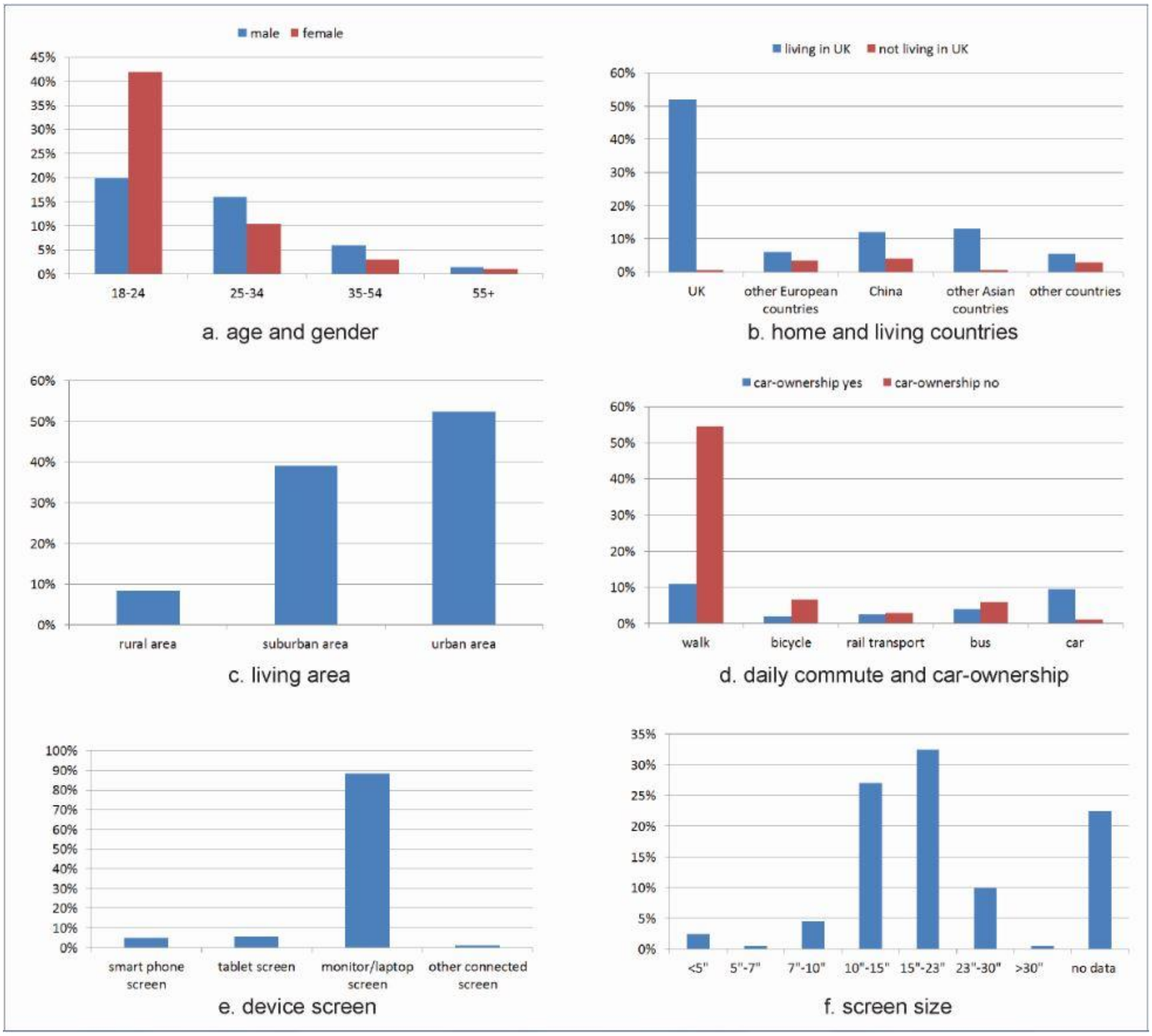


Figure 5 Distribution of demographic, transport and device groups of the 200 participants.

Using the 4800 visual pleasantness ratings (200 participants × 24 ratings/participant) with the participant variables (dummy-coded) and image variables (Table 1 for all the 120 images) attached to each rating, a forced-entry regression analysis, which assesses the unique contribution of each independent variable that is not shared by other independent variables, was applied to test the effect of participant groups on the visual pleasantness rating. Full correlation of the participant variables with the visual pleasantness ratings was also applied to offer additional information for interpretation since it is possible for an independent variable to appear unimportant in a forced-entry regression when it actually has high correlation with the dependent variable. Table 2 shows the regression result, only significant predictors are listed. Since the prediction level of the regression model is low (adj $R^2 = 0.287$), this part of discussion remains tentative.

Table 2. Result of the regression against the 4800 visual pleasantness ratings (adj $R^2 = 0.287$, only significant predictors shown).

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Partial R^2
	B	**Std. Error**	**Beta**			
(Constant)	72.090	13.302		5.419	.000	
Original road	-15.490	.745	-.309	-20.802	.000	.084
Road with timber barrier	-21.026	.846	-.368	-24.855	.000	.115
Road with transparent barrier	-17.077	.857	-.293	-19.929	.000	.077
Scattered trees between road and viewer	2.955	1.422	.063	2.078	.038	.001
Amount of buildings in the viewshed in midground (ABM)	-.019	.009	-.144	-2.041	.041	.001
Percentage of trees in the viewshed in foreground (PTF)	-.293	.118	-.197	-2.489	.013	.001
Percentage of trees in the viewshed in midground (PTM)	-.533	.138	-.440	-3.861	.000	.003
Percentage of buildings in the viewshed (PB)	-.706	.265	-.318	-2.664	.008	.002
Percentage of trees in the viewshed (PT)	1.085	.471	.597	2.304	.021	.001
Age 18-24	-6.855	1.976	-.150	-3.470	.001	.003
Age 25-34	-4.330	1.993	-.086	-2.173	.030	.001
Home country UK	3.159	1.181	.071	2.675	.008	.002
Home country China	15.917	1.285	.230	12.383	.000	.031
Home country other Asian country	3.568	1.243	.062	2.871	.004	.002
Living in UK	5.290	1.030	.076	5.135	.000	.005
Screen size <10”	2.674	1.207	.032	2.216	.027	.001
Screen size 15”-23”	-5.431	.823	-.115	-6.596	.000	.009
Screen size >23”	2.300	1.076	.032	2.137	.033	.001
Living in urban area	2.523	.622	.057	4.056	.000	.003
Living in rural area	4.374	1.094	.055	3.998	.000	.003
Daily commute bike	6.893	1.068	.087	6.451	.000	.009
Daily commute railway	5.859	1.371	.058	4.274	.000	.004
Daily commute car	-2.956	1.183	-.041	-2.499	.012	.001

Dependent Variable: Visual Pleasantness

It is shown by the coefficients and Partial R^2s that the ratings were largely dependent upon the characteristics of the motorway. The coefficients and Partial R^2s of the existing landscape variables are small, but given that the value ranges of these continuous landscape variables are much larger than those dummy-coded participant variables, they still accounted for a larger variation in the ratings. So it might be concluded that participant groups had limited effect on ratings, differences in ratings given to scenes of different motorway and landscape scenarios were mainly decided by the scene content itself. So the effect of participant groups will not be addressed further in the following discussion. It is noticeable however that participants whose home country is China generally gave much higher ratings (12.8 higher than those from the UK), which might be explained by that the greener UK-based scenes were more appreciated by the Chinese participants. The differences resulted from screen size were also relatively large (variation in ratings up to 8.1). While screen size did not show significant effect on ratings in Wherrett (2000), the larger size-difference of devices today especially when comparing smartphones and PCs might require more attention to the possible effect of screen size for such studies. One unexpected result is that those who commute by car gave more negative ratings to the scenes of which the majority have motorway content (3.0 lower than walkers and 9.8 lower than cyclists).

3.2. The effect of the motorway project

The *t*-test was used to analyse the visual impact induced by the motorway in four different motorway scenarios. Table 3 shows the result for each scenario. Since visual impact in this study was measured as reduction in mean visual pleasantness ratings given to the same view without and with motorways, possible visual impact values would range from -100 to 100, where a negative value means the introduction of the motorway enhances the visual quality of the view, 0 means no change in visual quality of the view, and a positive value means detracts from the visual quality of the view.

Table 3. Visual impact induced by motorways in different project scenarios.

Motorway scenario	Mean visual pleasantness without road	Mean visual pleasantness with road	Mean visual impact	*t*	df	*p*	Effect size*
Original road	57.4	41.2	16.2	14.595	29	< 0.001	0.880
With timber barrier	55.1	34.2	20.9	18.574	21	< 0.001	0.943
With transparent barrier	55.4	38.5	16.9	13.783	21	< 0.001	0.900
With tree screen	55.1	55.9	-0.8	-0.476	12	0.643	-

*effect size calculated as $r^2 = t^2/(t^2 + df)$

It shows that the introductions of the original motorway, motorway with timber noise barrier, and motorway with transparent noise barrier all lead to a significant reduction in the visual quality of the scenes. The effects of them were all very large and that with timber noise barrier came the largest. On average, the original motorway caused visual impact of 16.2; the installation of timber noise barrier increased the visual impact to as high as 20.9, whereas the installation of transparent noise barrier made no noticeable increase. The different detrimental effects can be explained by the higher detactability of the opaque timber barrier and the usually negative visual effect of noise barriers (Bendtsen, 1994). However, this study did not address the visual impact of moving traffic, and when traffic is introduced, opaque barriers may have a mitigation effect in some cases by blocking undesirable views to the traffic (Kotzen & English, 2009).

When the motorway was screened by trees, the difference in visual pleasantness ratings with and without motorways is not significant, which implys that tree screen had a strong mitigation effect and could reduce visual impact considerably or even entirely. However, this does not mean that the issuse of visual impact of motorways can be addressd simply by applying tree screening. Regardless of the cost or any other limitations, new plantings will have little effect within a few years and may need more than 15 years to become fully established (Highways Agency, 2010).

Corresponding to Table 3, Figure 6 shows the visual impact of motorways of different scenarios scattered over distance to road. Overall, visual impact decreased as distance increased except in the with-tree-screen scenario. The correlations indicate that the relationship was stronger in the with-barrier scenarios. Approximately at all the distances, noise barriers tended to increase visual impact, especially the more visible timber barrier, while tree screen had a mitigation effect and made the impact considerably lower.

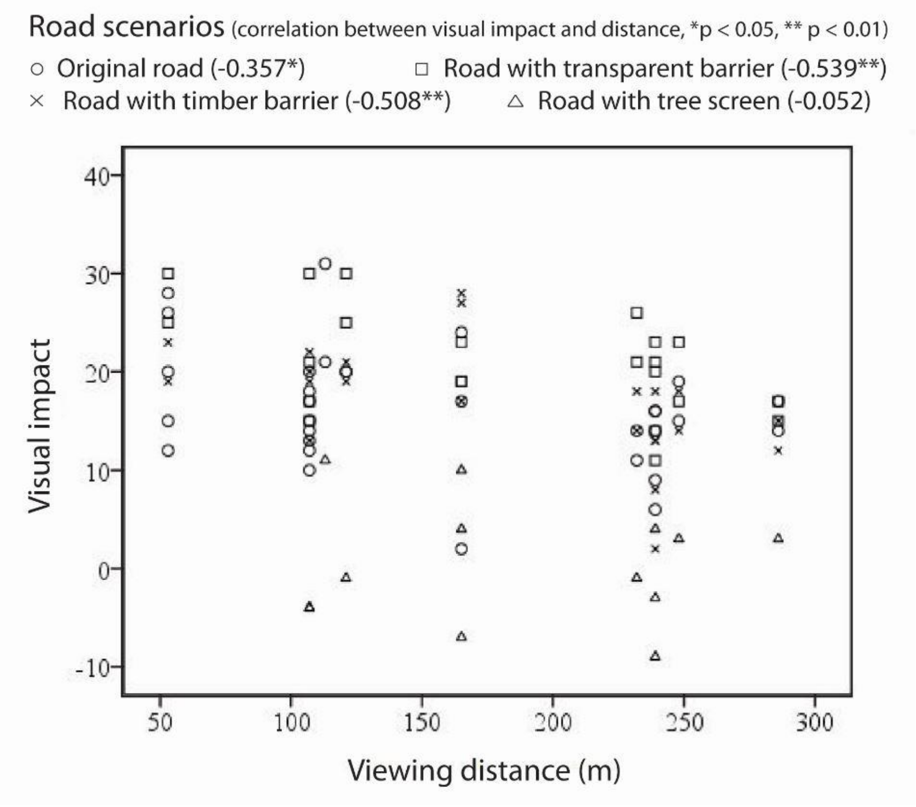


Figure 6 Visual impact of motorways at different distances.

3.3. The effect of the existing landscape

Correlation between visual pleasantness of the baseline scenes and the measures of trees and buildings in the viewshed of the scenes, as well as between visual impact of the motorway and the measures of trees and buildings, are shown in Table 4. Correlations of visual pleasantness and visual impact with the slope measures of the visible land were also examined.

Table 4. Correlations between ratings and landscape measures in the viewshed.

	AB	**ABF**	**ABM**	**ABB**	**AT**	**ATF**	**ATM**	**ATB**	**SLPavg**
Visual pleasantness	-0.472**	-0.388*	-0.562**	-0.356*	0.355	0.677**	0.575**	-0.013	0.638**
Visual impact	-0.326**	0.116	-0.311**	-0.284**	-0.083	0.196	0.120	-0.218*	0.177
	PB	**PBF**	**PBM**	**PBB**	**PT**	**PTF**	**PTM**	**PTB**	**SLPstdv**
Visual pleasantness	-0.504**	-0.278	-0.391*	-0.402*	0.608**	0.619**	0.392*	0.480**	0.308
Visual impact	-0.220*	0.103	0.038	-0.164	0.154	0.236*	0.300**	0.183	-0.077

*$p < 0.05$.
** $p < 0.01$
▨ Strong correlation (|Pearson's r| > 0.5)

The result shows that there were significant negative correlations of the visual pleasantness of the baseline scenes with the presence of buildings in the view, and significant positive correlations with the presence of trees in the view. It indicates that the appearance of buildings detracts from the visual quality while trees enhance it, which is generally consistent with findings in other visual landscape studies that assessed various scenes using various presenting media (e.g., Anderson & Schroeder, 1983; Bishop & Hulse, 1994; Shafer, 1969; Steinitz, 1990). A significant positive correlation was also found between the visual pleasantness and the average slope of the visible land. However, since only a limited variation of slope was tested in this study, and the average slope was also found highly correlated with most of the significant land cover variables, the relationship between the average slope and the visual pleasantness remains questionable in this study.

Similar but less strong correlations were found between the visual impact of the motorway in the scenes and the measures of trees and buildings in the viewshed. Generally the visual impact was significantly negatively correlated with the amount of buildings in the viewshed, but with the percentage of buildings in the viewshed, only the overall measure in the whole viewshed was significantly correlated at a relatively low level. Correlations with measures of trees were less clear. As for the amount of trees in the viewshed, only those in the background had a significant correlation with the visual impact and the correlation was negative. Stronger and positive correlations were found of the visual impact with percentage of trees in the viewshed in foreground and percentage of trees in the viewshed in midground. It indicates that visual impact of motorway tends to be lower where there are more buildings and/or less trees in the view, which further suggests that sites that are originally less visually attractive are less sensitive to the visual intrusion of motorways and tend to have a lower visual impact caused by them. However, since visual impact is not a direct measure but obtained by comparing baseline and post-construction scenes, the relationship of it with the land cover measures is not straightforward and thus less strong. No significant correlation between visual impact and slope measures was found.

To analyse the specific effect of the scattered trees between the motorway and the viewpoint, *t*-test was used to compare the visual impacts of 28 scenes with scattered trees and their corresponding scenes without scattered trees, as well as the visual pleasantness of the two groups of scenes in their without-motorway baseline scenarios. It shows that the presence of scattered trees between the motorway and the viewpoint reduced the visual impact by 1.9 on average, the reduction was significant and the effect size was medium (t = 2.414, df = 27, p = 0.023, r^2 = 0.178). The baseline sites were also more visually pleasant when there were scattered trees, with a mean visual pleasantness rating 5.6 higher than that without scattered trees (t = -5.158, df = 12, $p < 0.000$, r^2 = 0.689). The higher visual pleasantness of sites with scattered trees in the baseline scenario is consistent with the finding of the enhancing effect of trees within short distance in this study. However, the lower visual impact occurring on sites with scattered trees where the original visual quality is higher is contradict to the higher sensitivity of these sites found in this study. This might be explained by the visual absorption effect of the landscape elements (in this case the scattered trees) between the object and viewers (Hadrian et al., 1988).

3.4. Prediction of the visual impact using GIS

3.4.1. The prediction model

Using motorway characteristics variables and existing landscape character variables in Table 1 for 88 with-road images as independent variables, and visual impact as dependent variable, linear regression analysis was applied to develop models for predicting visual impact. Scenes with tree screen were excluded for analysis as the road-visibility based prediction would not be suitable for scenarios where the motorway is screened by trees. The obtained regression models using different combinations of variables are shown in Table 5. From Model 1 to Model 4, the prediction power decreases as the number of predictors used decrease. To be used in practice, an ideal model should use only a small number of predictors while have a high prediction power, so Model 3 was chosen to predict visual impact in this study for its good balance between number of predictors and prediction power.

Table 6 shows the details of Model 3. *Presence of timber barrier, Presence of transparent barrier, Amount of buildings in the viewshed in midground, Amount of trees in the viewshed in midground, Amount of buildings in the viewshed in background, Amount of trees in the viewshed in background, Percentage of buildings in the viewshed in foreground, Percentage of buildings in the viewshed in midground, Percentage of trees in the viewshed in background, Percentage of trees in the viewshed, and Distance to road*, were identified as predictors of visual impact and a relatively good level of prediction (adj R^2 = 0.636) was achieved. Higher prediction levels were achieved by regression models in some similar studies, 0.902 in

Bishop et al. (2004); 0.83 in Grêt-Regamey et al. (2007); and 0.69 in Schirpke et al. (2013). However, given that much smaller numbers of scenarios (less images, and/or less controlled variables, and/or less levels of controlled variables) were assessed in those studies, which means much smaller variations needed to be explained and thus high prediction levels were more achievable, the 0.636 prediction level found in this study is thought to be acceptable. The input data needed for the model in this study is also more readily available and does not require complex data transformations that are not common in the general planning practice.

Table 5. Tested regression models

Model	Number of predictors	R^2	Adjusted R^2	Std. Error of the Estimate	Note
Model 1	24	0.781	0.676	3.452	All independent variables entered, high multicollinearity.
Model 2	13	0.709	0.647	3.602	Only independent variables with partial $R^2 > 0.02$ entered, three variables have tolerance value < 0.1.
Model 3	11	0.690	0.636	3.659	Only independent variables with partial $R^2 > 0.02$ entered, two of the three variables with tolerance value < 0.1 removed.
Model 4	6	0.622	0.588	3.892	Stepwise entry.

The predictors used in the model show a good level of consistency with the results in Section 3.2 and 3.3 regarding the effects of the motorway project and the existing landscape. The presence of both the two types of barriers are included for prediction, with the *presence of timber barrier* having a larger coefficient as it increased the visual impact much higher. *Distance to road* was also selected as a predictor as visual impact has a clear decrease by distance as was found in Section 3.2. *Amount of buildings in the viewshed in midground* and *Percentage of buildings in the viewshed in foreground* have negative coefficients and contributes to the predicted visual impact more rapidly than *Amount of buildings in the viewshed in background and Percentage of buildings in the viewshed in midground* which have positive coefficients. So overall, using this model, the presence of buildings in the view is more likely to lead to a lower visual impact as is indicated in Section 3.3. *Amount of trees in the viewshed in midground, Amount of trees in the viewshed in background* and *Percentage of trees in the viewshed in background* all have positive coefficients, while *Percentage of trees in the viewshed* has a negative coefficient with a medium-sized partial R^2, indicating similar contributions of the presence of trees in the view as was found in Section 3.3 that it generally increases visual impact but in less consistent ways than that of buildings.

Table 6. Regression model chosen for visual impact prediction (adj $R^2 = 0.636$).

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Partial R^2
	B	Std. Error	Beta			
(Constant)	19.678	3.486		5.645	.000	
Presence of timber barrier	6.948	1.065	.525	6.524	.000	.403
Presence of transparent barrier	2.777	1.061	.210	2.617	.011	.098
Amount of buildings in the viewshed in midground	-.019	.004	-.535	-4.418	.000	.236
Amount of trees in the viewshed in midground	.016	.003	.688	4.477	.000	.241
Amount of buildings in the viewshed in background	.0005	.002	.036	.202	.841	.001
Amount of trees in the viewshed in background	.003	.002	.222	1.350	.182	.028
Percentage of buildings in the viewshed in foreground	-1.166	.423	-.363	-2.755	.008	.108
Percentage of buildings in the viewshed in midground	.157	.064	.432	2.472	.016	.088
Percentage of trees in the viewshed in background	.116	.056	.279	2.077	.042	.064
Percentage of trees in the viewshed	-.243	.089	-.460	-2.732	.008	.106
Distance to road	-.057	.011	-.706	-5.258	.000	.305

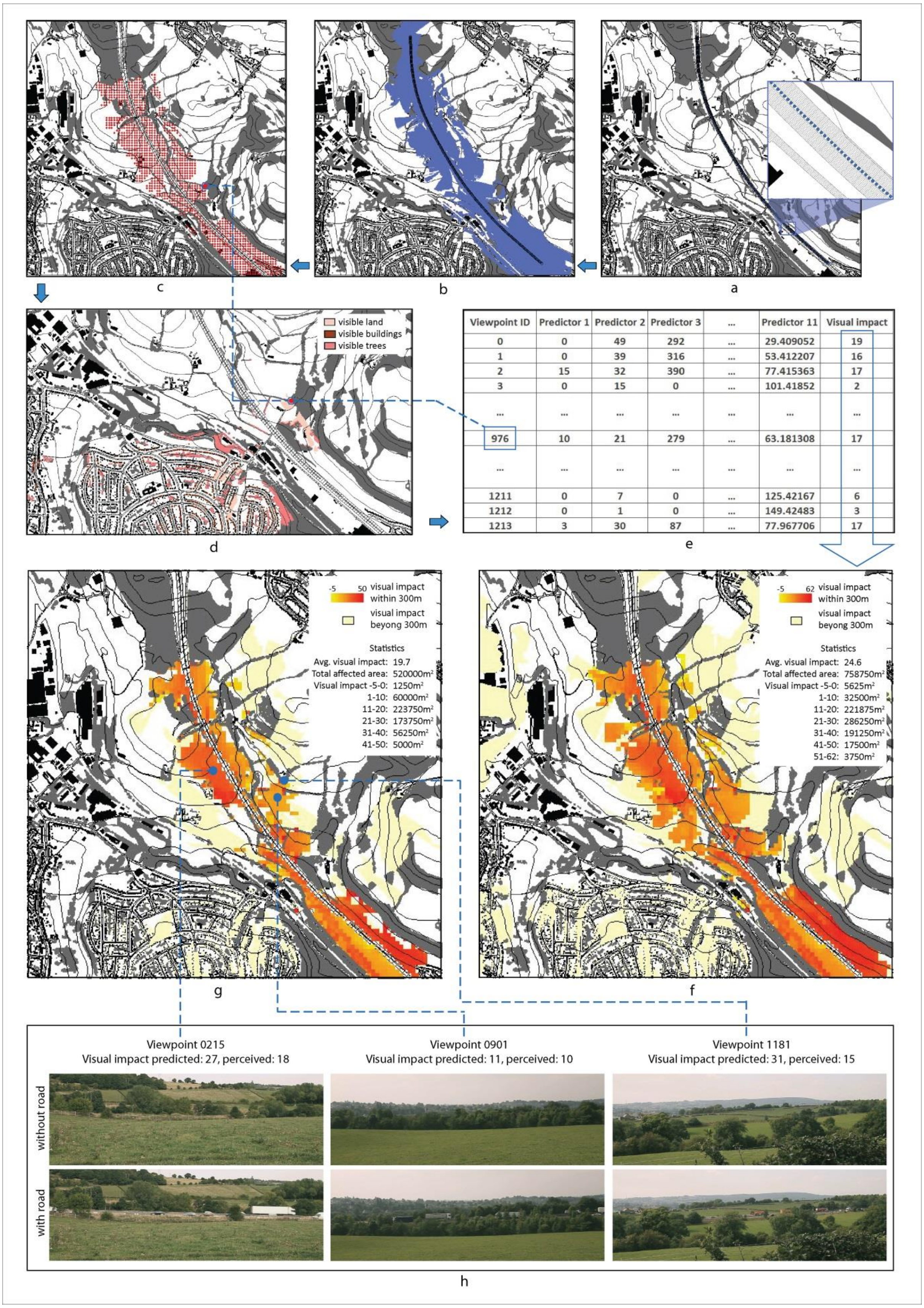
3.4.2. The visual impact maps

To predict visual impact for the whole affected area, the prediction model was applied to a grid of viewpoints covering the affected area in GIS. Figure 7 shows the procedure. To define the affected area, a line of target points were assigned on the road central line with 5m intervals to represent the road (540 points in total) (Figure7-a), and viewshed analysis with a 300m limit was performed for each target point. The obtained 540 viewsheds were then merged together to create the viewshed of the road line, i.e., the affected area (Figure7-b). For road without barrier, the absolute height of the road surface (0m above ground) was assigned to each target point for viewshed analysis, while for road with barrier, a 5m offset was applied. A 25m × 25m grid of viewpoints was then created within the affected area excluding areas covered by trees (Figure7-c). The 25m × 25m resolution used here was for the purpose of computational efficiency, and was thought to be sufficient for outcomes of large scale mappings demonstrated in this study. Landscape content visible from each viewpoint was still measured in 5m x 5m resolution in the same way as described in Section 2.2 (Figure7-d). The difference was that the horizontal field of view of each viewpoint was set 180° and towards the road, and the vertical field of view 180° covering -90° to 90°, since viewers on actual site can get wider views as they move their eyes, heads and bodies (Smardon et al., 1986). However, the use of wider field of view, particularly the wider horizontal field of view, meant the amounts of trees and buildings in the viewsheds from these viewpoints would probably reach very high values outside the range of the input variables used for developing the prediction model. To avoid over extrapolation, amounts of trees and buildings in viewshed were transformed by multiplying 72°/180°. With the values of required predictors calculated for each viewpoint, the regression model was applied to calculate value of visual impact received at each viewpoint (Figure7-e).

Figure 7-f shows the map of visual impact of motorway with timber barrier on the original base site, and Figure 7-g shows the map of visual impact of motorway without barrier (the original road) on the original base site. Visual impact induced by the original motorway ranges from -5 to 50 with an average of 19.7 (see Section 3.2. for the definition of the scale). Since the M1 was opened around the 1960s and plantings along it have been well established, the motorway is not highly visible and only affects a relatively small area of 520000m^2 within the 300m limit. The installation of timber noise barrier, which is 5m in height, not only increases the maximum impact to 62 and average impact to 24.6, but also considerably extends the affected area to 758750m^2. Since this study did not address the effect of traffic, absolute height of the road surface was used for viewshed analysis in scenarios without noise barrier. However, Highways Agency (1993) suggest that 4m above road surface should be added to take account the height of traffic, which will largely increase the extent of the potential visual impact of motorways without barrier. It can be seen in the two maps that a large area beyond the 300m limit is affected in both the scenarios with and without noise barriers. While visual impact value is not calculated for this area in this study, consideration should still be given to this area in an assessment. Highways Agency (1993) suggests a cut-off line at a distance of 1000m from the road for the UK context.

3.4.3. Verification and application

Photos taken at Viewpoint 0215, 0901, and 1181, along with their photoshopped copies of baseline scenes where the road was removed, were used in the supplementary survey to verify the predicted visual impact (Figure 7-h). The three viewpoints were chosen as they were accessible on site and offer some variations on the impact map. In both the predicted and perceived results, visual impact at Viewpoints 0215 and 1181 are relatively close to each other while that at Viewpoint 0901 is much lower, showing a certain level of consistency. However, the agreement at Viewpoint 1181 is weak. There is also some inconsistency in the scales of predicted and perceived impacts. The predicted impact seems to use a larger range of levels and thus tends to give impact higher in values than the perceived one (comparing the predicted mean impact to the mean impact in Table 3 will also reveal this tendency). Nevertheless, this should not be much a problem in interpreting the predicted results. Special attention might need to be given to the extreme levels, e.g., those below 0 or higher than 40 or 50, as there are potential risks of extrapolation of input predictors, although they only count for a very small part of the affected area. In general, there is confidence to say that the derived visual impact maps can show the extent of the impact with largely reliable “human-perceived” impact levels.



Viewpoint ID	Predictor 1	Predictor 2	Predictor 3	...	Predictor 11	Visual impact
0	0	49	292	...	29.409052	19
1	0	39	316	...	53.412207	16
2	15	32	390	...	77.415363	17
3	0	15	0	...	101.41852	2
...	...	...	...	...	...	...
976	10	21	279	...	63.181308	17
...	...	...	...	...	...	...
1211	0	7	0	...	125.42167	6
1212	0	1	0	...	149.42483	3
1213	3	30	87	...	77.967706	17

Figure 7 Procedure of visual impact mapping: a. target points representing the road; b. affected area with the 300m limit; c. 25m × 25m grid of viewpoints; d. measuring view content for each viewpoint; e. calculating visual impact received at each view

With affected area and impact level shown, the visual impact maps would be helpful for comparing alternative road plans and mitigation measures in visual impact assessment, or for trade-off analysis against other environmental impacts in GIS. The maps can also be used to find visually desirable locations for new developments, scenic stops or recreational paths in areas adjacent to existing motorways. The maps shown here only consider the effects of the characteristics of the motorway project and character of the existing landscape. To take into consideration the effect of viewer sensitivity, simple attempts can be made by overlapping the visual impact map onto a land use map where subjective weightings for viewer sensitivity are assigned for each land use category (Hadrian et al., 1988), or by measuring viewer exposure with a good approximation of affected viewer number and viewer locations (Federal Highway Administration, 1988). Further studies are required to investigate the more detailed effect of viewer sensitivity, which includes susceptibility of the viewers to changes in views and the value attached to particular views (Landscape Institute and Institute of Environmental Management and Assessment, 2013).

4. Conclusions

This study aimed to investigate the effects of the characteristics of the motorway project and the character of the existing landscape on the perceived visual impact of motorways, and to develop a GIS-based model to predict the perceived impact. A preference survey using computer-visualised scenes was carried out online to obtain perception-based judgements on the visual effect of motorways. Based on the survey result, a visual impact prediction model using map-based input variables was developed and the predicted impact was mapped in GIS.

It was found from the survey result that the introduction of a motorway significantly detracted from the visual quality of the views. Installation of noise barriers, especially the opaque timber barriers, further increased the resulted visual impact, while tree screening considerably reduced the impact. For the effect of the existing landscape, it indicated that visual impact tended to be lower on sites that were less visually attractive with more buildings in the views, and scattered trees between the motorway and the viewpoint offered a visual absorption effect which slightly reduced the visual impact.

Presence of timber barrier, Presence of transparent barrier, Amount of buildings in the viewshed in midground, Amount of trees in the viewshed in midground, Amount of buildings in the viewshed in background, Amount of trees in the viewshed in background, Percentage of buildings in the viewshed in foreground, Percentage of buildings in the viewshed in midground, Percentage of trees in the viewshed in background, Percentage of trees in the viewshed, and Distance to road were identified as predictors for the visual impact prediction model which was applied to a grid of viewpoints in GIS to generate maps of visual impact of motorways in different scenarios. Distribution of areas affected by visual impact of different levels was shown on the generated maps. Further work is needed to include the effects of moving traffic and viewer sensitivity.

The proposed GIS-based prediction model can assess the visual impact of motorways for the whole affected areas automatically using judgement obtained from preference surveys, offering results that are more reliable than those from the conventional expert-based approaches. With the proposed model, perceived visual impact of alternative motorway plans with changing future land cover scenarios can be easily calculated and mapped to assist decision making in the planning process.

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Appendix A. Distribution of the 120 images over the 100 questionnaires.

Questionnaire	The 24 images in the questionnaire (shown as Image No.)
questionnaire 1	1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,117
questionnaire 2	2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,22,23,24,25,26,118
questionnaire 3	3,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27,119
questionnaire 4	4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,24,25,26,27,28,120
questionnaire 5	5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,25,26,27,28,29
questionnaire 6	6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29
questionnaire 7	7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30
questionnaire 8	8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31
questionnaire 9	9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32
questionnaire 10	10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33
questionnaire 11	11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34
questionnaire 12	12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35
questionnaire 13	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36
questionnaire 14	14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37
questionnaire 15	15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38
questionnaire 16	16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39
questionnaire 17	17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40
questionnaire 18	18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41
questionnaire 19	19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42
questionnaire 20	20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43
questionnaire 21	21,25,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48
questionnaire 22	22,26,,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,46,47,48,49,50
questionnaire 23	23,27,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,47,48,49,50,51
questionnaire 24	24,28, 30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,48,49,50,51,52
questionnaire 25	29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,49,50,51,52,53
questionnaire 26	30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53
questionnaire 27	31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54
questionnaire 28	32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55
questionnaire 29	33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56
questionnaire 30	34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57
questionnaire 31	35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58
questionnaire 32	36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59
questionnaire 33	37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60
questionnaire 34	38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61
questionnaire 35	39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62
questionnaire 36	40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63
questionnaire 37	41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64
questionnaire 38	42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65
questionnaire 39	43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66
questionnaire 40	44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67
questionnaire 41	45,49,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72
questionnaire 42	46,50,52, 53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,70,71,72,73,74
questionnaire 43	47,51,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,71,72,73,74,75
questionnaire 44	48,52,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,72,73,74,75,76
questionnaire 45	53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,73,74,75,76,77
questionnaire 46	54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77
questionnaire 47	55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78
questionnaire 48	56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79
questionnaire 49	57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80
questionnaire 50	58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81

questionnaire 51	59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82
questionnaire 52	60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83
questionnaire 53	61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84
questionnaire 54	62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85
questionnaire 55	63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86
questionnaire 56	64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,88
questionnaire 57	65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,88,89
questionnaire 58	66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,88,89,90
questionnaire 59	67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,88,89,90,91
questionnaire 60	68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,88,89,90,91,92
questionnaire 61	69,73,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96
questionnaire 62	70,74,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,94,95,96,97,98
questionnaire 63	71,75,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,95,96,97,98,99
questionnaire 64	72,76,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,96,97,98,99,100
questionnaire 65	77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,97,98,99,100,101
questionnaire 66	78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101
questionnaire 67	79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102
questionnaire 68	80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103
questionnaire 69	81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104
questionnaire 70	82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105
questionnaire 71	83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106
questionnaire 72	84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107
questionnaire 73	85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108
questionnaire 74	86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109
questionnaire 75	87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110
questionnaire 76	88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106, 107,108,109,110,111
questionnaire 77	89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106, 107,108,109,110,111,112
questionnaire 78	90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106, 107,108,109,110,111,112,113
questionnaire 79	91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106, 107,108,109,110,111,112,113,114
questionnaire 80	92,93,94,95,96,97,98,99,100,101,102,103,104,105,106, 107,108,109,110,111,112,113,114,115
questionnaire 81	93,97,99,100,101,102,103,104,105,106, 107,108,109,110,111,112,113,114,115,116,117,118,119,120
questionnaire 82	94,98,100,101,102,103,104,105,106, 107,108,109,110,111,112,113,114,115,116,118,119,120,1,2
questionnaire 83	95,99,101,102,103,104,105,106, 107,108,109,110,111,112,113,114,115,116,117,119,120,1,2,3
questionnaire 84	96,100,102,103,104,105,106, 107,108,109,110,111,112,113,114,115,116,117,118,120,1,2,3,4
questionnaire 85	101,102,103,104,105,106, 107,108,109,110,111,112,113,114,115,116,117,118,119,1,2,3,4,5
questionnaire 86	102,103,104,105,106, 107,108,109,110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5
questionnaire 87	103,104,105,106, 107,108,109,110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6
questionnaire 88	104,105,106, 107,108,109,110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7
questionnaire 89	105,106, 107,108,109,110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8
questionnaire 90	106, 107,108,109,110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9
questionnaire 91	107,108,109,110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10
questionnaire 92	108,109,110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11
questionnaire 93	109,110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11,12
questionnaire 94	110,111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11,12,13
questionnaire 95	111,112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11,12,13,14
questionnaire 96	112,113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15
questionnaire 97	113,114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16
questionnaire 98	114,115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17
questionnaire 99	115,116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
questionnaire 100	116,117,118,119,120,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19