

Visualization Tools for Visual Impact Assessments: A Study of Existing Technologies

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Abstract: In the last few decades, digital technology has dramatically altered how visual resource management and visual impact assessments (VIAs) are conducted. The recent emergence of low-cost immersive technology offers a suite of tools that could facilitate the VIA process. However, to date there is limited empirical evidence evaluating how these emerging technologies could influence VIA. The research presented here begins to fill this gap by comparing immersive virtual environments to existing 2D photo-based methods for assessing the visual impacts of development. 23 participants familiar with VIAs rated the visual qualities of different scenes presented as 360° images, Google Earth and 2D images. Results show a high similarity in perceived impacts between 2D images and Google Earth; 360° images were rated consistently lower. Overall, participants indicated that immersive visualization may have a role in VIAs, but it is critical these technologies be evaluated against on-site assessments before being adopted.

Keywords: Visual impact analysis, visual resource management, photosphere image, Google Earth

1 Introduction

Dedication to the preservation, protection and creation of natural beauty has inspired civilizations, ancient religions, artists and philosophers. Such appreciation of nature is still palpable today as evidenced in the United States by the protection of National Parks and Scenic Byways. Yet, the character of many of our most inspiring landscapes has fundamentally been altered as a result of the unparalleled growth of human development and associated rapid rise of resource extraction in the past century. The National Environmental Protection Act (NEPA) was signed into law in 1970 to “ensure for all Americans... aesthetically and culturally pleasing surroundings” (NATIONAL ENVIRONMENTAL POLICY ACT (NEPA), SEC 101 [42 USC § 4331], 1969), amongst numerous other environmental systems.

Since this law was signed, visual impact assessments (VIAs) have been used to protect scenic resources, scenic experiences and historic properties throughout the US (SULLIVAN et al. 2018). Over the past half century VIA processes have been refined in part due to the emergence of digital technologies (SHAFER et al. 1974, STAMPS 1990, OH 1994, STAMPS 2010) with evidence of a continued exploration into the role digital technologies play in landscape management (see GOBSTER et al. 2019). Technology advances so rapidly, such as with low-cost and high-quality virtual reality, smartphone-based cameras, Google Earth and 360° cameras, that it is important to ensure research keeps pace with these advancements in order to understand the implications of use and adoption of these technologies.

A key component to VIA process is documenting existing conditions and measuring/predicting the visual impacts from new development or resource extraction. Negative visual impacts to landscape scenery can result from environmentally damaging practices such as forest harvests or mining activities, as well as the addition of infrastructure such as renewable energy,

energy transmission lines, oil pipelines and buildings. While on-site evaluation is the preferred method for VIA, if on-site visits become more challenging or cost prohibitive, it will be important to find ways to facilitate regulators making assessments that ensure the protection of scenic resources. Digital technologies may play a role in this future but must be carefully evaluated for their effectiveness at being a proxy for on-site assessments.

Photographing a site has historically been used as the primary medium for demonstrating existing conditions conventionally using a 50 mm lens to capture images from key observation points (PALMER 2008). With the surge in digital photographic techniques (e. g. via panoramas) and smart phone high resolution cameras these technologies are becoming far more common than an SLR with 50 mm camera lens. Rigorous and defensible research is needed to evaluate how these new technologies, in addition to other immersive technologies, compare to existing standards.

This project compares some of the newest technologies to the existing 50 mm standard. If new technologies prove as reliable or better alternatives, it could lead to more accurate assessment of current conditions and measurable impacts, possibly reducing project costs and mitigating visual impact along the way. Our specific research questions are: How appropriate are Google Earth and photosphere (360°) images as visualization surrogates for 2D images when conducting a visual impact assessment (VIA)? Specifically, do Google Earth and photosphere images produce similar VIA results compared to 2D images? We hypothesized there would be a statistically similar result across these medium.

2 Methodology

2.1 Methodology Overview

To evaluate visual impact, we developed an approach that employed a structured, linear step-wise process to systematically evaluate the influence three different imagery medium might have on visual impact assessment ratings. These steps include: 1) site selection, 2) project development, 3) building models (2D images, photosphere, Google Earth), 4) modification of models (Photoshop and SketchUp), 5) conducting the survey, and 6) data analysis. Details of each of these are included in the following subsections.

2.2 Site Selection and Digital Development

The first step of this research was to find suitable observation points from which assessments could be made. Observation points were selected from open space and pastures in a grassland prairie landscape. Viewpoints were selected based upon visible land area and land cover type. Landscape preference studies have found the combination of open-landscapes, and visible distance (landscapes with high visible land areas) are preferred over enclosed landscapes (IVERSON 1985, CLAYTON & OPOTOW 2003). Land cover collected from the National Land over Database (UNITED STATES GEOLOGIC SURVEY 2011) was used to accumulate viewpoints that overlooked developed, natural and cultural landscapes. A balance of developed, natural and cultural land cover within views was desirable to accurately represent visible landscapes of the region.

In total, eight observation points were selected with a photograph and photosphere image taken at each. The objective was to acquire varying types of views based upon the aforementioned factors of land cover type, visible land area, and viewpoint importance. By having a variety of view types, the results of the study are more representative of the ecoregion.

Hypothetical developments were generated and placed in the landscape. The hypothetical projects varied by two factors: development type and its location in the landscape. Proposed developments were based on those found in the surrounding landscapes and included large scale wind farms, singular wind turbines and oil pump jacks.

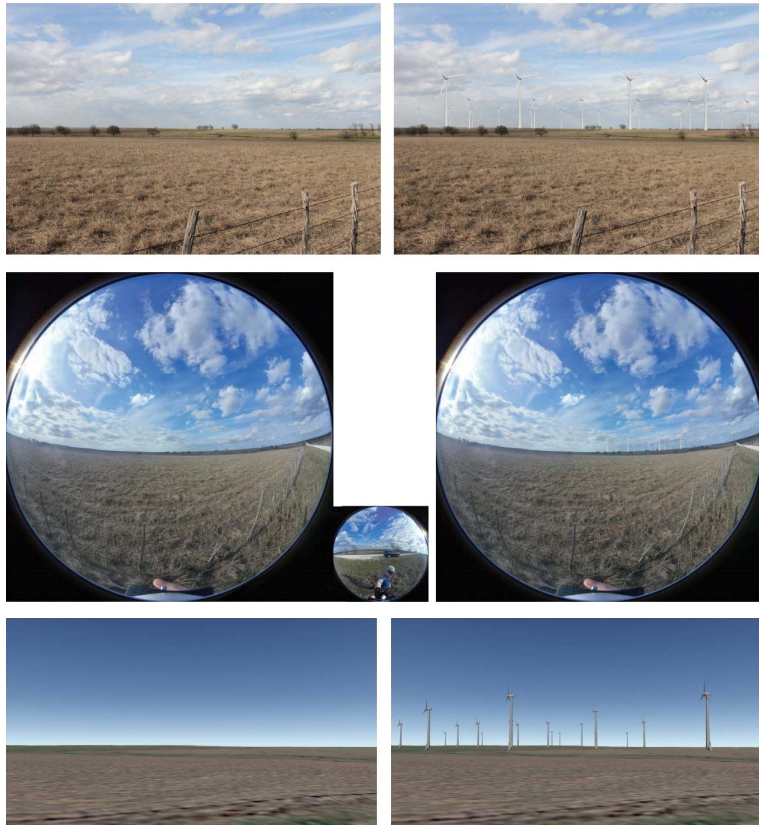


Fig. 1: Existing landscape (left) and edited landscape (right) for each display type: 2D image taken using Canon DSLR with 50mm lens with focal distances on horizon (top); photo sphere captured using Samsung 360 camera 2017 model with horizon as focal distance (middle); Google Earth (bottom). All images captured from 3pm – 5pm from each viewpoint with partly cloudy conditions.

Different technologies were used to modify the existing site images (without development) to give the appearance of development (representations of images shown in Figure 1). For the 2D photograph a photomontage was rendered with the proposed development produced through Photoshop and scaled appropriately. In Google Earth, 3D Sketchup models were

imported into the landscape at a location that matched the same location in the 2D images. Building models for photosphere images utilized Adobe Premier and Adobe Photoshop programs, and like the Google Earth technique, a three-dimensional model was placed into the landscape. These images were then used within an online survey platform.

2.3 Survey Development

The survey platform for this study was Qualtrics, combined with other digital materials. The survey and materials were sent to the participants via email. As part of the online survey, participants acknowledged and accepted participation in the study and no remuneration was provided. The first page of the survey included informed consent, giving the researcher the ability to use their survey data. Declining to participate resulted in the survey being terminated. If participants consented, demographic information was then collected including participant work experience, education/training, which sector they work in, and how active they are in the outdoors. No identifying information was collected within this section; participants could decline to submit at any time. Monitor size and reading distance were not controlled.

Following demographic data collection, participants then began the assessment phase of the experiment. Eight observation points were displayed via three visualization methods at each point. In total, 24 assessments were made. The order in which the observation points and visualization methods presented were randomized to eliminate order effects. For each assessment, before and after images were presented side by side allowing the participant to easily compare visual changes in the landscape.

For each assessment five factors were rated by participants: 1) character type and how well the development matches the landscape character; 2) view extent and how much the project encompasses the view; 3) contrast, examined how much the project contrasted with its surroundings in terms of forms, lines, colors and textures; 4) how the development added/subtracted focal points in the view; and 5) how the development was similar to other development in the view (if any). We employed KAPLAN'S (1985) rating preference system which has been used in numerous landscape visual studies and has been described as a simple and accurate method to collect landscape visual preference data (KELLOMÄKI and SAVOLAINEN, 1984, R. KAPLAN 1985, OH 1994). Participants rated the impact on a five-point Likert scale (1 = least visual impact, 5 = most visual impact). Descriptors of how each factor should be rated were given to ensure a consistent approach across all participants.

The survey (DEPRIEST 2018) was developed in part by Mark Meyer and Melanie Peters of the National Park Service, Robert Sullivan from Argonne National Laboratory, and the lead author of this research through analysis of each of the major land managing government agencies visual impact assessment processes. The agencies analysed includes the Bureau of Land Management, the United State Forest Service, the Federal Highway Administration, as well as the Scottish Natural Heritage.

2.4 Data Analysis and Aggregation

Collected data was aggregated from the survey and analysed using a one-way analysis of variance (ANOVA) because of its ability to distinguish three or more categories within the independent variables.

In this study, the three categories of the independent variables (visualization methods) were 2D images, Google Earth and photosphere images. *P*-values were calculated to determine the level of correlation between the differing visualization methods. For this research, a significance value of less than 0.05 indicated significant difference between variables. From the survey responses, the mean values of the five rated variables (change in landscape character, view extent, contrast, focal points, and inconsistent elements) were compared between the three-visualization mediums. To compare mean scores across the three media formats, a total mean value was calculated between the five rated elements. Demographic variables were analysed using a one-way ANOVA with a Tukey Post Hoc analysis used to identify how groups differed on their mean preference ratings according to age, gender, and experience.

3 Results

The survey was sent to 75 visual resource researchers and professionals, we achieved a 30 % response rate (23 responses). The data were analysed using a one-way ANOVA to compare the mean values of 2D images, photosphere images, and Google Earth. The Tukey Post Hoc test was conducted to identify the variables in which significant differences occurred. The ANOVA demonstrated that assessors rated photosphere images lower for visual impact than 2D images or Google Earth.

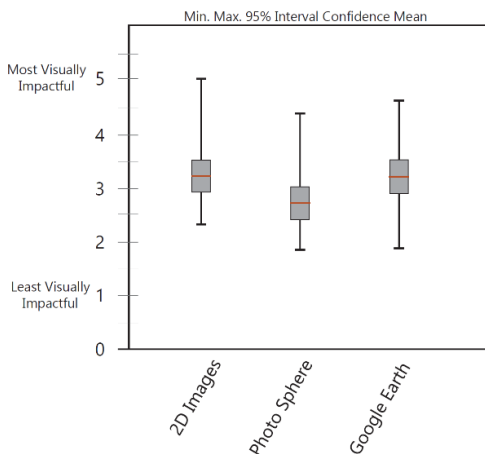


Fig. 2:
ANOVA comparing mean ratings based on type of medium

This was determined by averaging the five rated elements (*landscape character, view extent, contrast, focal points, and inconsistent elements*) used in each assessment from all viewpoints and all participants. On average, participants rated 2D images ($M = 3.21$) and Google Earth ($M = 3.20$) consistently, yet Google Earth had a slightly higher standard deviation (1.42) compared to 2D images (1.26). Photosphere images were rated significantly lower ($M = 2.73$, $SD = 0.384$, $F_{2,21} = 3.357$, $p < 0.05$, Cohen's $f = 0.443$) indicating a lower visual impact perceived by participants compared to 2D images or Google Earth. Figure 2 represents the minimum and maximum average rating, along with the 95 % confidence interval and the mean values of each visualization method.

A further analysis was conducted in which the five rated elements were assessed separately, rather than using the mean for all elements. There was no statistically significant difference caused by medium on *character type* or *inconsistent elements*. However, the difference in medium did influence the ratings for *view extent*, *focal points* and *contrast*. For *view extent* one-way ANOVA showed significant differences ($F_{2,21} = 4.659, p = 0.013$) between the mean values of 2D images ($M = 3.15$), photosphere images ($M = 2.35$), and Google Earth ($M = 2.98$). For *contrast* the one-way ANOVA also showed photosphere images ($F_{2,21} = 4.063, p = 0.022$) had a lower rating mean ($M = 2.64$) when compared to 2D images ($M = 3.26$) and Google Earth ($M = 3.28$). The same outcome existed for *focal points* with the one-way ANOVA ($F_{2,21} = 4.873, p = 0.011$) showing that photosphere images ($M = 2.78$) are, on average, rated lower than other visualization methods (2D images $M = 3.47$; Google Earth $M = 3.28$). For each of these three elements, photosphere was rated statistically lower than the other two mediums, while there was not statistically significant difference between the 2D images and Google Earth. These results are summarized in Table 1 along with effect sizes.

Table 1: Summary results table for each assessment element. Asterisk indicates $p < 0.05$

Element	$F_{2,21}$	p	Cohen's f	Outcome
Character type	0.455	0.796	NA	
Inconsistent elements	0.95	0.392	NA	
View extent	4.659	0.013*	0.552	Tukey analysis showed photosphere resulted in statistically significant less visually impactful assessments.
Focal points	4.873	0.011*	0.568	
Contrast	4.063	0.022*	0.505	

Analysis of the demographic data was conducted to discover any possible trends toward differences in gender and age. Age classes were separated into five groups (18-30, 31-40, 41-50, 51-60, and 60+). The one-way ANOVA indicated that the age groups 51-60 and 60+ rate visual impacts lower across all media, however, not to a level of significant difference. Similarly, there was no difference evaluated regarding gender, unlike that of Ode et al. (2009). Finally, a one-way ANOVA was conducted to determine if experience played a role in the mean ratings. For this study experience was separated into three groups: 1) those having conducted less than 3 visual impact assessments, 2) those having conducted between 4 and 10 visual impact assessments, and 3) those who have conducted more than 10 visual impact assessments. The result showed no statistically significant difference, but this should be taken with caution as the distribution of experience groups differed where one group had a substantially higher sample rate.

4 Discussion

Ideally, visual impact assessments would be done in person for a fully immersive and contextual experience, however there are many instances where 2D images are used as an alternative to on-site evaluations because natural, climatic, and anthropocentric conditions (such as logistical burdens and cost) make visits prohibitive. Technology can provide 360° experiences of spaces to inform circumstances where site visits are prohibitive. This research is the first that we know of to systematically compare 360° technology with 2D images and Google

Earth. The summary outcome is that the study rejects the hypothesis of consistent ratings across visualization media, finding that using a photosphere image will typically allow for more built development to occur than using a 2D image or Google Earth platforms.

There are some notable limitations of this study. For instance, a control group of on-site assessments was not conducted. However, it was impossible to have all these professionals gathered to conduct this assessment. A future gathering of professionals would provide an opportunity for data collection, including evaluating the role augmented reality has on ratings. Additionally, there are some obvious differences between technologies, including that the imagery captures the range of elements in the foreground such as fences, hedges and other infrastructure, where Google Earth did not include these elements. Increasing realism and resolution could influence future results. Further, additional technology could be compared (e. g. virtual reality), but this would require all participants to have the same technology and be able to effectively manage the technological hurdles to create a similar study experience. This study looked at wind turbines as the subject matter for landscape change, however turbines are dynamic and full of movement that could not be captured in static images. In the future animations could replace static images.

While this study did manage to demonstrate how medium can influence ratings of visual impacts, these data should be considered carefully before any major changes to industry standards are made. A few additional considerations to improve the quality of the data or to repeat this study include:

- 1) Increase the number of participants: this study included 23 professionals in total. While the results did demonstrate statistical significance and the effect sizes were large, increasing the number of professionals would add to the value of this research through repetition and an expanded demographic pool.
- 2) Increase the diversity of demographics and experience: this would involve ensuring a better distribution of ages, genders and experience conducting visual impact assessments to ensure a more equal distribution of these potential factors. Further, it could be worthwhile to include the public in these evaluations to compare differences between “experts” and the public.
- 3) Increasing the number of sites that are studied: the existing study was conducted in a vast, open space grassland. Additional landscapes should be tested, including coastal systems, mountainous terrain and forested areas.
- 4) Improving the procedural controls on technology: while we took great care in controlling the experience through an online survey platform (Qualtrics), the implementation of the photosphere image relied on an online video platform that condensed the quality of the image. We would recommend evaluating the role that the existing platforms, digital resolution and distance/context of development might have on the results. The role of these elements could then be considered across the range of rated elements found in Table 1.
- 5) We would also recommend including a question about the technology each individual used for this study (computer type, monitor resolution and size, etc.) so statistical controls could be used to identify how monitor size (as a covariate) might have influenced ratings for each medium.
- 6) Last, this study makes comparisons solely between technologies, where the control was the 2D image. Instead, and if possible, preference would be given to conduct this study on-site as the control, with another medium being evaluated against that site.

5 Conclusion

This study is the first systematic review of two readily available 3D technologies (photo-sphere imagery produced by 360° camera, and Google Earth) in comparison to industry standard 2D imagery. The procedures and assessment process can be reliably replicated in additional studies with other sites, technology and contexts. The key takeaways from this research are that immersive technology may play a role in facilitating visual impact assessments when travel costs are high, timelines are short and limited expertise exists near sites, but these must be carefully evaluated for their effectiveness at being a proxy for on-site assessments. Our findings demonstrate that Google Earth may be a reasonable alternative to 2D ratings of visual impact assessment based on the five elements proposed for future impact assessments. However, additional studies should be conducted using different sites, contexts, development proposals and with on-site comparisons.

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