The Best Paper Format and Viewing Distance to Represent the Scope and Scale of Visual Impacts

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Abstract: The accurate representation of the visual experience by photo-realistic simulations is central to the usefulness and credibility of visual impact assessments. However, little is known about how people view visual simulations. HUNTER & LIVINGSTONE (2012) investigated the best focal length for photographic landscape representation. However, they did not investigate whether (1) the view is best represented by a single-frame or panoramic photograph, (2) the optimum size for displaying simulations, or (3) the distance at which participants found it "comfortable and natural" to hold the photographs This paper reports the results of a small investigation of to determine the paper simulation format that best portrays an off-shore wind project's scope and scale. It also compares the viewing distance that participants find most appropriate for each format to the geometrically correct viewing distance.

Keywords: Visual simulation, visual impact assessment

1 Introduction

Environmental impact assessments are routinely required as part of the permitting procedures for large development projects, and it has become common that these include a visual impact assessment (VIA) with professionally prepared photo-realistic simulations of how the changes will appear. In many cases these documents must be submitted as paper documents, but even digital PDF documents are formatted to reflect their hard-copy heritage. As a practical matter, this means that most simulations are formatted to be viewed printed on letter (8.5-by-11 in), A4 (21-by-29.7 cm), tabloid (11-by-17 in), or A3 (29.7-by-42 cm) paper.

Perhaps surprisingly, there is relatively little guidance in simulation preparation. The most common professional practice has been to use a so called normal lens to record the existing condition – 50 mm on a 35 mm film or FX digital camera, or 35 mm on a DX digital camera. This results in an image with approximately a 40° horizontal and 27° vertical angle of view (a 35 mm lens is a couple degrees narrower on a DX sensor). However, many people opposed to wind development said that these simulations did not adequately represent their scale and scope. In response, THE HIGHLAND COUNCIL (2010, p. 4) promulgated a new standard:

> *A 70 mm focal length lens on a 35 mm SLR is required for distances up to 1.5 kilometres from the viewpoint to the nearest turbine and a 75 mm focal length lens for distances exceeding 1.5 kilometres. We may require additional focal lengths for long distance views.*

The Council commissioned a study to test this new standard. It was decided that wind energy developments would be excluded from the study because public opposition might bias the result. HUNTER & LIVINGSTONE (2012, p. 12) conducted onsite surveys at nine viewpoints using 39-by-26 cm photographs printed on A3 paper and mounted on a 5 mm foam board that asked participants:

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> *very specifically to consider whether each photograph made the focal point appear: (i) "too large and too close"; (ii) "too small and too far away"; or (iii) at "about the correct size and distance" in comparison to the 'real life' view*

He found that 79 mm was the mean focal length respondents thought best represented the view's scale and depth. PALMER et al. (2016, p. 239) were unable to replicate Hunter's results, finding that:

> *At each location, the 50 mm focal length was judged to most closely represent the relevant surroundings in order to understand the view in its landscape surroundings.*

HUNTER & LIVINGSTONE (2012, p. 23-24) also made several observations and recommendations concerning the correct viewing of visual simulations intended for visualizing wind energy developments, which is somewhat odd, since none of his viewpoints included wind turbines.

> *5.3.1 This study also uncovered some important considerations for the viewing of photographs for VIA. Firstly, it is apparent that the size of the printed image size is of utmost importance. Currently, The Highland Council Standards specify that images should be printed on an A3 page with a vertical height of 240 mm and a horizontal width of 360 mm to preserve the 3:2 proportions of the single frame image. The recommended binocular viewing distance (from the eye) for an image of this size is about 500 mm (approximately the diagonal of an A3 page) (The Highland Council, 2010).*
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> *5.3.2 In this study, we were very specific with participants that the images should be held at a 'comfortable' viewing distance (but not necessarily at 'arm's length'). It was noticeable that the natural viewing distance for most respondents was instinctively about 500 mm for the A3 images (but note this was generally short of an arm's length for most participants). However, because perceptions of depth and scale are proportional to the viewing distance, if an image is held too close to (or too far away from) the eye then the effect will be to make the focal point(s) in the image appear larger (or smaller) than observed in the landscape.*
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> *5.3.3 It is therefore important that clear instruction is provided as to how the images should be viewed. We fully endorse the original recommendations made in University of Newcastle (2002) on viewing distance in regards to "what is comfortable and natural for the viewer should dictate the technical detail and not vice versa". It is our view that most respondents would be required to hold a 50 mm focal length image at an unnaturally close viewing distance before the image would provide an adequate representation of the actual scale and depth observed in the landscape. The fact that the panoramic images constructed from multiple images which are included in Environmental Statements for wind energy developments are often not viewed in-situ means the provision of viewing instructions is all the more important as there is no means of verifying the realism of the visualisation.*

5.3.4 There is an unavoidable trade-off between the focal length of a photograph and the field of view. Images taken at a longer focal length have a narrower vertical and horizontal angle of view and one consequence of this is the loss of foreground detail. In the initial field tests for this study we observed that the choice of focal length made by some participants was influenced not only by the relative scale of the focal point in the landscape but also by other cues, particularly the extent of foreground visible in the image. Such effects are likely to confuse the assessment of visual impact where the primary concern is the scale of a proposed development rather than the impact on the wider landscape. We therefore recommend that guidance be provided when viewing single frame and panoramic visualisations in the field such that individuals are instructed to view the images in a natural and comfortable manner such that any immediate foreground visible in the landscape but not in the photograph is obscured from the observer's view by the image itself.

However, Hunter's research did not investigate whether (1) the view is best represented by a single-frame or panoramic photograph, (2) the optimum size for displaying simulations, or (3) the distance at which participants found it "comfortable and natural" to hold the photographs. The research reported here presents the initial results of a study demonstrating how these three questions might be investigated.

2 Methods

The above questions define the minimum elements of the experimental design. First the investigation must evaluate both a single-frame and panoramic simulation of the same view. Second, both types of simulations must be printed on at least two sizes of paper that are used during a project's review. Third, measurements must be taken of the distance at which respondents view the simulations. Finally, respondents must evaluate how well each simulation format portrays the project's scope and scale. It was decided to use only one viewpoint in order to keep the procedure simple and make it possible to conduct as a class exercise. A wind project simulation was selected to increase the relevance of the results.

2.1 BOEM Offshore North Carolina Visualization Study

In support of its off-shore wind planning process, the BUREAU OF OCEAN ENERGY MANAGEMENT (2013a) contracted with T. J. Boyle Associates to prepare photorealistic visual simulations depicting:

- 18 different viewpoints along the North Carolina coast.
- Four lighting conditions (morning, afternoon, starlit night and misty nights).
- Three distances (10, 15, and 20 nautical miles [nm] from shore).
- Layouts were provided for 200 wind turbines with 1,000-meter spacing for each of the above scenarios.
- Two turbine models (Siemens 3.6 MW and Vestas 7 MW).

The turbines are mounted on a support structure approximately 13 m above the water. The height from the support structure to the Siemens turbine hub is 80 m, and to the upright blade tip it is 147 m; the rotor diameter is 107 m. The height from the support structure to the Vestas turbine hub is 105 m, and to the upright blade tip it is 200 m; the rotor diameter is 164 m.

The field photography used a Nikon D7000 camera and Nikkor DX AF-S 35 mm lens, which is equivalent to a 52 mm lens on a full-frame (FX) camera. The camera was mounted at eye-level on a levelling tripod and Manfrotto 3D Super-pro panoramic head. Location and azimuth were recorded in the photograph metadata with a Solmeta Geotagger Pro; a Garmin GPS and hand-held compass were used to independently verify these measurements. Photographs to be stitched into a panoramic image were taken across the horizon in 25° increments, centred on the proposed layout. This was followed by a matching row raised 15°, and then lowered 15° and 30°. A panoramic photograph was stitched in Autopano Pro and cylindrically projected. The image was cropped to 124° horizontally and 55° vertically (NZILA 2010).

Visual simulations were created using both the panoramic and the central single-frame photographs. The turbines were positioned and modelled with Wind PRO. Turbine visibility accounted for earth's curvature and atmospheric refraction (k = .075). Final image editing was performed with Adobe Photoshop.

2.2 Simulation Formats and Appropriate Viewing Distance

This study used the Long Point Camps (latitude 34.898969°, longitude -76.255147°) afternoon simulation with the nearest Vestas wind turbine 10 nm from the viewer. There are four formats – panorama simulation was printed as a wall-mounted poster, such as one might find at a public hearing, and on tabloid-sized paper (similar to A3); the single-frame simulation was printed on tabloid and letter-sized paper (similar to A4). The tabloid and letter-size sheets were mounted on light cardboard to make them easier to hold. Figure 1 shows the single-frame image within the panorama.

Fig. 1: The Long Point Camps panoramic simulation, with the single-frame simulation indicated in red. The above image is reduced from original. While small, the turbines had a well-defined appearance in the original.

The single-frame photograph has a 37.3° horizontal angle of view. Sheppard provides the formula to calculate the correct viewing distance so the simulation matches this field of view (SHEPPARD 1989, page 185).

$$\frac{\frac{1}{2} \textit{simulation width}}{\tan\left(\frac{1}{2} \textit{horizontal angle of view}\right)}$$

This formula is intended for an unprotected photograph. However, the panoramic simulations have a cylindrical projection, which requires a different calculation for viewing distance.

$$\frac{\textit{panorama width} * 360}{2\pi * \textit{angle of view}}$$

Table 1 lists the four simulation formats with their angle of view, physical dimensions, and appropriate viewing distance.

Table 1: The angle of view, dimensions and viewing distance for the simulations

	Angle of View (°)		Dimensions (cm)		Viewing Distance (cm)
Simulation Formats	**Horizontal**	**Vertical**	**Horizontal**	**Vertical**	
A: Panorama Poster-Size	124	55	147.3	72.1	67.8
B: Panorama Tabloid-Size	124	55	42.7	20.6	19.8
C: "Normal" Photo Tabloid-Size	37.3	25.1	40.1	26.7	59.4
D: "Normal" Photo Letter-Size	37.3	25.1	26.2	17.3	38.6

2.3 Class Exercise Comparing Simulations Formats and Viewing Distance

This exercise was designed to be conducted during a college-level class or public meeting. The four simulations formats were located at separate "viewing stations," with a fifth station for measuring each person's height and arm length from the shoulder break to the first knuckles. Participants were asked to work in pairs, progressing through the stations in any order. They were instructed to:

> *View each simulation in a way that is both comfortable for you and you believe communicates the project's scope (i. e., extent in the landscape) and scale (i. e., size relative to other features) most accurately. Have your partner measure the distance between the center of the simulation and the bridge of your nose and enter that distance on your sheet. Then use the 7-point scale to rate the effectiveness of the simulation format in communicating the project's scope and scale, where "4" is just right.*

Measurements and ratings at each station were recorded on the individual's response sheet. After completing the stations, respondents were asked:

> *Can you tell me in a few words why each format is effective or not – its strengths and weaknesses?*

Finally, each participant was asked the year their age, gender, level of education, and whether they had landscape architecture training.

3 Results

The participants were 14 students completing a professional undergraduate degree in landscape architecture; most were 22 years old. Their average height was 175.0 cm, with a standard deviation of 8.1 cm; mean arm length was 63.2 cm, with a standard deviation of 5.0 cm. The relationship of height to arm length is quite strong (adjusted R squared is 0.715, $F = 33.6$, $p \leq 0.0001$):

$$\textit{Arm length} = (\textit{Height} * 0.53) - 11.4$$

3.1 Simulations Formats and Viewing Distance

Table 2 reports the measured and correct viewing distance for the four simulation formats. In general, participants viewed the panoramic simulations from too far away – 175% of the correct distance for viewing the poster and 184% for the tabloid-size. In contrast, they tended to hold the "normal" single-frame simulation too close – 77% of the correct distance for viewing the tabloid-size and 90% for the letter-size. These differences are statistically significant, except for the letter-size format.

These results suggest that participants found it uncomfortable to view the panoramic simulations as close as they should. The cylindrical panoramic poster is intended to be mounted in a circular frame with a 68 cm radius. However, this special mounting is normally not available; panoramas are typically displayed on a wall or easel. In either case, the viewer is instructed to look straight into the simulation center. When looked at this way, the simulation completely fills the viewer's cone of vision and there is an enhanced sense of perspective.

Participants tended to hold the "normal" single-frame simulations a bit too close. Arm length is 138% of the correct viewing distance of the tabloid-size simulation, and maybe this was reaching the limits of comfortably holding and studying the mounted tabloid sheet – one participant did comment that it was a "little awkward to hold (could be better pinned)." On the other hand, the comfortable viewing distance for the mounted letter-size simulations was quite close to the correct viewing distance.

Table 2: Comparison of the measured and correct viewing distance for simulation formats

	Viewing Distance (cm)			
Simulation Formats	**Mean**	**Std Dev**	**Correct**	***t*-test (*p*)**
A: Panorama Poster-Size	118.5	50.0	67.8	3.79 (.002)
B: Panorama Tabloid-Size	36.5	8.8	19.8	7.07 (.000)
C: "Normal" Photo Tabloid-Size	45.9	8.3	59.4	-6.12 (.000)
D: "Normal" Photo Letter-Size	34.7	8.8	38.6	-1.68 (.116)

3.2 Simulations Formats and Representation of Project Scope

Table 3 reports the ratings for how well each simulation format represents the scope of the wind project, or its extent in the landscape. The rating for scope were (1) too confined, (4) just right, and (7) too expansive. The panoramas were judged to be somewhat more expansive than needed to understand the project's scope, the difference being statistically significant for the poster-format. In contrast the single-frame images were judged somewhat too confined, the difference being statistically significant for the letter-format.

A two-way ANOVA indicates that respondents judged the panoramic simulation as a better representation of the projects scope than the single-frame image ($F = 8.4$, $p = .000$); the size of the paper did not have a significant influence on perceived project scope ($F = .44$, $p = .646$).

Table 3: Ratings for simulation formats representation of project scope

Simulation Formats	Rating of Scope			*t*-test (*p*)
	"Just right"	Mean	Std Dev	
A: Panorama Poster-Size	4	5.00	1.04	3.61 (.003)
B: Panorama Tabloid-Size	4	4.79	1.42	2.07 (.060)
C: "Normal" Photo Tabloid-Size	4	3.50	1.02	-1.84 (.089)
D: "Normal" Photo Letter-Size	4	3.14	1.17	-2.75 (.017)

3.3 Simulations Formats and Representation of Project Scale

Table 4 reports the ratings for how well each simulation format represents the scale of the wind project, or the size of the turbines relative to other landscape features. The rating for scale were (1) too small, (4) just right, and (7) too large. The scale of the wind turbines viewed in the tabloid-size single-frame simulation was judged "just right." Scale was judged as too small in the other formats, with the difference being statistically significant for the tabloid-size panorama and letter-size single-frame simulations.

Table 4: Ratings for simulation formats representation of project scale

Simulation Formats	Rating of Scale			*t*-test (*p*)
	"Just right"	Mean	Std Dev	
A: Panorama Poster-Size	4	3.64	0.93	-1.44 (.174)
B: Panorama Tabloid-Size	4	2.21	1.25	-5.34 (.000)
C: "Normal" Photo Tabloid-Size	4	4.00	0.55	0.00 (1.00)
D: "Normal" Photo Letter-Size	4	3.21	0.89	-3.29 (.006)

A two-way ANOVA indicates that respondents' judgement of scale is significantly affected by both type of simulation ($F = 25.3$, $p = .000$) and paper size ($F = 10.5$, $p = .000$). The scale was judged to be better represented by the single-frame format ($\bar{x} = 3.61$) compared to the panorama ($\bar{x} = 2.91$), which might be a reflection of the respondents viewing the panoramic simulations from too great a distance. In generally, respondents thought that the scale was better represented by a larger paper size – the panoramas printed as a poster and the single-frame simulations on tabloid paper.

3.4 Viewer Experience of Simulation Formats

In addition to the quantitative measurements, respondents all provided short comments about the strengths and weaknesses of each format.

Poster panorama. There was overall agreement in the comments that the benefits of the panoramic poster: "Comfortably fill field of vision – feels most like 'I'm there'" and "Large image allows more detail." One participant indicated they liked this format because it was "Easy to read, more variety in viewing distance." However, strengths can also be recognized as weaknesses by the same group: "Too expansive – eyes move around a lot," "Foreground is distracting," and "Harder for more than one person to view at once."

When the simulations were presented at public workshops in North Carolina, the panoramic posters were displayed both on a wall and in a curved frame. One participant captured the general agreement: "The panoramas where you're sitting down and they're curved give you the best perspective of what it would really be like on the beach, so I definitely think that's the best way to show the view" (BOEM 2013b, p. 15). The practical benefit of using a curved frame needs to be evaluated, or is flat display on a wall adequate?

Tabloid panorama. The strengths were similar to those identified for the poster panorama; in addition, a couple participants also indicated that the tabloid-size was more manageable. The weakness was also generally recognized: "Way too small to even understand the project." One could go cross-eyed holding it at the correct viewing distance (20 cm), and even with very high-resolution printing, the details of the distant turbines would be difficult to distinguish.

Tabloid single-frame. There was overall agreement that the tabloid single-frame format best represented the scale of the turbines: "Comfortable scale of turbines, good scale" and "Able to see detail." In addition, the scope was adequate – "Allows context to be understood easily." That it "can easily be held in one hand and see contents of picture clearly" was also recognized as a pragmatic strength. Under weaknesses the loss of scope was recognized: "Not enough foreground context" and "Can't tell extent of windmill site."

Letter single-frame. There was greater diversity of strengths, but one had a sense they were stretching for something good to say – "Photo size is nice in the hand" and "Easy to produce?" The weaknesses were clearer: "Can't see windmills, can't see extent of them" and "Very tiny, lacks detail, strains eyes."

4 Discussion and Conclusions

The author's practical VIA experience has a decidedly scholarly bent focusing on the review as well as the preparation of renewable energy project VIAs (Apostol et al. 2016; BOEM 2013a; Palmer 2015). In particular, serving as a scenic expert charged with reviewing my colleagues work has created a discourse about simulations that has led to an apparent consensus in how best to present simulations. Existing and proposed conditions are based on a high-resolution single-frame photograph taken with a "normal" lens. The simulation is printed as large as possible on a tabloid-sized sheet, with only the viewpoint identification on these pages. There is a separate tabloid cover sheet that often includes a panoramic view to provide context with the area of the single-frame photo outlined in red, and a small location map indicating the viewpoint and angle of view. The cover sheet also includes more detailed information about the photography and project. Finally, the cover sheet instructs the viewer to view the simulations at a specific distance to preserve the visual scale of the project. These guidelines have now becoming part of the legal guidance for preparing visual simulations of large development projects (e. g., NH SEC 2015).

This best professional practice is supported by the research presented here. The single-frame tabloid format received the best overall ratings. Participants were asked to view each format in a way that was both comfortable and that communicated the project's scope and scale most accurately. It is instructive that the two tabloid-size images were held at significantly different distances ($t = 4.15$, $p = .001$). Therefore, it can be inferred that participants understood the panoramic image must be held closer than the single-frame image to more accurately represent the project's scope and scale. Where scope is not adequately represented by a single-frame simulation, it is recommended that a two slightly overlapping side-by-side single-frame simulations be prepared. This preserves the simulation's finer details and provides superior representation of project scale, while avoiding the awkwardness of displaying a very large panoramic poster.

Future Research

Simulations are intended to convey an accurate visual impression, meaning that it should be as close as possible to the visual experience at the viewpoint. When they fail to do this, it undermines the usefulness and credibility of the VIA. The research reported here indicates that format and viewing distance can affect the accuracy of how simulations are perceived. However, this small study is far from definitive, and there are additional issues associated with simulation format and viewing distance that warrant further exploration. Among the possible additional issues worthy of investigation are:

- Compare simulation formats to the view in the field in order to verify whether the geometrically correct viewing distance also best represents the perceived scope and scale.
- Compare the panoramic poster mounted on a wall to displayed in a curved frame, and perhaps other immersive displays.
- Compare the viewing distances of simulations based on photographs with different focal lengths and their relation to the correct viewing distance.
- Evaluate whether people can follow directions for correct viewing distance, and whether it changes the perception of scope and scale.
- Compare viewing paper copy, which is printed at 600 dpi with a display monitor, which has lower resolution and uses a different color model.
- Alternative virtual reality (VR) and augmented reality (AR) presentation formats may soon be readily available for public use; at this time the necessary equipment is both expensive and primarily associated with video games. When this happens, they should be included in future investigations.

These are issues of practical significance to VIA practice. As professionals it is our responsibility to investigate and improve our methods and establish guidelines for best professional practice. The author is seeking collaborators willing to help him with this task.

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