October 13th, 2017

How useful is GSV as an environmental observation tool? An analysis of the evidence so far.

Katherine Nesse
Seattle Pacific University

Leah Airt
Seattle Pacific University

How useful is GSV as an environmental observation tool? An analysis of the evidence so far.

Presented at the 57th Annual ACSP Conference
October 13, 2017

Katherine Nesse
Seattle Pacific University
Sociology
3307 Third Avenue W
Seattle, WA 98119
206-378-5378 | knesse@spu.edu

Leah Airt
Seattle Pacific University
Library
3307 Third Avenue W
Seattle, WA 98119
206-281-2788 | airtl@spu.edu

Abstract. Researchers in many disciplines have turned to Google Street View to replace pedestrian- or car-based in-person observation of streetscapes. It is most prevalent within the research literature on the relationship between neighborhood environments and public health but has been used as diverse as disaster recovery, ecology and wildlife habitat, and urban design. Evaluations of the tool have found that the results of GSV-based observation are similar to the results from in-person observation although the similarity depends on the type of characteristic being observed. Larger, permanent and discrete features showed more consistency between the two methods and smaller, transient and judgmental features were less consistent. There are some difficulties in using GSV for research purposes including, 1) the fixed point of view, 2) the processing, 3) the quality, and 4) the fixed point in time of the images. These issues have had little discussion by researchers using GSV but could bias their results in some circumstances and therefore should be addressed by researchers using GSV.

Key words. Google Street View, neighborhood audit, survey, observational methods, street, systematic social observation

About the Authors. Katherine Nesse is an Assistant Professor of Urban Studies and Leah Airt is the Business and Social Sciences Librarian at Seattle Pacific University.

Many disciplines study streets and street-adjacent phenomena. The conventional way of observing streets has been from the vantage of a pedestrian or car. Within the field of public health, research on the connection between street design and health outcomes of residents has utilized walking surveys of street features such as sidewalk width, proximity to parks and trails, and the presence of bike lanes. Wildlife ecologists have used car-based surveys of nests of specific species. Other researchers have relied on other in-person modes of observation such as from the vantage of a bicycle or taking an in-person photograph with a special camera. Some have also recorded in-person observations with film to analyze later. With the rise and increased coverage of Google Street View, more and more researchers are exploring its the use as a replacement for in-person modes of observation.

Google Street View (GSV) is increasingly used by researchers to replace conventional in-person modes of observation in research of street and street-adjacent phenomena. GSV is a service developed privately by Google, Inc. to enable users to have a 360-degree view around a point on a street from the vantage of a car. The service was officially launched in 2007 in the United States and now captures the streets in many countries across the world with especially good coverage in Europe and North America (Hoelzl and Marie 2014). The service can be accessed online through Google Maps or through Google Earth. There are other remote visual recording tools, including Bing StreetSide, Microsoft Visual Oblique, and Mapillary (Juhász and Hochmair 2016), some of which have been used by researchers. We focus on GSV as opposed to other street-side recording services because it is the most widely used in research.

There is wide-spread acceptance of GSV as a viable alternative to in-person observation within the published literature. It is significantly less costly and time-intensive and allows researchers to easily access places remote from their physical location. In this paper, we analyze: the extent GSV has been used as a replacement for in-person observation and other conventional forms of observation and the evidence that it can replace the conventional modes of observation. We systematically searched for papers, articles, books and other literature using GSV as a street-level observation tool in research or testing its use and literature about the capabilities and potential for the use of GSV in research.

Methodology

In reviewing the literature on the use of GSV as a research tool for street-level observation, we wanted to be comprehensive. We used a systematic approach for identifying publications that either, 1) used GSV as a research tool, 2) evaluated GSV as a research tool, or 3) contributed to the theory regarding its use as a research tool. As English-language researchers, we focused on English-language publications and acknowledge we may have missed some research published in other languages. Our search was conducted between October 2016 and June 2017.

We searched for articles primarily using academic databases including Ebsco's Academic Search Premier, WorldCat, and Google Scholar. The following keywords were used and were based, in part, on a list used by Charreirre et al. (2014):

Google Street View
Omnidirectional imagery
Google AND urban design NOT "google scholar"
Google AND built environment
Google AND urban environment
"Street View" AND ecology
"Street View" AND public health
StreetSeen
"Place Pulse"
"Beautiful Street Project"

We also used the bibliographies to identify additional works, asked scholars in relevant fields for suggestions, and visited the websites of research groups we knew were conducting research related to GSV or in-person observations to see if they had working papers not yet published in a peer-reviewed venue. We focused primarily on academic works, but we did include other works that had some other merit such as works in trade publications that described the application of GSV in a particular context.

A three-step process was used to determine whether to include an article in this literature review: 1) identify articles; 2) screen; 3) categorize. First, we identified an article based on the title and publication name and added it to a list that we would look into further. In this first level of screening, we determined whether it was potentially related to GSV, academic in nature, or, if not academic, likely to have some other information helpful for understanding the use of GSV in an academic context.

Next, the articles were screened for the use of GSV for conducting street-level local assessments. We understand this activity broadly to include systematic social observations (term used by Clarke et al. 2010) or neighborhood audits (Badland et al. 2010) as well as habitat surveys (Olea and Mateo-Tomás 2013) and car surveys (Deus et al. 2015). If the abstract indicated that the article used GSV and used it as a tool for street-level observation, evaluated its use as a tool or contributed to the theory of its use as a tool for street-level observation, we obtained the full-text of the work.

Finally, articles were categorized into three categories as defined below. Articles that did not fit these three categories were excluded from the review.

- Examples: This category of articles included researchers who used GSV for some purpose in their research of local areas. Some of these articles also assessed the accuracy of this tool as part of their reported research but the main point of the article was to use GSV to examine the phenomena.
- Evaluations: Articles in this category include those that evaluate GSV as a tool for research as the main point of the article. Most of these studies compare GSV to other data collection methods but some evaluate GSV in other ways. Some researchers also included an application of the GSV measures.
- Theory: This category of articles is broad and included articles describing how GSV operates, how it mediates the experience of the world for the viewer, and potential pitfalls to using GSV in a research application.

As a result of this process, this paper reviews 125 works related to the use of GSV for street-level observation in research. The sources in this literature review are primarily from peer-reviewed publications as shown in Figure 2. Less than 15 percent of the works are from non-peer-reviewed sources with the largest source being theses and dissertations (6 percent). The universe of the works we reviewed is diverse. 49 works were examples of the use of GSV in research, 46 evaluated the use of GSV in research, and 31 explored theoretical issues related to the use of GSV in research. A complete listing of articles is located in Table 1, although the categories are not mutually exclusive.

Population of Articles

GSV began in 2007 and its use in research has been increasing since then. Figure 1 shows the frequency of articles published by year. Articles before 2010 explored the use of GSV in theory. A prescient article from 1998 explored the possibilities of web-based mapping for research in urban environments (Doyle, Dodge and Smith 1998). In 2010, 4 articles either evaluated or used GSV in research (Badland et al. 2010, Clarke et al. 2010, Curtis, Duval-Diop and Novak 2010, Mazerolle and Blaney 2010) in addition to 2 that were dedicated to theoretical issues (Anguelov et al. 2010; Bimber 2010). Since then its use has increased steadily across all three categories of articles. Employees of Google have also contributed to articles explaining the general and more technical aspects of how GSV works (Anguelov et al. 2010; Frome et al. 2009; Vincent 2007) which enhance the theory around its use as a tool of street-level observation.

GSV is available throughout North America, most of South America, and Europe (Germany and Austria are notable exceptions to the availability of GSV imagery in Europe). It is also available in many countries in Southeast Asia and the Pacific Islands such as Indonesia, Australia, and up the Pacific coast of Asia to Japan and South Korea. Most of the rest of Asia is not available in GSV with the exception of some parts of Russia and Mongolia. Most of Africa and the Middle East also do not have GSV imagery (Google, Inc. 2017). Given the availability of GSV, it is not surprising that the majority of the studies we have seen have been based on GSV imagery from the United States, Australia, and several countries in Europe. Our population of articles included 21 countries.

A wide-variety of disciplines have been using GSV, although it is most widely used in the health fields and the number of publications using GSV for street-level observation is increasing.

The publications in this review come from the fields of:

- Health
- Interdisciplinary
- Natural Environment
- Social Science
- Structural Environment
- Computer Science
- Humanities

Health fields, including public health and epidemiology, have been leaders in using GSV as a tool of street-level observation with some early and influential articles such as Badland et al. (2010) and Rundle et al. (2011). Figure 3 shows that 30 percent of the articles in this review are from the health fields. Papers from fields related to the natural environment such as geography and ecology comprise about 14 percent of the articles. Social science fields such as sociology and criminology comprised about the same percent of the articles (about 13 percent) as did the articles from structural environment fields such as architecture and urban design (about 11 percent). However, interdisciplinary works are very common (about 19 percent of the articles). The interdisciplinary articles generally draw from the fields listed above but more than one of them. For example, one article, Odgers et al. (2012), evaluated the use of GSV to systematically observe children's neighborhoods, crossing several social sciences. Another example is a recent article draws on the fields of forestry and urban design, evaluating GSV as an alternative to aerial photos in measuring tree cover (Jiang et al. 2017).

The majority of the papers were written by authors who only wrote a single paper about GSV or using GSV; however, there were two research groups that have written quite a few papers using GSV or evaluating it. Both research groups have also reviewed the literature, focusing on epidemiology literature (Bader, Mooney, Bennett and Rundle 2017; Charreire et al. 2014). One group of researchers called the Sustainable Prevention of Obesity Through Integrated Strategies (SPOTLIGHT) is a program of the European Commission. It has brought together interdisciplinary researchers from universities across the European Union to identify social factors that can reduce obesity (SPOTLIGHT n.d.). These papers (Bethlehem et al. 2014; Charreire et al. 2014; Compernolle et al. 2016; Edwards et al. 2013; Feuillet et al. 2016; Lakerveld et al. 2012; Mertens et al. 2017; Roda et al. 2016; Rutter, Glonti and Lakerveld 2016) focus on the development and implementation of a tool to quantify features of the streetscape that may be associated with obesity such as the presence of sidewalks and bike lanes. The second research group that has published several articles using or evaluating GSV is the Built Environment and Health Research Group at Columbia University. This interdisciplinary group of US-based researchers focuses on links between the built environment and a variety of health-related activities of individuals and groups (BEH Research Group 2017). These papers (Bader et al. 2015; Bader et al. 2017; Mooney et al. 2014; Mooney 2016; Quinn 2016; Rundle et al. 2011) develop an instrument to use GSV to quantify physical disorder on a street and relate those measures to pedestrian injury and other neighborhood-level health and safety outcomes.

How GSV is used in research

GSV has been used to observe a wide variety of social, spatial, and environmental phenomena. The conventional mode of observation that GSV is replacing is most commonly a walking-based survey. In this section we describe both the purpose of the research in which GSV was employed for street-level observation and the types of characteristics that GSV was used to observe. The purpose for observing the street varied. The most common reasons were to examine questions related to the lifestyle of local residents, assessments of the physical environment, crime and personal injury, and demographic characteristics. It was used to observe many different things in and adjacent to the street from car and bike lanes to animal habitats. The most common type of characteristic was the aesthetic of the street including how well the street and adjacent building were cared for and how the observer felt about the street environment.

The primary conventional mode of observation that GSV had the potential to replace was the in-person walking survey. This was the comparison mode of observation in about 73 percent of studies that compared GSV to a conventional mode of observation. This type of observation is done by a person or a pair of people with a checklist or other physical audit tool which they fill out as they walk up and down the street (Badland et al. 2010, Ben-Joseph et al. 2013, Berland and Lange 2017, Bethlehem et al. 2014, Clarke et al. 2014, Clews et al 2016, Edwards et al. 2013, Griew et al. 2013, Gullon et al. 2015, Kelly et al. 2013, Lee and Talen 2014, Less et al. 2015, Roda et al. 2016, Rundel et al. 2011). Four studies used an auto-based survey as the comparison mode of observation (Deus et al. 2015, Fleischhacker et al. 2012, Olea and Mateo Tomás 2013, Rousselet et al. 2013). One study used a bike-based survey (Vanwolleghem et al. 2014) as the comparison observational mode. A couple studies used GSV photos as an alternative to photographs (Carrasco-Hernandez, Smedley, and Webb 2014; Tongleamnak and Nagai 2017) or video (Wilson et al. 2012) made specifically for the research.

What GSV is used to research

Most articles using or evaluating GSV as a tool of street-level observation, were interested in measuring physical characteristics in order to better understand, measure, or characterize some other phenomena. About 14 percent of the articles focused on evaluating the use of GSV as a observational tool without relating it to other phenomena while the other 86 percent related it to some other physical characteristics, to lifestyle characteristics, to crime and bodily harm characteristics, or to demographic characteristics.

One of the most common purposes was to examine physical characteristics that could potentially be related to the lifestyle and decision-making activities of people living in the area. Researchers focused on relating the built environment to health outcomes (Bader et al. 2015; Quinn et al. 2016; Rundle et al. 2011; Vargo, Stone and Glanz 2012; Wu et al. 2014; Yamada-Rice 2011a), especially as it relates to older adults (Brookfield and Tilley 2016; Chudyk et al. 2014; Clarke and Gallagher 2013; Kim and Clarke 2015), and children (Carson and Janssen 2012; Odgers et al. 2012). Several researchers were interested in physical activity as it relates to health (Ben-Joseph et al. 2013; Comernolle et al. 2016; Griew et al. 2013; Kelly et al. 2014; Mooney et al. 2014) and, in particular, obesity (Bethlehem et al. 2014; Charreire et al. 2014; Roda et al. 2016). Many researchers were interested in transportation choice either motivated by health issues or urban design (Chiang, Sullivan and Larsen 2017; Evans-Cowley and Akar 2014; Gullón et al. 2015; Guo 2013a; Guo 2013b; Lee and Talen 2014; Mertens et al. 2017; Vanwolleghem et al. 2014; Yin and Wang 2016; Yin et al. 2015).

Studies characterized or evaluated the experience of the area (Adu-Brimpong et al. 2017; Bentley et al. 2016; Di Lillo et al. 2012; Pittam, O'Sullivan and O'Sullivan 2016) such as Yamada-Rice (2011b) who used images from GSV to compare the use of text and images in the urban environments of London and Tokyo. Others used the GSV images to create a typology of local areas or to create an index to characterize the local area (Ball 2014; Baltaretu et al. 2015; Cartlidge 2011; Doersch 2015; Feuillet et al. 2015; Hyam 2017; Li et al. 2015b; Wheeler 2015). Quite a few used GSV to assessed different types of infrastructure such as for energy (Abdulkarim et al. 2014; Carrasco-Hernandez, Smedley and Webb 2014), earthquake resilience (Bassett-Salom and Guardiolla-Villora 2014; Borelli et al. 2014; Curtis, Duval-Diop and Novak 2010; Saito and Spence 2011), drainage (Depwe and Rutherford 2015), wireless communication (Tongleamnak and Nagai 2017) signage (Wilson and Thompson 2015; Wilson, Thompson and Edwards 2015) and tax valuation (Sobczyk 2013). Four studies characterize the street-adjacent natural environment focusing on the flora (Mazerolle and Blaney 2010; Patel et al. 2011) or the fauna (Olea and Mateo-Tomás 2012; Rousselet et al. 2013).

Researchers used GSV to identify crime and personal injury. Most observed many different aspects of the street environment that influence crime in general (Curtis and Mills 2011; Curtis, A. et al. 2013; Kronkvist 2013; Maksymowicz & Tunikowski 2014). Some studies focused on a particular type of crime such as auto theft (Fujita 2011), residential burglary (Bates 2014), or drug possession (Marco et al. 2017). Others focused on a particular characteristic that contributes to crime such as alcohol (Clews et al. 2016; McKee et al. 2017). Several studies look at personal injury as a result of some event such as a vehicle collision (Hanson, Noland and Brown 2013; Johnson and Gabler 2016; Li, Zhang and Li 2015; Mooney et al. 2016).

Studies compared GSV images to census or community survey data in order to determine if there are visible signs of inequality, socioeconomic status, and gentrification. Income and income disparity was the primary characteristic of interest (Bader et al. 2017; Glaeser et al. 2014; Li et al. 2015a; Li et al. 2016; Salesses, Schechtner and Hidalgo 2013). Glaeser et al. (2015) used GSV in an attempt to predict income in areas where income is not well known. GSV was used to update descriptions of neighborhoods in previously conducted ethnographic studies (Bentley et al. 2016) and confirm neighborhood classifications on the Canadian Census (Gordon and Janzen 2013). Hwang and Sampson (2014) focused on racial inequality in cities and Naik et al. (2015) looked at many different demographic characteristics.

What GSV is used to measure

The papers focused on a broad variety of characteristics, shown in Figure 4. Some papers focused solely on one characteristic or set of characteristics while other covered characteristics in many of these categories. The majority of the articles measured the aesthetics of the area including building condition, the condition of the yard/garden, graffiti and litter. This category also includes studies that asked a large body of raters to make a sentimental judgement about the image such as whether it is beautiful or safe. Some of these characteristics were used to determine whether the neighborhood was in "disorder" or the degree of disorder. Disorder has been linked to poor health outcomes (Bader et al. 2015, Ben-Joseph et al. 2013, Clarke et al. 2010, Less et al. 2015, Mooney et al. 2014, Quinn et al. 2016, Rundle et al. 2011), crime (Bates 2014, Curtis and Mills 2011, Fujita 2011, Kronkvist 2013, Marco et al. 2017, McKee et al. 2017), and neighborhood social conditions (Carson and Janssen 2012, Hwang and Sampson 2014; Kim and Clarke 2015). In addition to building condition, graffiti and litter, other things that have been linked to disorder or neighborhood quality include the presence of alcohol containers or advertisements (Clews et al. 2016, Kim and Clarke 2015, Lee and Talen 2014).

Nearly half of the papers observed characteristics related to the adjacent land use. This includes whether properties adjacent to the street are being used for residential, commercial or industrial purposes but also studies that used GSV to document parkland or the geometry of buildings. Land use has been linked to many different phenomena including obesity (Bethlehem et al. 2014, Compernolle et al. 2016, Feuillet et al. 2016, Roda et al. 2016), physical activity (Adu-Brimpong et al. 2017, Chudyk et al. 2014, Compernolle et al. 2016, Gullón et al. 2015, Kelly et al. 2014, Kepper et al. 2017, Lee and Talen 2014, Vanwolleghem et al. 2014, Wilson et al. 2012, Yin and Wang 2016), crime (Bates 2014, Less et al. 2015, Maksymowicz, Tunikowski and Kosciuk 2014, McKee et al. 2017), and income and gentrification (Bentley et al. 2016, Glaeser et al. 2016, Hwang and Sampson 2014). Researchers have also linked land use characteristics to way-finding (Baltaretu et al. 2015), mental health (Wu et al. 2014), automobile usage (Guo 2013a, Guo 2013b), and population size (Gordon and Janzen 2013). Some studies classified or rated the area based on characteristics related to land use (Ball 2014, Cartlidge 2011, Saito and Spence 2011, Wheeler 2015). One looked at the building massing to create a 3-dimentional model of the street environment (Pittam, O'Sullivan and O'Sullivan 2016), something that Google is also working on (Anguelov et al. 2010).

Also common among the papers in this review was using GSV to document characteristics of the street itself that related to auto, bike, and pedestrian and pedestrian transportation. Auto-related characteristics included things like the number of lanes, presence of speed bumps, quality of the driving surface, and the presence of a parking lane (Abu-Brimpong et al. 2017, Bader et al. 2015, Badland et al. 2010, Baltaretu et al. 2015, Ben-Joseph et al. 2013, Bethlehem et al. 2014, Chiang, Sullivan and Larsen 2017, Chudyk et al. 2014, Clarke et al. 2010, Compernolle et al. 2016, Edwards et al. 2013, Feuillet et al. 2016, Fujita 2011, Griew et al. 2013, Gullón et al. 2015, Guo 2013a, Guo 2013b, Hanson, Noland and Brown 2013, Johnson and Gabker 2015, Kelly et al. 2013, Kelly et al. 2014, Kepper et al. 2017, Kim and Clarke 2015, Lee and Talen 2014, Maksymowicz, Tunikowski and Kosciuk 2014, McKee 2017, Mooney et al. 2016, Odgers et al. 2012, Rundle et al. 2011, Vanwolleghem et al. 2014, Wilson et al. 2012). One researcher used GSV specifically for observing drain locations (Depwe and Rutherford 2015). Pedestrian-related characteristics are generally similar but focused on the sidewalk. They include the presence or absence of a sidewalk, its width and the quality of the surface, and the presence of crosswalks and pedestrian signals (Abu-Brimpong et al. 2017, Bader et al. 2015, Badland et al. 2010, Ben-Joseph et al 2013, Bethlehem et al. 2014, Brookfield and Tilley 2016, Chiang, Sullivan and Larsen 2017, Chudyk et al. 2014, Clarke and Gallagher 2013, Compernolle et al.

2016, Edwards et al. 2013, Feuillet et al. 2016, Griew et al. 2013, Gullón et al. 2015, Hanson, Noland and Brown 2013, Kelly et al. 2013, Kelly et al. 2014, Kepper et al. 2017, Kim and Clarke 2015, Lee and Talen 2014, Maksymowicz, Tunikowski and Kosciuk 2014, McKee 2017, Mooney et al. 2016, Odgers et al. 2012, Roda et al. 2016, Rundle et al. 2011, Seekins, Rennie and Hammond 2014, Vanwolleghem et al. 2014, Vargo, Stone and Glanz 2012, Wilson et al. 2012). The most common bicycling-related characteristic was the presence or absence of a bike lane or other bike infrastructure. However, some studies looked at the biking characteristics similar to pedestrian and auto characteristics such as the biking surface (Abu-Brimpong et al. 2017, Bader et al. 2015, Badland et al. 2010, Ben-Joseph et al 2013, Bethlehem et al. 2014,.Compernolle et al. 2016, Feuillet et al. 2016, Gullón et al. 2015, Kelly et al. 2013, Kelly et al. 2014, Kepper et al. 2017, Maksymowicz, Tunikowski and Kosciuk 2014, Mertens et al. 2017, Odgers et al. 2012, Roda et al. 2016, Vanwolleghem et al. 2014, Wilson et al. 2012).

About a third of the studies used GSV to observe the natural environment. The focus of the papers ranged from the amount of open sky above a street (Carrasco-Hernandez, Smedley and Webb 2015; Tongleamnak and Nagai 2017, Yin and Wang 2016) to the amount of foliage on the street (Gleaser et al. 2015, Hyam 2017, Li et al. 2015a, Li et al. 2015b, Li et al. 2016, Li, Zhang and Li 2015, Wu et al. 2014). Some studies are interested in simply identifying and quantifying specific species in the environment (Berland and Lange 2017; Deus et al. 2015). But others are interested in aggregate characteristics of the natural environment such as the presence of street trees or shrubs (Clarke et al. 2010), the presence of grass buffers (Bader et al. 2015), or the presence of water features (Edwards et al. 2013).

Fewer studies looked at either signage or lighting. Some studies looked for specific signs such as no smoking signs (Wilson, Thompson and Edwards 2015; Wilson and Thompson 2015) while others looked at the total amount of signage (Yamada-Rice 2011a). Lighting was harder to estimate since virtually all GSV images are recorded during the day. Griew et al. (2013) measures lighting based on the presence of street lights and their spacing instead of based on the light emitted, which is a logical tactic when using GSV. A handful of studies looked at people and animals in GSV. The animals were not observed themselves, rather their nests were observed (Olea and Mateo-Tomás 2016, Rousselet et al. 2013). People, on the other hand were observed and counted through GSV (Bates 2014, Clews et al. 2016, Rundle et al. 2011, Yin et al. 2015).

Evaluation of GSV as a tool of street-level observation

Many researchers have evaluated the use of GSV as a tool of street-level observation. The most common way of evaluating it is to compare it to the conventional mode of observation, most often an in-person walking survey. The overall conclusion is that large, permanent features can be reliably observed in GSV while small, transient characteristics exhibit more variation from the conventional mode of observation; however, there is not consensus about exactly which objects fall into each category.

Drawing conclusions across all of the studies that evaluated GSV by comparing it to a conventional mode of observation is difficult because the methodology varied considerably between studies. The conventional mode of observation for most evaluative studies was a walking survey but the methodology of the walking survey varied quite a bit. Lee and Talen (2014) had surveyors walk in pairs, collaborating on one questionnaire and the in-person surveyors were different from those that did the survey through GSV. By contrast, Bethlehem et al. (2014) had individuals survey the streets in-person on their own and the same individuals completed the survey in GSV, using the same digital questionnaire both times. Rundle et al. (2011) compared the results from an earlier study of street segments to a survey of the same street segments by a research assistant a year later. Disregarding the inherent differences between raters, even if the three studies had been using the same questionnaire, one would expect different results from the comparison of the in-person survey and the GSV survey based only on the different methodology.

The questionnaires used in the studies also varied widely. Some studies used a previously validated instrument such as SPOTLIGHT (Bethlehem et al. 2014; Roda et al. 2016), SPACES (Badland et al. 2010), or the Active Neighborhood Checklist (Kelly et al. 2013; Wilson et al. 2012). It should be noted that each instrument focused on different sets of characteristics. For characteristics that are addressed in multiple surveys, they are recorded in different ways depending on the study. For example, both the SPOTLIGHT and SPACES instruments assess sidewalk condition. SPOTLIGHT asks the observer to assess the condition of the sidewalk based on three graduated categories (Bethlehem et al. 2014). SPACES asks a similar question about the smoothness of the path, also based on three categories but adds a fourth category to assess if the sidewalk is under construction (Pikora et al. 2000). These two could be comparable except that they give different descriptions of the type of sidewalk that falls in each of the three categories. In addition, SPACES also asks observers to provide more detailed questions about the path material and slope (Pikora et al. 2000). The Active Neighborhood Checklist, on the other hand, assesses sidewalk condition based on a series of yes/no questions about the continuity, width and bumps or cracks (Hoehner and Brownson 2011). While the different instruments address similar topics, the differences in the way they ask the questions make it difficult to compare the results across studies.

There are other parts of the survey that also impact the outcome and make it difficult to compare results across studies. How questions are asked can make a big difference in the results of the survey. Asking a question with a binary answer will certainly yield different results than asking for a count. Similarly, asking the observer to judge between "a little" and "a lot" means that different observers will return somewhat different results. The language used for the options may not be the same across surveys resulting in different interpretations by the observers even when the number of categories are the same. Given this variation, it is still striking that most of the surveys returned results that showed a general trend of similarity in results between in-person and GSV observations for large, permanent features and much less agreement for ephemeral things.

Charreire et al. (2014) reviewed 13 public health studies using GSV instead of an in-person survey of street conditions and found that there were "moderate to high levels of agreement...for items related to the land use dimension" (p. 5). They found high levels of agreement between in-person surveys and GSV surveys across studies for the presence of certain things such as sidewalks or bike lanes but low levels of agreement between the two modes for characteristics of them such as the slope, continuity or width. They also found weaker reliability between GSV and in-person surveys across studies for, "...items related to the dimension of safety and aesthetics linked to general aspects of streets, physical decay and disorder" (p. 7), such as the presence of trash, graffiti and building condition. In our wider survey of studies across more disciplines we found a similar general trend; however, there is considerable variation in findings between studies even when the general trend is similar.

Ben-Joseph, et al. (2013) found that GSV is useful, "for auditing street-level environments, but [is] less effective measuring temporal and fine-grain features" (p. 7). They could not identify any signs of disorder, such as liquor bottles, graffiti, garbage and needles, in GSV images even though they did find these things in in-person surveys in some areas. Similarly, Clews et al. (2016), who were only looking at alcohol-related phenomena in the environment, found 24 instances of alcohol-related litter in the in-person survey but only 1 in the GSV survey. In Bethlehem et al. (2014) the percent of agreement between the in-person and GSV surveys is quite high for the presence of graffiti (83 percent) and mediocre for the presence of litter (60 percent) but that is only because these are fairly rare events. When that is taken into account with a Kappa score, the level of agreement between the two modes of observation is low.

Trees (or the lack of them) are fairly permanent features in the urban environment. Berland and Lange (2017) found that 94 percent of the trees identified in the field matched trees identified in GSV with identical tree counts in 67 percent of the street segments surveyed. It is a fairly good agreement and some of the difference could be attributed to the difference in time between the in-person survey and when the GSV photographs were taken. Edwards et al. (2013) also found fairly high agreement in the number of trees counted in the in-person and GSV (87 percent agreement) however, the agreement between auditors observing the same area was fairly low (50 percent agreement). Ben-Joseph et al. (2013) asked if there were any trees present in the street segment surveyed (a yes/no question instead of a count) and had lower agreement between the in-person and GSV surveys (between 76 and 80 percent agreement, depending on where the trees were located).

Discussion

The comparison of GSV observations with in-person observations is helpful but not sufficient to understand the impact of this tool on research. We also need to understand whether GSV captures what the researcher is trying to measure and what the sources of measurement error are. The error sources may be somewhat similar to an in-person survey but may also be different because the interaction between the observer and the street is different. Measurement error in GSV can be tied to the time the images are taken, the point of view of the camera, the image quality, and the image processing. The first two, time and point of view can also be the source of error in the traditional survey methods, although, by using GSV the researcher has very limited control of those aspects of the research design. The later two, image quality and processing, are unique to this type of observation and leads to the question of whether the observation is biased by artifacts of the image production.

"...these technologies tell the "truth" of a given place only on the day…the Google Car…passes by" (Silbert 2016, p. 15). It could also be argued that an in-person survey also only captures a moment in time but that moment can more easily be chosen and quantified by the researcher. Google has begun dating the images in its database with the month and year the image was taken which helps to quantify the time error. However, "...we do not know the exact date and time at which the data were collected (only the month and year)" (Bader 2017, p. 36). The viewer is presented with the most recent image which may be only 6 months past or as far back as 2007. This time element may not have a big impact but in places that are changing rapidly or places that are making important changes even more slowly, such as a stigmatized neighborhood making economic strides, the difference in time can be important (Power et al. 2013).

If the location has been photographed multiple times, the viewer has the ability to navigate to older images of that location, although Google may remove older images at any time. Even if an overall street image is recorded multiple times, not every point on the street will be recorded multiple times. As the user navigates along the street, there may be date discontinuity. The images along the north half of a street may have been recorded in 2009 and the images from the south recorded in 2014. Or the data may jump back a forth between dates along its whole length. One research group tested how often the data changes on the GSV images over the course of street segments within a neighborhood (J.W. Curtis et al. 2013). They found that date discontinuity was prevalent in the US cities they tested. The samples they tested had between 20 and 135 points where the date changed along a road or 0.35 to 2.59 changes per kilometer of road (p. 6). This means that the observations are potentially coming from multiple years, even within one neighborhood. It can also mean that the observations are coming from different seasons. "Sometimes a street changes from summer at one end into winter at the other" (Haworth 2016, p. 442). Because Google now records the date on all of the GSV images, it is possible to quantify the error as long as the researcher is aware of these issues.

The point of view of the GSV camera is physically 2.5 meters above the ground (Li, Zhang and Li 2015). In most cases the camera is on the roadbed to the left or right of the centerline and this location is a different point of view from the traditional methods of observation. In addition, GSV cars are highly visible, not only because they have a camera attached to the top but also because they have flamboyant displays of the Google logo and branded designs. There are many examples in GSV photos of spontaneous reactions to the sighting of a GSV car and, less frequently, planned performances (Ingram and Rowland 2016). Observers surveying a street in-person may also inspire reactions but those reactions are likely to be different from the reactions to the GSV car. Google is encouraging users to take and upload their own 360° photos of places (French 2016) which introduces an intriguing option of choosing the point of view (and time) of the image, although these images currently tend to be of iconic locations.

In addition, "...political situations and military conflicts still set the limits for capturing the world as a whole today" (Bimber 2010, p. 23). Even within countries, places deemed less safe such as housing projects in Ireland (Power et al. 2013) or gated communities (Villar Lama and García Martín 2016) are not completely photographed. This can lead to an asymmetry in observation. Some studies excluded certain street segments that had been randomly sampled because they did not have GSV imagery. The omission of streets is not a random event; even without socio-political factors, Google prioritizes well-traveled streets over rural back roads or urban alleys. Places with roads too narrow for a GSV car must be photographed on foot, bicycle, or even snow mobile (Anguelov et al. 2010) which is done much less frequently.

The point of view, though fixed by the GSV camera (or a user's camera), is not the camera itself but the person viewing the results on a screen. That person must use his or her imagination to recreate the environment in his or her mind (Silbert 2016, Pink 2011). "It affords viewers possibilities to use their existing experiences of environments to sense what it might be or how it might feel to move through the 'real' locality represented on screen" (Pink 2011, p. 11). Lapenta (2011) relates the deprivation of a multidimensional sensory experience to the shadows in Plato's cave saying the images "are not reality, but only a projection on a screen" (p. 16). The experience of observing the street is mediated by the viewer's own experiences. If the viewer is not familiar with the place or has not walked the streets before, they may observe the GSV images differently from someone familiar with the area.

This recreation of reality can be the source of additional errors. The user must not only use his or her imagination to conceive what the area might be like, he or she must also imagine that a particular combination of pixels represents a tree or bicycle lane which is an important mental translation when decisions are being made based on the image. Harris (2015) questions the ethics of planners who use the tool to identify building code infractions as has become more and more common (e.g., Sobczyk 2013). Harris's objections stem primarily from privacy concerns as the people who own or occupy the places photographed do not give their consent. However, he also notes that the view through GSV is limited by the position of the camera and the limitations to interpreting traditional photography, giving "an 'allure of realism', which in turn risks undermining the sensible and appropriate use of visual imagery" (Harris 2015, p. 542). The process of viewers translating pixels into an image of the built environment is the precursor to the situation that many of the researchers found when they compared in-person observations to GSV observations: small things are difficult to identify. Even while GSV has increased the resolution of the photos since its debut in 2007 (Anguelov et al. 2010), it is still not high enough see something like a syringe on a sidewalk. While higher resolution can solve some issues related to translating the image into the lived environment, it cannot change a static image into a 3-dimensional experience of the space in motion (Pink 2011, Lapenta 2011). In GSV images, "distances are flattened and hollowed out, time is frozen, and the landscape becomes a tableau to be animated by the viewer's imagination alone." (Silbert 2016, p. 15).

And yet, it is not exactly like viewing a static photograph. While some researchers use a single view from the GSV experience (Evans-Cowley and Akar 2014, Li et al. 2015, Salesses 2012), most have the observer observe within the GSV navigation environment. "The 'picture bubble' is actually a Flash application that delivers a rich graphic experience, "...best experienced by rotating the view right or left 360 degrees or zooming in on details such as parking signs" (Vincent 2007, p. 119). As the observer moves the bubble around, the picture distorts in an imitation of reality. If the viewer is looking straight at a building, the vertical elements of the image, such as the sides of buildings will appear parallel but if the observer moves the bubble up to simulate looking up, the vertical elements will be distorted to converge at a vanishing point. For single-story buildings, this is not much of an issue but for tall buildings, the upper stories are distorted and often broken up between photographs from many points of view.

The distortions stem from the image creation process. The processing of images can introduce differences between the "real" and "photographed" environments that can lead to measurement errors. The 360 degree view at each point along the street is created using a "rosette" of cameras – 15 cameras mounted on a ball, each pointed 90 degrees from the tangent of the sphere (Anguelov et al. 2010). These images are projected onto a virtual spherical surface and merged together (Carrasco-Hernandez, Smedley, and Webb 2015, Vincent 2007). The result can have disruptions in the continuity of the image, such as where buildings do not quite line up or street poles appear multiple times or as half a pole. Some of the more dramatic results include pixelation and the wrong colors (Hotzel and Marie 2014), but even less dramatic results can cause the place to be perceived differently than it would be in person.

The stitching of images is not the only manipulation of the original 15 photographs as Google also blurs faces and license plates to protect the privacy of the people photographed. It does this through a complicated algorithm for detecting faces (Frome et al. 2009). Some faces and license plates are missed (false negatives) and some things are mistaken for faces or license plates (false positives). In an effort to blur all faces and license plates, GSV tends to have a lot of false positives (Frome et al. 2009). The result is that there are often blurred patches that are difficult to discern. The object may be clearer but more distant in another image from a little further down the street so the observer must use his or her imagination to discern what the blurred patch represents and whether it is of importance to his or her observation.

GSV "...challenges preexisting notions of privacy and prompts questions as to where the line ought to be drawn between what is considered public and private, as well as how far one's right to privacy regarding his or her own image extends" (Rakower 2011, p. 319). For the researcher, this is doubly important because of the need to protect research subjects. Harris (2015) summarizes the thoughts of one city planning professional, "...anyone can use it so it is legitimate for planning enforcement officers to use it too" (p. 538).

This is the approach that most researchers have taken as well. Because the images are accessible to the public, it must be ethical to use them for research purposes. The people in the GSV images have not consented to having their photograph taken (Elwood and Leszczynski 2011) and certainly not any secondary uses of their image such as participating in research. Even for those who do wish to have their image not blurred and made public in GSV, they do not have any recourse to request that.

Conclusion

The use of GSV in research has become widespread across many disciplines and is increasing, yet there are many unanswered questions about how to best use it in research. Many studies have concluded that it is comparable to in-person surveys for large, permanent characteristics, but the source of potential measurement errors is still poorly understood. The most clearly quantifiable source of error is the time the photograph was taken. This has become easier for the researcher to track now that Google publishes the month and year of the images; however, the researcher still has very little control over when the image is take or whether the image will remain accessible online. The point of view, in terms of the location of the camera, is consistent but similarly outside of the control of the researcher. The researcher may be able to control how the observer views the image but cannot control the reconstruction of the space that the observer makes in his or her mind. Finally, the image itself may introduce errors simply by being a flat image or through the processing of the image. The flat image obfuscates some things that would be clear in three dimensions, and the processing of the image introduces additional distortions that are not in the original photographs.

GSV has potential in aiding research. Its extensive reach across the globe (though by no means everywhere) allows observers to "see" environments they would not otherwise be able to because of the constraints of time and money. This means that researchers can potentially expand their observational locations at little cost. And yet, this very expansion could be biased by the limited availability of GSV images. The images are limited in location, but also in the ways detailed above: time, point of view, image quality and technology. Researchers need to address this bias and be careful about the population that they apply their findings to. They must weigh the cost effectiveness of using GSV against the lack of control they have over the images they use.

Table 1. All citations categorized by the type of article

	Example	Evaluation	Theory
1	Abdulkarim et al. 2014	Adu-Brimpong et al. 2017	Anguelov et al. 2010
2	Ball 2014	Bader et al. 2015	Bader et al. 2017
3	Baltaretu et al. 2015	Badland, et al. 2010	Bimber 2010
4	Basset-Salom & Guardiola-Villora 2014	Bates 2014	Doyle, Dodge and Smith 1998
5	Bentley et al. 2016	Ben-Joseph et al. 2013	Elwood and Leszczynski 2011
6	Borrelli et al. 2014	Berland and Lange 2017	French 2016
7	Brookfield and Tilley 2016	Bethlehem et al. 2014	Frome et al. 2009
8	Carson and Janssen 2012	Carrasco-Hernandez, Smedley and Webb 2014	Gibson 2014
9	Cartlidge 2011	Charreire et al. 2014	Glanz et al. 2016
10	Clarke and Gallagher 2013	Chiang, Sullivan & Larsen 2017	Harris 2015
11	Comernolle, et al. 2016	Chudyk et al. 2014	Haworth 2016
12	Curtis and Mills 2011	Clarke et al. 2010	Hoelzl and Marie 2014
13	Curtis, Duval-Diop and Novak 2010	Clews et al. 2016	Ingraham and Rowland 2016
14	Depwe and Rutherford 2015	Curtis, A. et al. 2013	Jiang et al. 2017
15	Di Lillo et al. 2012	Curtis, J.W. et al. 2013	Juhasz and Hochmair 2016
16	Doersch 2015	Deus et al. 2015	Lapenta 2011
17	Evans-Cowley and Akar 2014	Edwards et al. 2013	Lakerveld et al. 2012
18	Feuillet, et al. 2016	Fleischhacker et al. 2012	Meyer 2016
19	Fujita 2011	Goodspeed 2017	Pink 2011
20	Glaeser et al. 2015	Griew, et al. 2013	Power et al. 2013
21	Gordon and Janzen 2013	Gullón, et al. 2015	Rakower 2011
22	Guo 2013a	Hardion et al. 2016	Rutter, Glonti, & Lakerveld 2016
23	Guo 2013b	Kelly et al. 2013	Salesses 2012
24	Hanson, Noland and Brown 2013	Kepper et al. 2017	Schootman et al. 2016
25	Hwang and Sampson 2014	Kronkvist 2013	Silbert 2016
26	Hyam 2017	Lee & Talen 2014	Tickner 2016
27	Johnson and Gabler 2015	Less et al. 2015	Tsai and Chang 2013
28	Kelly et al. 2014	Li et al. 2015b	Uricchio 2011
29	Kim & Clarke 2015	Maksymowicz & Tunikowski 2014	Vandeviver 2014
30	Li et al. 2015a	Marco et al. 2017	Verhoeff 2012
31	Li et al. 2016	Mazerolle and Blaney 2010	Vincent 2007
32	Li, Zhang & Li 2015	Mooney et al. 2014	
33	McKee et al. 2017	Mygind et al. 2016	
34	Mertens et al. 2017	Odgers et al. 2012	
35	Mooney et al. 2016	Olea & Mateo-Tomas 2013	
36	Naik et al. 2015	Roda et al. 2016	
37	Patel et al. 2011	Rousselet et al. 2013	
38	Pittam, O'Sullivan and O'Sullivan 2016	Rundle et al. 2011	
39	Quinn et al. 2016	Seekins, Rennie and Hammond 2014	
40	Rossen, Pollack and Curriero 2012	Tongleamnak and Nagai 2017	
41	Saito & Spence 2011	Vanwolleghem et al. 2014	
42	Salesses, Schechtner and Hidalgo 2013	Wilson and Thompson 2015	
43	Sobczyk 2013	Wilson et al. 2012	
44	Vargo, Stone and Glanz 2012	Wilson, Thompson, & Edwards 2015	
45	Wheeler 2015	Wu et al. 2014	
46	Yamada-Rice 2011a		
47	Yamada-Rice 2011b		
48	Yin and Wang 2016		
49	Yin et al. 2015		

Figure 1. All citations by year of publication

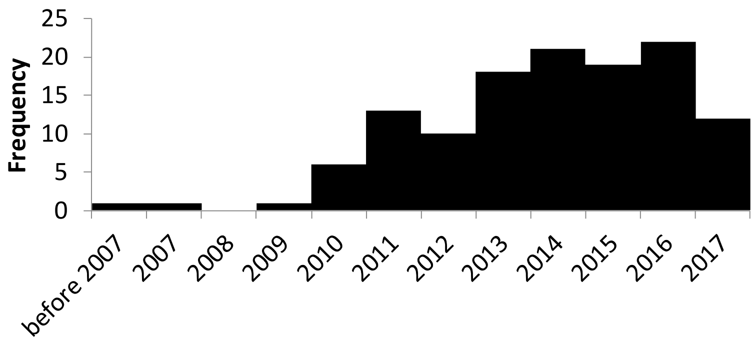


Figure 2. Papers by type of publication

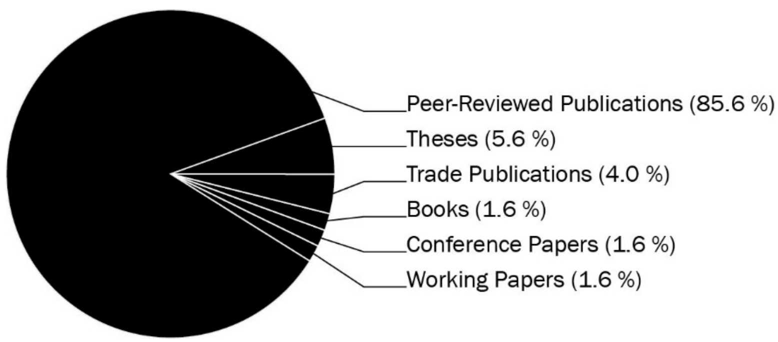


Figure 3. Papers by discipline

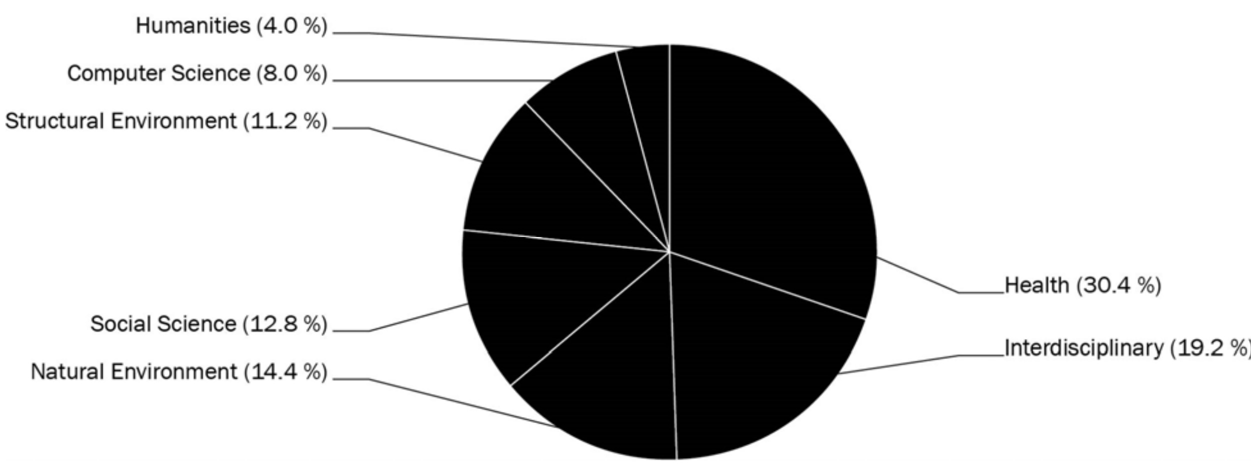
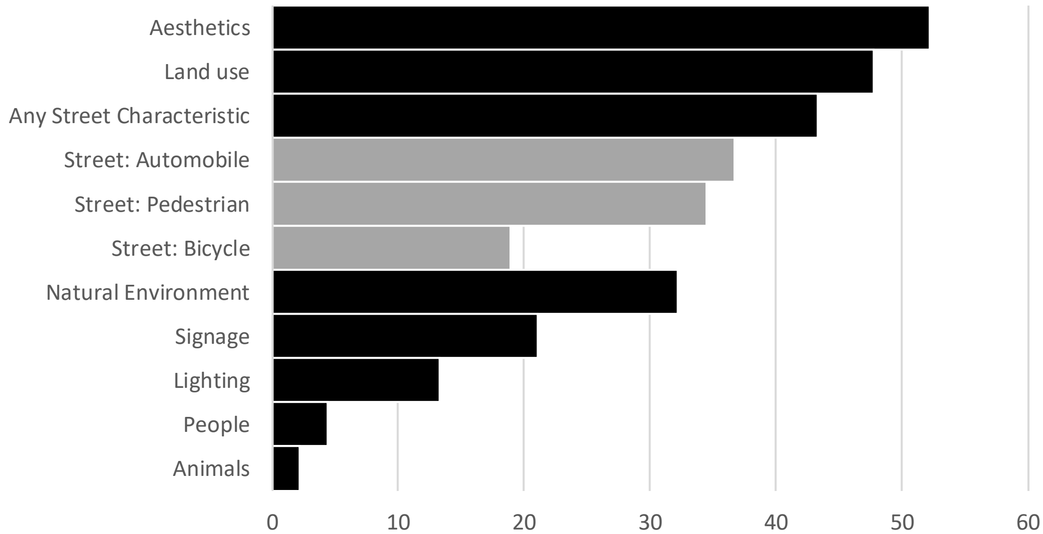


Figure 4. Percent of papers that made observations of types of street characteristics



Bibliography

Abdulkarim, B., Kamberov, R., & Hay, G. J. (2014). Supporting Urban Energy Efficiency with Volunteered Roof Information and the Google Maps API. *Remote Sensing*, 6(10), 9691–9711. https://doi.org/10.3390/rs6109691

Adu-Brimpong, J., Coffey, N., Ayers, C., Berrigan, D., Yingling, L. R., Thomas, S., … Powell-Wiley, T. M. (2017). Optimizing Scoring and Sampling Methods for Assessing Built Neighborhood Environment Quality in Residential Areas. *International Journal of Environmental Research and Public Health*, 14(3), 273. https://doi.org/10.3390/ijerph14030273

Anguelov, D., Dulong, C., Filip, D., Frueh, C., Lafon, S., Lyon, R., … Weaver, J. (2010). Google Street View: Capturing the World at Street Level. *Computer* (00189162), 43(6), 32–38.

Bader, M. D. M., Mooney, S. J., Lee, Y. J., Sheehan, D., Neckerman, K. M., Rundle, A. G., & Teitler, J. O. (2015). Development and Deployment of the Computer Assisted Neighborhood Visual Assessment System (CANVAS) to Measure Health-Related Neighborhood Conditions. *Health and Place*, 31, 163–172.

Bader, M. D. M., Mooney, S. J., Bennett, B., & Rundle, A. G. (2017). The Promise, Practicalities, and Perils of Virtually Auditing Neighborhoods Using Google Street View. *The ANNALS of the American Academy of Political and Social Science*, 669(1), 18–40. https://doi.org/10.1177/0002716216681488

Badland, H. M., Opit, S., Witten, K., Kearns, R. A., & Mavoa, S. (2010). Can Virtual Streetscape Audits Reliably Replace Physical Streetscape Audits? *Journal of Urban Health*, 87(6), 1007–1016. https://doi.org/10.1007/s11524-010-9505-x

Ball, J. (2014). Architectural Street Credibility: Reframing contemporary architecture to sidewalk level with images from Google Street View (PhD Dissertation). Arizona State University, Tempe, Ariz.

Baltaretu, A., Krahmer, E., & Maes, A. (2015). Improving Route Directions: The Role of Intersection Type and Visual Clutter for Spatial Reference. *Applied Cognitive Psychology*, 29(5), 647–660. https://doi.org/10.1002/acp.3145

Basset-salom, L., & Guardiola-víllora, A. (2014). Seismic performance of masonry residential buildings in Lorca's city centre, after the 11th May 2011 earthquake. *Bulletin of Earthquake Engineering*, 12(5), 2027–2048. https://doi.org/http://dx.doi.org.ezproxy.spu.edu/10.1007/s10518-013-9559-8

Bates, C. (2014). *Systematic social observation with virtual imagery: Urban density and residential burglary*. California State University, Long Beach. Retrieved from http://search.proquest.com/docview/1640916657

BEH Research Group. (2017, Oct. 1). Built environment and health research group – home. Accessed at https://beh.columbia.edu.

Ben-Joseph, E., Lee, J. S., Cromley, E. K., Laden, F., & Troped, P. J. (2013). Virtual and Actual: Relative Accuracy of On-Site and Web-based Instruments in Auditing the Environment for Physical Activity. *Health and Place*, 19(January), 138–150.

Bentley, G. C., McCutcheon, P., Cromley, R. G., & Hanink, D. M. (2016). Fitzgerald: A Return to the Neighborhood and Its Contemporary Structural and Geographical Contexts. *Professional Geographer*, 68(3), 414–426. https://doi.org/10.1080/00330124.2015.1102027

Berland, A., & Lange, D. A. (2017). Google Street View shows promise for virtual street tree surveys. *Urban Forestry & Urban Greening*, 21, 11–15. https://doi.org/10.1016/j.ufug.2016.11.006

Bethlehem, J. R., Mackenbach, J. D., Ben-Rebah, M., Compernolle, S., Glonti, K., Bárdos, H., … Lakerveld, J. (2014). The SPOTLIGHT virtual audit tool: a valid and reliable tool to assess obesogenic characteristics of the built environment. *International Journal of Health Geographics*, 13. https://doi.org/10.1186/1476-072X-13-52

Bimber, O. (2010). Capturing the World. *Computer* (00189162), 43(6), 22–23.

Borrelli, L., Antronico, L., Gullà, G., & Sorriso-Valvo, G. M. (2014). Geology, geomorphology and dynamics of the 15 February 2010 Maierato landslide (Calabria, Italy). *Geomorphology*, 208, 50–73. https://doi.org/10.1016/j.geomorph.2013.11.015

Brookfield, K., & Tilley, S. (2016). Using Virtual Street Audits to Understand the Walkability of Older Adults' Route Choices by Gender and Age. *International Journal of Environmental Research and Public Health*, 13(11), 1061. https://doi.org/10.3390/ijerph13111061

Carrasco-Hernandez, R., Smedley, A. R. D., & Webb, A. R. (2015). Using urban canyon geometries obtained from Google Street View for atmospheric studies: Potential applications in the calculation of street level total shortwave irradiances. *Energy & Buildings*, 86, 340–348. https://doi.org/10.1016/j.enbuild.2014.10.001

Carson, V., & Janssen, I. (2012). Neighborhood disorder and screen time among 10-16 year old Canadian youth: A cross-sectional study. *The International Journal of Behavioral Nutrition and Physical Activity*, 9, 66. https://doi.org/10.1186/1479-5868-9-66

Cartlidge, N. (2011). Typologies of Urban Beach Precincts of the Gold Coast, Australia. Spaces & Flows: An *International Journal of Urban & Extra Urban Studies*, 1(1), 185–202. https://doi.org/10.18848/2154-8676/CGP/v01i01/53754

Charreire, H., Mackenbach, J. D., Ouasti, M., Lakerveld, J., Compernolle, S., Ben-Rebah, M., … Oppert, J.-M. (2014). Using remote sensing to define environmental characteristics related to physical activity and dietary behaviours: A systematic review (the SPOTLIGHT project). *Health & Place*, 25, 1–9.

Chiang, Y.-C., Sullivan, W., & Larsen, L. (2017). Measuring Neighborhood Walkable Environments: A Comparison of Three Approaches. *International Journal of Environmental Research and Public Health*, 14(6), 593. https://doi.org/10.3390/ijerph14060593

Chudyk, A. M., Winters, M., Gorman, E., McKay, H. A., & Ashe, M. C. (2014). Agreement between Virtual and In-the-Field Environment Audits of Assisted Living Sites. *Journal of Aging and Physical Activity*, 22(3), 414–420. https://doi.org/10.1123/JAPA.2013-0047

Clarke, P., & Gallagher, N. A. (2013). Optimizing Mobility in Later Life: The Role of the Urban Built Environment for Older Adults Aging in Place. *Journal of Urban Health*, 90(6), 997–1009. https://doi.org/10.1007/s11524-013-9800-4

Clarke, P., Ailshire, J., Melendez, R., Bader, M., & Morenoff, J. (2010). Using Google Earth to Conduct a Neighborhood Audit: Reliability of a Virtual Audit Instrument. *Health & Place*, 16(6), 1224–1229. https://doi.org/10.1016/j.healthplace.2010.08.007

Clews, C., Brajkovich-Payne, R., Dwight, E., Ahmad Fauzul, A., Burton, M., Carleton, O., … Thomson, G. (2016). Alcohol in urban streetscapes: a comparison of the use of Google Street View and on-street observation. *BMC Public Health*, 16, 442. https://doi.org/10.1186/s12889-016-3115-9

Compernolle, S., Cocker, K. D., Roda, C., Oppert, J.-M., Mackenbach, J. D., Lakerveld, J., … Group, W. S. (2016). Physical Environmental Correlates of Domain-Specific Sedentary Behaviours across Five European Regions (the SPOTLIGHT Project). *PLOS ONE*, 11(10), e0164812. https://doi.org/10.1371/journal.pone.0164812

Curtis, A., & Mills, J. W. (2011). Crime in Urban Post-Disaster Environments: A Methodological Framework from New Orleans. *Urban Geography*, 32(4), 488–510. https://doi.org/10.2747/0272-3638.32.4.488

Curtis, A., Curtis, J. W., Kennedy, S. W., Kulkarni, A., & Auer, T. (2013). A methodology for assessing dynamic fine scale built environments and crime: A case study of the lower 9th ward after Hurricane Katrina. In M. Leitner (Ed.), *Crime Modeling and Mapping Using Geospatial Tenologies* (Vol. 8, pp. 203–225). New York: Springer.

Curtis, A., Duval-Diop, D., & Novak, J. (2010). Identifying spatial patterns of recovery and abandonment in the Post-Katrina holy cross neighborhood of New Orleans. *Cartogr. Geogr. Inf. Sci Cartography and Geographic Information Science*, 37(1), 45–56.

Curtis, J. W., Curtis, A., Mapes, J., Szell, A. B., & Cinderich, A. (2013). Using google street view for systematic observation of the built environment: analysis of spatio-temporal instability of imagery dates. *International Journal of Health Geographics*, 12(1), 1–18. https://doi.org/10.1186/1476-072X-12-53

Depwe, E. E., & Rutherford, C. (2015). *Extracting curbside storm drain locations from street-level images*. Urbana, Ill.: University of Illinois at Urbana-Champaign. http://hdl.handle.net/2142/88213

Deus, E., Silva, J. S., Catry, F. X., Rocha, M., & Moreira, F. (2015). Google Street View as an alternative method to car surveys in large-scale vegetation assessments. *Environmental Monitoring And Assessment*, 188(10), 560–560. https://doi.org/10.1007/s10661-016-5555-1

Di Lillo, A., Daptardar, A., Thomas, K., Storer, J. A., & Motta, G. (2012). Compression-Based Tools for Navigation with an Image Database. *Algorithms*, 5(1), 1–17. https://doi.org/10.3390/a5010001

Doersch, C., Singh, S., Gupta, A., Sivic, J., & Efros, A. A. (2015). What Makes Paris Look Like Paris? *Communications of the ACM*, 58(12), 103–110. https://doi.org/10.1145/2830541

Doyle, S., Dodge, M., & Smith, A. (1998). The potential of Web-based mapping and virtual reality technologies for modelling urban environments. *CEUS Computers, Environment and Urban Systems*, 22(2), 137–155.

Edwards, N., Hooper, P., Trapp, G. S. A., Bull, F., Boruff, B., & Giles-Corti, B. (2013). Development of a Public Open Space Desktop Auditing Tool (POSDAT): A remote sensing approach. *Applied Geography*, 38, 22–30. https://doi.org/10.1016/j.apgeog.2012.11.010

Elwood, S., & Leszczynski, A. (2011) Privacy, reconsidered: New representations, data practices, and the geoweb, *Geoforum*, 42(1), pp. 6–15. doi:10.1016/j.geoforum.2010.08.003."

Evans-Cowley, J., & Akar, G. (2014). StreetSeen Visual Survey Tool for Determining Factors That Make a Street Attractive for Bicycling. Transportional Research Record: *Journal of the Transportation Research Board*, 2468, 19–27. https://doi.org/http://dx.doi.org/10.3141/2468-03

Feuillet, T., Charreire, H., Roda, C., Ben Rebah, M., Mackenbach, J. D., Compernolle, S., … Oppert, J.-M. (2016). Neighbourhood typology based on virtual audit of environmental obesogenic characteristics. *Obesity Reviews*, 17, 19–30. https://doi.org/10.1111/obr.12378

Fleischhacker, S. E., Rodriguez, D. A., Evenson, K. R., Henley, A., Gizlice, Z., Soto, D., & Ramachandran, G. (2012). Evidence for validity of five secondary data sources for enumerating retail food outlets in seven American Indian Communities in North Carolina. *International Journal of Behavioral Nutrition and Physical Activity*, 9, 137. https://doi.org/10.1186/1479-5868-9-137

French, J. (2016). How we do it. *Planetarian*, 45(2), 58–58.

A. Frome, G. Cheung, A. Abdulkader, M. Zennaro, B. Wu, A. Bissacco, H. Adam,H. Neven, L. Vincent, Large-scale privacy protection in Google Street View,in: Computer Vision, *2009 IEEE 12th International Conference on IEEE*, 2009,pp. 2373–2380.

Fujita, S. (2011). *Why are older cars stolen?: examining motive, availability, location, and security* (PhD Disseration). Rutgers University, New Brunswick, NJ. Retrieved from https://rucore.libraries.rutgers.edu/rutgers-lib/36286/

Gibson, R. (2014). Narrative Hunger: GIS Mapping, Google Street View and the Colonial Prospectus. *Cultural Studies Review; Carleton*, 20(2), 250–265.

Glaeser, E. L., Kominers, S. D., Luca, M., & Naik, N. (2015). *Big Data and Big Cities: The Promises and Limitations of Improved Measures of Urban Life* (Working Paper No. 21778). National Bureau of Economic Research. https://doi.org/10.3386/w21778

"Glanz, K., Handy, S. L., Henderson, K. E., Slater, S. J., Davis, E. L., & Powell, L. M. (2016). Built environment assessment: Multidisciplinary perspectives. *SSM - Population Health*, 2, 24–31. https://doi.org/10.1016/j.ssmph.2016.02.002

Goodspeed, R. (2017). Research note: An evaluation of the Elo algorithm for pairwise visual assessment surveys. *Landscape & Urban Planning*, 157, 131–137. https://doi.org/10.1016/j.landurbplan.2016.06.009

Gordon, D. L. A., & Janzen, M. (2013). Suburban Nation? Estimating the Size of Canada's Suburban Population. *Journal of Architectural & Planning Research*, 30(3), 197–220.

Griew, P., Hillsdon, M., Foster, C., Coombes, E., Jones, A., & Wilkinson, P. (2013). Developing and testing a street audit tool using Google Street View to measure environmental supportiveness for physical activity. *International Journal of Behavioral Nutrition & Physical Activity*, 10, 103–109. https://doi.org/10.1186/1479-5868-10-103

Gullón, P., Badland, H. M., Alfayate, S., Bilal, U., Escobar, F., Cebrecos, A., … Franco, M. (2015). Assessing Walking and Cycling Environments in the Streets of Madrid: Comparing On-Field and Virtual Audits. *Journal of Urban Health*, 92(5), 923–939. https://doi.org/http://dx.doi.org.ezproxy.spu.edu/10.1007/s11524-015-9982-z

Guo, Z. (2013). Residential Street Parking and Car Ownership. *Journal of the American Planning Association*, 79(1), 32–48. https://doi.org/10.1080/01944363.2013.790100

Guo, Z. (2013). Home parking convenience, household car usage, and implications to residential parking policies. *Transport Policy*, 29, 97–106. https://doi.org/10.1016/j.tranpol.2013.04.005

Hanson, C. S., Noland, R. B., & Brown, C. (2013). The severity of pedestrian crashes: an analysis using Google Street View imagery. *Journal of Transport Geography*, 33, 42–53. https://doi.org/10.1016/j.jtrangeo.2013.09.002

Hardion, L., Leriche, A., Schwoertzig, E., & Millon, A. (2016). Species Distribution 2.0: An Accurate Time- and Cost-Effective Method of Prospection Using Street View Imagery. *Plos One*, 11(1), e0146899–e0146899. https://doi.org/10.1371/journal.pone.0146899

Harris, N. (2015). The Use of Surveillance Technologies in Planning Enforcement. *Planning Practice & Research*, 30(5), 528–547. https://doi.org/10.1080/02697459.2015.1076133

Haworth, L. (2016). 34 Ways to Coca-Cola 34 Walking Guides to 34 Bristols. *ACME: An International E-Journal for Critical Geographies*, 15(2), 440–481.

Hoelzl, I., & Marie, R. (2014). Google Street View: navigating the operative image. *Visual Studies*, 29(3), 261–271. https://doi.org/10.1080/1472586X.2014.941559

Hwang, J., & Sampson, R. J. (2014). Divergent Pathways of Gentrification Racial Inequality and the Social Order of Renewal in Chicago Neighborhoods. *American Sociological Review*, 79(4), 726–751. https://doi.org/10.1177/0003122414535774

Hyam, R. (2017). Automated Image Sampling and Classification Can Be Used to Explore Perceived Naturalness of Urban Spaces. *PLoS ONE*, 12(1), 1–10. https://doi.org/10.1371/journal.pone.0169357

Ingraham, C., & Rowland, A. (2016). Performing Imperceptibility: Google Street View and the Tableau Vivant. *Surveillance & Society*, 14(2), 211–226.

Jiang, B., Brian Deal, HaoZhi Pan, Linda Larsen, Chung-Heng Hsieh, Chun-Yen Chang, & William C. Sullivan. (2017). Remotely-sensed imagery vs. eye-level photography: Evaluating associations among measurements of tree cover density. *Landscape and Urban Planning*, 157, 270–281. https://doi.org/10.1016/j.landurbplan.2016.07.010

Johnson, N. S., & Gabler, H. C. (2015). Injury Outcome in Crashes with Guardrail End Terminals. *Traffic Injury Prevention*, 16(2), S103–S108. https://doi.org/10.1080/15389588.2015.1065976

Juhász, L., & Hochmair, H. H. (2016). User Contribution Patterns and Completeness Evaluation of Mapillary, a Crowdsourced Street Level Photo Service. *Transactions in GIS*, 20(6), 925–947. https://doi.org/10.1111/tgis.12190

Kelly, C., Wilson, J., Baker, E., Miller, D., & Schootman, M. (2013). Using Google Street View to Audit the Built Environment: Inter-rater Reliability Results (No. 8836612) (pp. 108–112). *Springer Science & Business Media B.V.* Retrieved from http://ezproxy.spu.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&AuthType=ip&db=a9h&AN=85300224&site=ehost-live

Kelly C, Wilson JS, Schootman M, Clennin M, Baker EA, Miller DK. The built environment predicts observed physical activity. *Frontiers in Public Health*. 2014;2:52.

Kelly, C., Wilson, J. S., Schootman, M., Clennin, M., Baker, E. A., & Miller, D. K. (2014). The Built Environment Predicts Observed Physical Activity. *Frontiers in Public Health*, 2. https://doi.org/10.3389/fpubh.2014.00052

Kepper, M. M., Sothern, M. S., Theall, K. P., Griffiths, L. A., Scribner, R. A., Tseng, T.-S., … Broyles, S. T. (2017). A Reliable, Feasible Method to Observe Neighborhoods at High Spatial Resolution. *American Journal of Preventive Medicine*, 52, S20–S30. https://doi.org/10.1016/j.amepre.2016.06.010

Kim, M., & Clarke, P. (2015). Urban social and built environments and trajectories of decline in social engagement in vulnerable elders: Findings from Detroit's Medicaid home and community-based Waiver population. Research on Aging, 37(4), 413–435. https://doi.org/10.1177/0164027514540687

Kronkvist, K. (2013). Systematic Social Observation of Physical Disorder in Inner-City Urban Neighborhoods Through Google Street View: The Correlation Between Virtually Observed Physical Disorder, Self-Reported Disorder and Victimization of Property Crimes (Master thesis). Malmö University, Malmö, Sweden. Retrieved from https://dspace.mah.se/handle/2043/15962

Lakerveld J, Brug J, Bot S et al. Sustainable prevention of obesity through integrated strategies: the SPOTLIGHT project's conceptual framework and design. BMC Public Health 2012; 12: 793.

Lapenta, F. (2011). Geomedia: on location-based media, the changing status of collective image production and the emergence of social navigation systems. *Visual Studies*, 26(1), 14–24. https://doi.org/10.1080/1472586X.2011.548485

Lee, S., & Talen, E. (2014). Measuring Walkability: A Note on Auditing Methods. *Journal of Urban Design*, 19(3), 368–388. https://doi.org/10.1080/13574809.2014.890040

Less, E. L., McKee, P., Toomey, T., Nelson, T., Erickson, D., Xiong, S., & Jones-Webb, R. (2015). Matching study areas using Google Street View: A new application for an emerging technology. *Evaluation and Program Planning*, 53, 72–79. https://doi.org/http://dx.doi.org.ezproxy.spu.edu/10.1016/j.evalprogplan.2015.08.002

Li, X., Zhang, C., Li, W., Kuzovkina, Y. A., & Weiner, D. (2015). Who lives in greener neighborhoods? The distribution of street greenery and its association with residents' socioeconomic conditions in Hartford, Connecticut, USA. *Urban Forestry & Urban Greening*, 14(4), 751–759. https://doi.org/10.1016/j.ufug.2015.07.006

Li, X., Zhang, C., Li, W., Ricard, R., Meng, Q., & Zhang, W. (2015). Assissing street-level urban greenery using Google Street View and a modified green view index. *Urban Forestry and Urban Greening*, 14, 675–685. http://dx.doi.org/10.1016/j.ufug.2015.06.006 1618-8667/

Li, X., Zhang, C., Li, W., & Kuzovkina, Y. A. (2016). Environmental inequities in terms of different types of urban greenery in Hartford, Connectict. *Urban Forestry & Urban Greening*, 18, 163–172.

Li, X., Zhang, C., & Li, W. (2015). Does the Visibility of Greenery Increase Perceived Safety in Urban Areas? Evidence from the Place Pulse 1.0 Dataset. *ISPRS International Journal of Geo-Information*, 4(3), 1166–1183. https://doi.org/10.3390/ijgi4031166

Maksymowicz, K., Tunikowski, W., & Kościuk, J. (2014). Crime event 3D reconstruction based on incomplete or fragmentary evidence material - Case report. *Forensic Science International*, 242, e6–e11. https://doi.org/10.1016/j.forsciint.2014.07.004

Marco, M., Gracia, E., Martín-Fernández, M., & López-Quílez, A. (2017). Validation of a Google Street View-Based Neighborhood Disorder Observational Scale. *Journal of Urban Health*, 94(2), 190–198. https://doi.org/10.1007/s11524-017-0134-5

Mazerolle, D., & Blaney, S. (2010). Google Street View: a new online tool with potential application to roadside invasive species detection and monitoring. In E. Rindos (Ed.), *5th Biennial Weeds Across Borders Conference*, Shepherdstown, USA, 2010 (pp. 77–83).

"McKee, P., Erickson, D. J., Toomey, T., Nelson, T., Less, E. L., Joshi, S., & Jones-Webb, R. (2017). The Impact of Single-Container Malt Liquor Sales Restrictions on Urban Crime. *Journal of Urban Health*, 94(2), 289–300. https://doi.org/10.1007/s11524-016-0124-z

Mertens, L., Compernolle, S., Deforche, B., Mackenbach, J. D., Lakerveld, J., Brug, J., … Van Dyck, D. (2017). Built environmental correlates of cycling for transport across Europe. *Health & Place*, 44, 35–42. https://doi.org/10.1016/j.healthplace.2017.01.007

Mooney, S. J., Bader, M. D. M., Lovasi, G. S., Neckerman, K. M., Teitler, J. O., & Rundle, A. G. (2014). Validity of an Ecometric Neighborhood Physical Disorder Measure Constructed by Virtual Street Audit. *American Journal of Epidemiology*, 180(6), 626–635. https://doi.org/10.1093/aje/kwu180

Mooney, S. J., DiMaggio, C. J., Lovasi, G. S., Neckerman, K. M., Bader, M. D. M., Teitler, J. O., … Rundle, A. G. (2016). Use of Google Street View to Assess Environmental Contributions to Pedestrian Injury. *American Journal of Public Health*, 106(3), 462–469. https://doi.org/10.2105/AJPH.2015.302978

Mygind, L., Bentsen, P., Badland, H., Edwards, N., Hooper, P., & Villanueva, K. (2016). Public open space desktop auditing tool—Establishing appropriateness for use in Australian regional and urban settings. *Urban Forestry & Urban Greening*, 20, 65–70. https://doi.org/10.1016/j.ufug.2016.08.001

Naik, N., Kominers, S. D., Rasker, R., Glaeser, E., & Hidalgo, C. A. (2015). *Do people shape cities or do cities shape people? The co-evolution of hysical, social and economic change in five major US Cities* (NBER Working Papers No. W21620) (p. 38). Cambridge, Mass.: National Bureau of Economic Research. Retrieved from http://www.nber.org/papers/w21620

Odgers, C. L., Caspi, A., Bates, C. J., Sampson, R. J., & Moffitt, T. E. (2012). Systematic social observation of children's neighborhoods using Google Street View: a reliable and cost-effective method. *Journal of Child Psychology & Psychiatry*, 53(10), 1009–1017. https://doi.org/10.1111/j.1469-7610.2012.02565.x

Olea, P. P., & Mateo-Tomás, P. (2013). Assessing Species Habitat Using Google Street View: A Case Study of Cliff-Nesting Vultures. PLOS ONE, 8(1), e54582. https://doi.org/10.1371/journal.pone.0054582

R. Patel, N. Warren, M. Williams, E. Chen, X. Xu, *An Investigation of Urban Agriculture on Residential Blocks in Vancouver*, EOSC 448E/ENVR400 Undergraduate Essay, Environmental Science Undergraduate ResearchPapers and Reports, University of British Columbia, Vancouver, 2011,https://circle.ubc.ca/handle/2429/38881.

Pink, S. (2011). Sensory digital photography: re-thinking "moving" and the image. *Visual Studies*, 26(1), 4–13. https://doi.org/10.1080/1472586X.2011.548484

Pittam, J., O'Sullivan, P. D., & O'Sullivan, G. (2016). A remote measurement and mapping technique for orderly rapid aggregation of building stock geometry. *Automation in Construction*, 71, 382–397. https://doi.org/10.1016/j.autcon.2016.08.013

Power, M. J., Neville, P., Devereux, E., Haynes, A., & Barnes, C. (2013). "Why bother seeing the world for real?": Google Street View and the representation of a stigmatised neighbourhood. *New Media & Society*, 15(7), 1022–1040. https://doi.org/10.1177/1461444812465138

Quinn, J. W., Mooney, S. J., Sheehan, D. M., Kaufman, T. K., Lovasi, G. S., Rundle, A. G., … Bader, M. D. M. (2016). Neighborhood physical disorder in New York City. *Journal of Maps*, 12(1), 53–60. https://doi.org/10.1080/17445647.2014.978910

Rakower, L. H. (2011). Blurred Line: Zooming in on Google Street View and the Global Right to Privacy. *Brooklyn Journal of International Law*, 37(1), 317–347.

Roda, C., Charreire, H., Feuillet, T., Mackenbach, J. D., Compernolle, S., Glonti, K., … Oppert, J.-M. (2016). Mismatch between perceived and objectively measured environmental obesogenic features in European neighbourhoods. *Obesity Reviews*, 17, 31–41. https://doi.org/10.1111/obr.12376

Rossen, L.M., Pollack, K.M., Curriero, F.C., 2012. Verification of retail food outlet location data from a local health department using ground-truthing and remote-sensing technology: assessing differences by neighborhood characteristics. *Health Place* 18, 956–962.

Rousselet, J., Imbert, C.-E., Dekri, A., Garcia, J., Goussard, F., Vincent, B., … Rossi, J.-P. (2013). Assessing Species Distribution Using Google Street View: A Pilot Study with the Pine Processionary Moth. *PLOS ONE*, 8(10), e74918. https://doi.org/10.1371/journal.pone.0074918

Rundle, A. G., Bader, M. D. M., Richards, C. A., Neckerman, K. M., & Teitler, J. O. (2011). Using Google Street View to Audit Neighborhood Environments. *American Journal of Preventive Medicine*, 40(1), 94–100. https://doi.org/10.1016/j.amepre.2010.09.034

Rutter, H., Glonti, K., & Lakerveld, J. (2016). The way ahead: where next for research into obesogenic environments? *Obesity Reviews*, 17, 108–109. https://doi.org/10.1111/obr.12382

Saito, K., & Spence, R. (2011). Mapping urban building stocks for vulnerability assessment – preliminary results. *International Journal of Digital Earth*, 4, 117–130. https://doi.org/10.1080/17538947.2010.513114

Salesses, M. P. (2012). *Place Pulse : Measuring the collaborative image of the city*. Thesis, Massachusetts Institute of Technology.

Salesses, P., Schechtner, K., & Hidalgo, C. A. (2013). The collaborative image of thecity: mapping the inequality of urban perception. *PloS One*, 8(7).

Schootman, M., Nelson, E. J., Werner, K., Shacham, E., Elliott, M., Ratnapradipa, K., … McVay, A. (2016). Emerging technologies to measure neighborhood conditions in public health: implications for interventions and next steps. *International Journal of Health Geographics*, 15, 1–9. https://doi.org/10.1186/s12942-016-0050-z

Seekins, T., Rennie, B., & Hammond, J. (2014). Part Ii: Theoretical and Methodological Approaches to Environment: Exploring the Feasibility of Using "Google Street View" to Assess the Accessibility of Community Environments: Developing Definitions and Observational Protocol for Image Recognition and Classification. *Research in Social Science & Disability*, 8, 123–139. https://doi.org/10.1108/S1479-354720140000008007

Silbert, S. (2016). Mapping Meaning On Ways of Wayfinding. *Metalsmith*, 36(4), 12–17.

Sobczyk, M. (2013). In Lithuania, the Tax Man Cometh Right After the Google Car Passeth. (Cover story). *Wall Street Journal* - Eastern Edition, 261(126), A1–A10.

SPOTLIGHT. (n.d.). Sustainable Prevention of obesity through integrated strategies – Home. Accessed at https://www.spotlightproject.eu.

Tickner, A., atickner@lib.msu.ed. (2016). The Liquid Galaxy in the library. *Library Hi Tech*, 34(4), 657–668. https://doi.org/10.1108/LHT-04-2016-0045

Tongleamnak, S., & Nagai, M. (2017). Simulation of GNSS Availability in Urban Environments Using a Panoramic Image Dataset. *International Journal of Navigation & Observation*, 1–12. https://doi.org/10.1155/2017/8047158

Tsai, V. J. D., & Chang, C.-T. (2013). Three-dimensional positioning from Google street view panoramas. *IET Image Processing*, 7(3), 229–239. https://doi.org/10.1049/iet-ipr.2012.0323

Uricchio, W. (2011). The algorithmic turn: photosynth, augmented reality and the changing implications of the image. Visual Studies, 26(1), 25–35. https://doi.org/10.1080/1472586X.2011.548486

Vandeviver, C. (2014). Applying Google Maps and Google Street View in criminological research. *Crime Science*, 3(1), 13. https://doi.org/10.1186/s40163-014-0013-2

Vanwolleghem, G., Van Dyck, D., Ducheyne, F., De Bourdeaudhuij, I., & Cardon, G. (2014). Assessing the environmental characteristics of cycling routes to school: a study on the reliability and validity of a Google Street View-based audit. *International Journal of Health Geographics*, 13(1), 1–17. https://doi.org/10.1186/1476-072X-13-19

Vargo, J., Stone, B., & Glanz, K. (2012). Google Walkability: A New Tool for Local Planning and Public Health Research? *Journal of Physical Activity and Health*, 9(5), 689–697. https://doi.org/10.1123/jpah.9.5.689

Verhoeff, N. (2012). *MediaMatters : Mobile Screens : The Visual Regime of Navigation*. Amsterdam, NL: Amsterdam University Press. Retrieved from http://site.ebrary.com/lib/alltitles/docDetail.action?docID=10559578

Vincent, L. (2007) Taking online maps down to street level, *Computer* 40(12), 118–120. https://www.computer.org/csdl/mags/co/2007/12/mco2007120118.pdf

Wheeler, S. M. (2015). Built Landscapes of Metropolitan Regions: An International Typology. *Journal of the American Planning Association*, 81(3), 167–190. https://doi.org/10.1080/01944363.2015.1081567

Wilson, N., & Thomson, G. (2015). Suboptimal smokefree signage at some hospitals: Field observations and the use of Google Street View. *The New Zealand Medical Journal* (Online); Christchurch, 128(1415), 56–59.

Wilson, J. S., Kelly, C. M., Schootman, M., Baker, E. A., Banerjee, A., Clennin, M., & Miller, D. K. (2012). Assessing the built environment using omnidirectional imagery. *American Journal of Preventive Medicine*, 42(2), 193–199. https://doi.org/10.1016/j.amepre.2011.09.029

"Wilson, N., Thomson, G., & Edwards, R. (2015). The potential of Google Street View for studying smokefree signage. *Australian And New Zealand Journal Of Public Health,* 39(3), 295–296. https://doi.org/10.1111/1753-6405.12361

Wu, Y.-T., Nash, P., Barnes, L. E., Minett, T., Matthews, F. E., Jones, A., & Brayne, C. (2014). Assessing environmental features related to mental health: a reliability study of visual streetscape images. *BMC Public Health;* London, 14, 1094. https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-14-1094

Yamada-Rice, D. (2011). New media, evolving multimodal literacy practices and the potential impact of increased use of the visual mode in the urban environment on young children's learning. *Literacy*, 45(1), 32–43. https://doi.org/10.1111/j.1741-4369.2011.00578.x

Yamada-Rice, D. (2011). A Comparative Study of Visuals in the Urban Landscapes of Tokyo and London. *Visual Communication*, 10(2), 175–186. https://doi.org/10.1177/1470357211010002040l

Yin, L., & Wang, Z. (2016). Measuring visual enclosure for street walkability: Using machine learning algorithms and Google Street View imagery. Applied Geography, 76, 147–153. https://doi.org/10.1016/j.apgeog.2016.09.024

Yin, L., Cheng, Q., Wang, Z., & Shao, Z. (2015). "Big data" for pedestrian volume: Exploring the use of Google Street View images for pedestrian counts. *Applied Geography*, 63, 337–345. https://doi.org/10.1016/j.apgeog.2015.07.010