

SYSTEMATIC REVIEW

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Applying Google Maps and Google Street View in criminological research

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Abstract

Online mapping technologies such as Google Maps and Street View have become increasingly accessible. These technologies have many convenient uses in everyday life, but law enforcement agencies have expressed concern that they could be exploited by offenders and might alter existing offending patterns and habits. For environmental criminologists, they have the potential to open up new approaches to conducting research. This paper draws on the results of earlier studies in related fields and a handful of criminological studies to discuss how these online mapping applications can trigger new research questions, and how they could be considered a valuable methodological addition to criminological research.

Keywords: Google Maps; Street View; Environmental criminology; Innovation; Methodology; Methods

Introduction

Although Google Maps and Street View have not been developed with scientific research in mind, they create interesting possibilities for research. Several scientific disciplines were quick to implement these web mapping applications in their research. For instance, geographers rely on aerial photography from Google Maps as an alternative to expensive commercial satellite imagery (Pringle 2010) and biologists tap into Street View imagery to assess the habitat of certain animal species (Olea and Mateo-Tomás 2013). However, while there are abundant examples of studies that apply Google Maps and Street View in related scientific fields, only a few criminological studies have tapped into the power of online mapping technologies for research purposes. Whereas the general public, offenders and law enforcement agencies have already discovered the power of these online mapping services and use them daily, criminologists, somewhat surprisingly, seem not to have fully discovered the advantages of using Google Maps and Street View in their research. In this article I argue that the proliferation of online mapping technologies opens up several new approaches for criminologists to conduct environmental criminological research in particular. A small number of criminological studies have already shown that these technologies can be a valuable addition

to environmental criminological research, and this article considers how they might be implemented in future criminological research. Drawing on previous criminological applications, I discuss how the availability of Google Maps and Street View can generate new research questions; and how they could be considered important additions to the methodological toolkit of criminologists.

This article is structured as follows. First, some background information on Google Maps and Street View is provided, and the existing literature in relation to their application in related fields and previous studies is reviewed. Next, several potential uses for these online mapping technologies in environmental criminological research are explored. Third, their advantages and drawbacks are discussed. Fourth, readers are provided with an outline of where to find additional information on how to use these mapping technologies. Fifth, an interesting future development of environmental criminological research that is rooted in the availability of web mapping technologies is identified, and finally several suggestions for further reading are provided.

Background

An introduction to Google Maps and Street View

Google Maps

Originally launched in 2005, Google Maps (Google 2014c) is a free-to-use, web-based mapping service that combines

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conventional cartographic maps with satellite imagery and high-resolution aerial photography. The maps are embedded with additional information on terrain, street and road names, famous landmarks and buildings, public transit, real-time and typical traffic information. Users can conveniently switch between map and satellite view, or opt for a hybrid view that overlays the information available in the map view onto the satellite view (see Figure 1). For a number of cities worldwide, 45° aerial imagery is available allowing users to get a better understanding of the size and proportions of buildings as well as observe certain landmarks from four different perspectives.

The available aerial imagery is generally believed to be no older than three years and is updated on a regular basis. Users can update the map data in real time using Google Map Maker (Google 2014b) and, following approval, these updates are implemented in Google Maps (Sridharan 2011). The underlying aerial imagery database also powers Google Earth, a downloadable geographical information program with similar functionalities to Google Maps that allows users to access map data from their desktop. Three-dimensional mapping was also made available in Google Maps in late 2011 (McClendon 2011).

Additional services that are available in Google Maps include Street View, a route planner for driving, public transit, walking and bicycling, and a business locator. Users are also able to create and share custom maps (Liebert 2013). The custom maps environment (Google 2014g) allows users to add additional layers of content

such as places, labels, photos, and videos to the underlying Google Maps map. Moreover, users can draw lines, shapes and patterns directly on the map, add directions, and organize and compare up to three different datasets. Once created, custom maps can be shared and users can work together to create a collaborative custom map.

Google Maps has considerably simplified looking up addresses, and has made mapping and cartography accessible to the masses. Over a billion users access Google Maps and its related services such as Street View on a monthly basis (Choudhary 2013) and the Google Maps mobile app is used at least once a month by more than one in two smartphone users, making it the most popular smartphone app worldwide (Smith 2013). Essentially, Google Maps is an easy-to-use mapping application that allows its users to locate addresses quickly, and provides cartographic maps augmented with digital information and high-resolution aerial imagery.

Street View

Street View^a is a service available in Google Maps that supplements the original two-dimensional map view of Google Maps with three-dimensional, 360° street-level panoramic imagery (see Figure 2). Launched in 2007 in a handful of U.S. cities, Street View currently covers locations on all seven continents (Google 2014j). Almost total coverage has been achieved in North America, Australia, Japan and most countries in Europe. Additional Street View imagery is currently being collected in a range of countries.

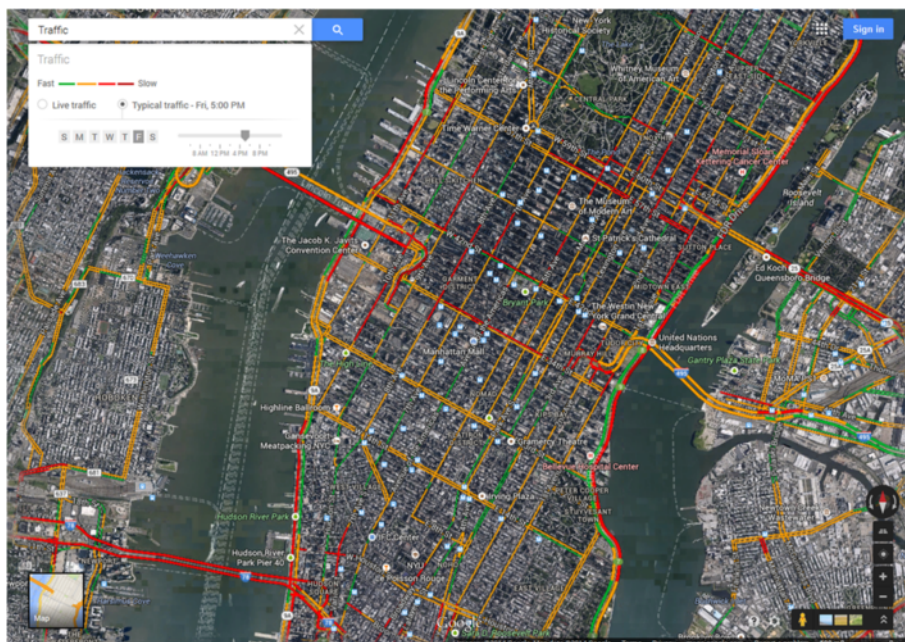


Figure 1 Example of hybrid map view with typical traffic information.



Figure 2 Example of Street View image.

Street View imagery is captured through a diverse fleet of vehicles equipped with specialist cameras (Vincent 2007). After collection, photos are digitally processed and 'stitched' together to obtain the familiar 360° panoramas. These images are connected to the Google Maps map and embedded with information on the street name and the approximate address. To protect the privacy of bystanders that are inadvertently captured on camera, faces and license plates are pixelated (Google 2014h). Users can make additional requests for blurring out images that feature the user, their family, their home or their car, and have tools available to request the removal of inappropriate or sensitive images.

The majority of images currently captured by the Street View fleet is of near high-definition quality (Cawley 2010). Up to September 2010 the images being collected were low resolution, and some areas can therefore only be experienced in Street View in low-resolution quality. In time, the low-resolution imagery will be replaced with higher-resolution photos. Although Street View imagery is intermittently updated and higher-resolution imagery is made available whenever possible, it is unclear how regularly these updates occur. Users can also update the available imagery themselves or supplement it by creating immersive 360° views called 'photo spheres' (Rapoport 2013). Once these individual spheres are connected and uploaded to Street View, other users can navigate them just like they would navigate Street View. As of April 2014, users have the option to go back in time and explore historical imagery from past Street View collections dating

as far back as 2007 (Shet 2014). Moreover, in a limited number of cities users can virtually visit businesses participating in the Business Photos program (Chang 2013). Essentially, Street View allows users to explore the real world virtually, without losing the underlying map context provided by Google Maps (Vincent 2007).

Google Maps and Street View in scientific research

Web mapping technologies have been embraced by disciplines such as geography, archaeology and ecology, but also by several social scientific disciplines. Regardless of the discipline, two particular applications can generally be distinguished. First, Google Maps and Street View have been implemented as convenient tools to reduce the costs and expertise needed to conduct research. Second, a smaller number of studies have shifted their focus towards these applications and treat them as full-grown research subjects in their own right, generating new and significant research questions.

Geography, archaeology, and ecology

Researchers working in the disciplines of geography, archaeology, and ecology quickly incorporated web-based mapping technologies into their research designs, and did so on a relatively large scale. Google Maps in particular has been implemented in a diverse range of studies, although applications of Street View remain more limited.

The freely available satellite images from the Google Maps database have primarily served as inexpensive alternatives to costly commercial satellite imagery. While remote sensing and the use of satellite images are not new in scientific research (e.g., Mertens and Lambin 2000), the costs and necessary technical expertise required to apply these methods have certainly been reduced with the widespread availability of easy-to-use and inexpensive online mapping applications such as Google Maps (Pringle 2010; Kennedy and Bishop 2011). Areas that were previously considered too remote or too expensive to access in person can now be relatively easily surveyed from the researcher's computer (Myers 2010; Pringle 2010). For instance, the Google Maps satellite imagery database has been used to scan large parts of the Arabian peninsula for prehistoric ruins and structures (Kennedy 2011; Kempe and Al-Malabeh 2013), to obtain better estimates of fish catches in the Persian Gulf (Al-Abdulrazzak and Pauly 2013), and to estimate forestry biomass in India (Ploton et al. 2011). Other studies have tapped into the Google Maps satellite imagery database to map the glacial geomorphology of the central Tibetan plateau (Morén et al. 2011), and the English Lake District (Brown et al. 2011).

There are also examples of some rather less conventional applications of online mapping technology. Archaeologists have examined Google's satellite images to chart the growth of the Guantánamo Bay prison complex, and have provided the public with an independent map of the prison camp (Myers 2010). Similarly, by analyzing satellite images from the aerial imagery database underlying Google Maps, the looting of archaeological sites across the world has been tracked in order to provide a better understanding of the scale and impact of the problem (Contreras 2010; Contreras and Brodie 2010). Other examples include studies that used Google Maps to support and map the process of collaborative spatial decision-making (Rinner et al. 2008) or to collect spatial information from participants filling in an online questionnaire (Bearman and Appleton 2012; Snizek et al. 2013).

Although the number of studies that have implemented Street View so far is limited, Street View has particular advantages for research and is considered a novel and convenient way of obtaining environmental information. Examples include studies in which Street View imagery was a source of information that allowed the habitat of certain animal species to be assessed (Olea and Mateo-Tomás 2013), or where it served as a tool to map the spatial distribution of a particular population (Rousselet et al. 2013; Gordon and Janzen 2013) or to obtain information on pedestrian and road infrastructure (Hanson et al. 2013; Guo 2013).

Lastly, some studies have focused on the online mapping technologies themselves. These studies have principally

assessed the quality of the information contained in Google Maps and Street View (Paradiso 2013; Davis and de Alencar 2011; Wai Yeung et al. 2013). Attention has also been paid to the usability of web mapping applications from a user's perspective (Nivala et al. 2008).

The social sciences

The social sciences have also embraced web mapping technologies, albeit somewhat later and on a smaller scale than the disciplines mentioned above. While applications of Google Maps remain relatively limited in the social sciences, Street View has been implemented in a host of studies and has the potential to become a useful tool for quickly collecting large amounts of data on the built and social environment (Sampson 2013).

Google Maps is predominantly being applied as a tool to visualize data. It is only sporadically used as a source of geographically relevant information. It has, for instance, been used to map the spatial distribution and interconnectedness of scientific output (Leydesdorff and Bornmann 2012; Bornmann et al. 2014; Leydesdorff and Persson 2010) and to geo-reference poetry in urban spaces (Berry and Goodwin 2013). Yet there are examples of more innovative applications. Psychologists have used Google Maps to collect information on places visited by participants in a study on daily activity (Wolf et al. 2013). In addition to keeping a diary of places they visited during the study and being monitored via GPS, participants were required to pinpoint the places they visited in Google Maps. Google Maps can also be a particularly powerful tool to nurture crowdsourced and crowdcasted science, by letting users create and share maps embedded with information on their environment (Hudson-Smith et al. 2009; Kindynis 2014; Lefer et al. 2008). Thanks to such initiatives, social scientists and the general public alike are now able to collect, visualize and share vast amounts of data (Hudson-Smith et al. 2009) ranging from population density (e.g., LondonProfiler.org), to the number of violent crimes in a particular area (e.g., maps.met.police.uk), to the geography of America's prison industry (e.g., prisonmap.com).

A large number of public health studies have looked into the suitability of studying Street View imagery in order to collect data on the built environment. In general, their results suggest that virtually auditing a particular neighborhood is a reliable, cost- and time-effective alternative to actual on-site visits (cf. *inter alia* Ben-Joseph et al. 2013; Badland et al. 2010; Clarke et al. 2010).

Finally, the substantive aspects of the technology have also been explored. Studies have looked into how Google Maps is being used by students (García-Martín and García-Sánchez 2013) and the merits it has as a didactic tool in educational settings (Ovidia 2012; Patterson 2007). The development of Google Maps has been studied from

a political-economic perspective and its implementation has been situated within a historical and broader socio-economic context (Lee 2010). Street View has also received substantial attention. The way that Street View represents stigmatized neighborhoods and might contribute to their stigmatization has been criticized (Power et al. 2013). Other scholars have looked into how the implementation of Street View sparked privacy concerns (Geissler 2011) and redefined our perception of privacy (Elwood and Leszczynski 2011).

Google Maps and Street View in environmental criminological research

Only a handful of criminological studies have so far implemented Google Maps and Street View in one way or another in their research designs. This is somewhat surprising, since the general public, offenders and law enforcement agencies have already discovered the advantages online mapping technology offers in their daily life and work. Iraqi and Palestinian militants have admitted to using web-based mapping applications to select possible targets for terrorist attacks (Levinson 2007). Similarly, graffiti writers and shoplifters in London were found to use Street View to look for new targets (Kindynis 2014). Burglars are believed to 'google' for potential targets and may be using online mapping technologies when casing homes for break-ins (Michaels 2011). Householders also believe Street View might contribute to burglary (The Telegraph 2010; Pyatt 2009; Power et al. 2013), a concern that is shared by ex-burglars (Sterling 2011) and police unions (De Tijd 2011) alike. Interestingly, these applications also offer law enforcement agencies the opportunity^b to establish new forms of surveillance and crime control (Kindynis 2014), while simultaneously empowering ordinary citizens by providing them with new tools to control law enforcement agencies (EURONEWS 2013) or give expression to their concerns about crime (Hudson-Smith et al. 2009).

For the few criminological studies that have implemented Google Maps and Street View in their research design, online mapping technologies have either been the object of criminological enquiry or have been used as a methodological tool to help researchers reduce costs and overcome particular difficulties in their research. Drawing on these studies, I discuss two major aspects of Google Maps and Street View in relation to environmental criminological research, namely: how these online mapping applications can generate new research questions; and how they could be considered an important addition to the criminologist's methodological toolkit.

Mapping out new research questions

Web-based mapping technologies could themselves constitute the object of criminological enquiry — for instance,

law enforcement agencies and former burglars share a concern that the availability of Google Maps and Street View helps burglars to prepare for their offenses. It is exactly this concern that Van Daele et al. (2012) scrutinized in a study that examined whether burglars are likely to rely on online mapping technologies to select a suitable target.

Van Daele et al. (2012) set out to examine whether the proliferation of online mapping technologies might contribute to burglary and alter known burglary patterns. First, they explored whether it is likely or not that burglars rely on Google Maps and Street View to search for potential targets. Burglars look for targets in their awareness space (Brantingham and Brantingham 1981). Before the advent of web-based mapping tools, this awareness space was established while performing routine activities such as traveling to work or visiting friends. This required burglars to visit potential targets beforehand. Now, however, by browsing through Google Maps and Street View burglars can become aware of previously unknown areas and case potential targets. Since Google Maps and Street View enable armchair exploration (McClendon 2010), the burglar's awareness space and the number of potential targets are potentially vastly expanded.

Second, Van Daele et al. (2012) examined whether the use of Street View makes burglars rely on different target characteristics than when they select a suitable target on the street. Burglars are known to exhibit some degree of planning (Bennett and Wright 1984) and pay attention to characteristics of the built environment when selecting a suitable target (Nee and Meenaghan 2006; Palmer et al. 2002). Target characteristics are typically observed while walking down the street, but can also be assessed through the imagery available in Street View. Van Daele et al. (2012) therefore argued that it would be logical for burglars to rely on such tools during the planning stage, since it potentially decreases the costs of a burglary by reducing preliminary travel costs and the risks associated with casing a potential target. However, it remains unclear whether the nature of the type of images in Street View (e.g., snapshot, image quality, limited zoom possibility) actually allows them to carry out a detailed assessment of the suitability of a house as a burglary target.

To answer their research questions, Van Daele et al. (2012) recruited undergraduate criminology students who were instructed to select a characteristic burglary target and to give at least three reasons why it is suitable. A quarter of the participants were not given additional instructions and could select their target as they saw fit. The rationale for this choice was to see whether participants would spontaneously use web mapping technologies in their search. A quarter of the participants were asked to

select their target on the streets, another quarter was ordered to only use Google Maps and Street View and a final quarter was also limited to Google Maps and Street View but had to take a photograph of the selected house as well. This photograph was added to make the situation correspond more closely to an actual burglary. After all, when a burglar has selected a potential target on Google Maps he still has to visit the house to burglarize it.

Regarding their first research question, Van Daele et al. (2012) conclude that it is fairly unlikely that burglars would make use of Google Maps and Street View on a large scale. Participants that were not given additional instructions on how to select a target did not use these applications spontaneously when looking for targets. Moreover, the participants that used Google Maps and Street View predominantly used them to assess targets in areas they were already familiar with. The availability of online mapping technologies did not result in participants looking for targets outside their awareness space. In other words, participants did not randomly explore Google Maps and Street View until they came across a suitable target. Their pre-established awareness space guided their use of the web mapping applications and determined where they looked for targets in these online tools. In addition, the requirement to take a photograph of the proposed target made participants predominantly look for targets near their starting point (Van Daele et al. 2012).

Van Daele et al. (2012) also found that participants who used Street View to select a suitable target did not rely on different target characteristics to participants who selected targets on the street. Interestingly, participants who used Google Maps and Street View to select a target paid a considerable amount of attention to the level of accessibility of the neighborhood and street in which the target is located, although they did not pay significantly more attention to accessibility than participants that did not use Google Maps and Street View.

While this study has its limitations — for instance, it is unclear to what extent participants possessed the same level of experience in using web mapping applications and whether non-burglars such as criminology students can replicate burglars' decisions on potential targets (Garcia-Retamero and Dhami 2009; Nee and Meenaghan 2006) — the setup is novel and its conclusions are interesting. Moreover, it is, to my knowledge, the only study that has explored how contemporary web mapping technologies affect crime, and is a prime example of how Google Maps and Street View could become the object of more criminological enquiry. The experiment could potentially be re-created using convicted burglars as subjects, to gain insight into how they make use of these tools, or the experiment could implement additional software that tracks how web-based mapping technologies are

used when looking for targets. The introduction of Street View in an area closely resembles a natural experiment and offers the opportunity to conduct observational research. Other potential research questions that could be addressed are, for instance, whether homeowners decide to pixelate their house in Street View in anticipation of or in reaction to burglary victimization and how is this related to their perceived fear of crime? How homeowners' decisions to pixelate their house affect the chance of burglary victimization? Furthermore, how does offenders' online searching behavior affect their offline target selection process: does their offline awareness space guide their online searching behavior or do offenders become familiar with previously unknown areas through their online searching behavior? Does the introduction of Street View in an area affect local crime figures? Finally, the recent availability of a time-travelling option in Street View offers researchers a chance to study the effect of changes in features of houses, streets or neighbourhoods on local crime figures and crime prevention policies.

An important addition to the methodological toolkit

In addition to the research questions online mapping technologies might trigger, their availability is a boon to criminologists and Google Maps and Street View could become powerful methodological tools in criminological research (Kindynis 2014). First, they enable environmental criminologists to collect data on the physical environment, often in a cost- and time-efficient manner. Using Google Maps in environmental criminological research might allow researchers to address some of the drawbacks related to using conventional maps, and Street View seems to be particularly helpful as a tool to remotely collect data on the built environment. Moreover, the many underlying application programming interfaces (API) could reduce the resources required to obtain certain types of information.

Second, the proliferation of online mapping technologies allows to reconsider established practices in environmental criminological research. Moreover, Google Maps constitutes a helpful tool to visualize environmental criminological data and make research results easily accessible to a broad audience.

Data collection

Google maps and conventional maps Conventional maps have often been used in criminological research to collect data. They are particularly powerful data-gathering instruments when interviewing offenders and can be used to collect information (Summers et al. 2010). Yet using conventional maps has its disadvantages, and some of these could be addressed by using Google Maps.

Summers et al. (2010) discuss in detail how conventional maps such as hand-drawn sketch maps and standard

cartographic maps can be used during offender interviews to tap into information that might not otherwise be revealed. They allow researchers to collect information on the spatial awareness of offenders, explore their activity patterns and look into the spatial distribution of their offenses (see also Canter and Hodge 2000). Sketch maps drawn by hand are valuable instruments to tap into offenders' knowledge of their physical environment and the offenses that take place there (Canter and Hodge 2000). Conventionally, researchers obtain these maps by providing offenders with a pencil and paper and asking them to draw a map of the areas they are familiar with and committed their offenses in. The outcome of researchers' requests to draw a sketch map is dependent on a range of factors, such as offenders' ability to understand the task, and the size of the paper provided (Canter and Hodge 2000; Summers et al. 2010). The size of paper, for instance, might limit the amount of information that an offender is able to include in a sketch map. Moreover, offenders vary in their drawing ability and it is sometimes particularly difficult for researchers to assess the accuracy of a hand-drawn map and relate it to the cartographic map of the area (Summers et al. 2010). Interestingly, cartographic maps are not often used by researchers when interviewing offenders, possibly because of the difficulty of selecting the correct scale of map — the map needs to cover a large enough geographical area yet still be readable (Summers et al. 2010). Even when researchers have given considerable thought to the scale of a map, it might still be too small or not detailed enough to elicit all the relevant information during an offender interview.

The Google Maps environment offers a solution to some of these limitations. In a way, Google's custom maps allow users to combine sketch maps with cartographic maps. Users can add layers of information to these customized cartographic maps and can use the styling and drawing options to demonstrate underlying patterns or add context where needed. This information can be directly related to the underlying cartographic map, making it easier for researchers to understand how the sketch map is related to the context of the underlying cartographic map. Moreover, users can freely change the scale of the Google Maps map, making the map's scale less important and eliminating the limitation that the size of the paper introduces to hand-drawn maps. Obviously, using Google Maps will not affect an offender's drawing ability and researchers will still need to assure participants that they are interested in the information contained in the sketch maps and not in how the maps look (Summers et al. 2010).

Street view and neighborhood audits Environmental criminologists have shown, and continue to show, an interest in how physical features of the environment

affect human behavior (Bottoms and Wiles 1997). A variety of methods for obtaining data on the built environment are at the researcher's disposal, such as self-report surveys, census data, and neighborhood audits (Rundle et al. 2011). Neighborhood audits, or systematic social observations, are completed in person and on site by trained observers (e.g., *inter alia* Sampson and Raudenbush 1999; Day et al. 2006; Clifton et al. 2007; Brownson et al. 2004). They allow a researcher to precisely define the theoretically relevant variables, and assess the reliability and validity of the measures. However, large-scale projects are often unfeasible (for a notable exception see Sampson and Raudenbush 1999) because of the costs and time required to travel to the study area and conduct the audit (Rundle et al. 2011; Ben-Joseph et al. 2013). Moreover, residents may perceive such audits as invasive (Caughy et al. 2001). A virtual audit of the study area might offer a solution to some of the drawbacks inherent to on-site audits. When carrying out a virtual audit, observers will not travel to the study area in person but will instead browse through the available Street View imagery and virtually walk through the targeted area as they would when visiting the area in person.

A number of public health studies have already looked into the opportunities that Street View offers for collecting data on the built environment, and confirm that audits using Street View imagery offer a convenient and reliable alternative to on-site audits (Wilson and Kelly 2011; Wilson et al. 2012; Kelly et al. 2013; Ben-Joseph et al. 2013; Odgers et al. 2012; Badland et al. 2010; Clarke et al. 2010; Taylor et al. 2011; Rundle et al. 2011; Griew et al. 2013; Kronkvist 2013). The results obtained through Street View are generally valid and consistently show acceptable levels of reliability. Street View also offers the potential to greatly reduce costs and time, since the need to travel to the study area is eliminated (Odgers et al. 2012; Badland et al. 2010; Clarke et al. 2010; Taylor et al. 2011; Rundle et al. 2011; Griew et al. 2013; Kronkvist 2013). Furthermore, researchers have the added convenience that the study area can be re-visited whenever needed — for instance, when more data needs to be collected or when additional supervision or quality control is needed during the data collection phase (Clarke et al. 2010; Rundle et al. 2011). In addition, these measurements do not have an impact on local residents (Rundle et al. 2011).

The major disadvantage of using Street View in environmental audits is that small-scale items, such as the presence of cigarette butts or the condition of sidewalks, cannot be reliably measured, and more qualitative assessments relating to the social environment, such as the general level of social disorder, are not accurately assessed (Kelly et al. 2013; Ben-Joseph et al. 2013; Wilson

et al. 2012; Odgers et al. 2012; Rundle et al. 2011; Clarke et al. 2010; Griev et al. 2013; Kronkvist 2013). Moreover, it is often unclear whether the images accurately reflect the current on-site situation. The timing of the recording may confound what can be seen. This is especially true for environmental features that are subject to temporal variability (Coupe and Blake 2006; Nee and Taylor 2000; Fujita 2011), such as shrubbery and hedges, the presence of cars on the street and driveway, and whether shutters are closed or lights around the house are on. Finally, the quality of the images sometimes prohibits reliable assessments of detailed features of the built environment (Ben-Joseph et al. 2013; Badland et al. 2010; Taylor et al. 2011; Kronkvist 2013).

Notwithstanding these disadvantages, it is a promising and viable alternative to on-site audits that can be used in several ways. For instance, researchers could combine online and offline audits in their research design. Initially, online audits could be used to cover a large area, and save money and time. In a follow-up phase, researchers could use those resources to actually visit the study area. Small-scale items could then be accurately measured and the social environment could be qualitatively assessed. Moreover, online mapping technologies could also be used on-site, while the audit is conducted. Since Google Maps is available on smartphones and tablets, researchers could quickly consult Google Maps to rate certain house features without intruding on the occupants' privacy (e.g., Does the house have a backyard? How large is the house? Does the garden border other gardens?) or access Street View images and make use of the time-travelling option to check what the street looks like on other times of the day or year. Another example could be to initially geocode certain locations (e.g., police stations, schools and certain local businesses and bars) and when researchers are near a location while conducting the audit they are prompted to answer additional questions or pay attention to specific features.

Finally, Street View has already been successfully used to measure environmental characteristics in environmental criminological research. For instance, in a study of the mechanisms of theft of older cars (Fujita 2011), Street View imagery allowed the researcher to estimate the number of vehicles parked on street segments in Newark, New Jersey, as well as their make, model and generation. Measures of land use and physical disorder were also obtained by auditing Street View images. Kronkvist (2013) related virtually observed physical disorder to victimization of property crime. Comparisons of self-reported perceived levels of disorder with data on physical disorder collected through Street View indicate that virtual audits yield reliable data on physical disorder and allow to predict neighborhood differences in victimization. Similarly, a Canadian study of the effects of physical and

social features on burglary victimization used Street View to virtually assess design features of houses (Apps 2012). The results from all these studies support the idea that Street View is a reliable tool to collect data on a range of environmental characteristics and that it can be used successfully in an environmental criminological setting.

Google Maps API Researchers that want to get more out of Google Maps and Street View than the visual interface offers, might want to consider using one of the many underlying APIs. These require researchers to have a basic understanding of programming but allow them to perform a variety of time and resource intensive tasks relatively easily and without cost. For instance, researchers can use the Geocoding API to easily convert address information into precise geographic coordinates that can then be plotted on a map or vice versa. The Places API allows to query the Google database for place information on a variety of categories such as businesses and schools. The result is a list of summary information including location, business hours and price categories. More comprehensive information about a particular place can be accessed by using the Place Details API. Journey-to-crime researchers will be particularly interested in the Directions API and the Distance Matrix API. The former API lets users calculate directions between a set of locations for a range of transport modes including driving and walking. The latter API provides recommended travel distances and times for a matrix of address locations. Google's API picker (Google 2014l) provides a comprehensive overview of the available APIs and suggests the appropriate API for a range of common things that users may want to do in Google Maps or Street View.

Method

Re-assessing established research practices In addition to the possibilities that Google Maps offers to collect data, it also allows researchers to reconsider established practices in environmental criminological research. An example of this can be found in the study by Caplan et al. (2011) in which they examined the crime-detering effect of police-monitored CCTV cameras on the streets of Newark, New Jersey, and used aerial imagery from Google Maps to improve the measurement of the line of sight of CCTV cameras.

Caplan et al. (2011) began with the assertion that despite the mixed results of research, CCTV cameras are increasingly being installed in public spaces with the intention to deter crime. They argued that cameras inherently have a limited effect on discouraging crime. First, any deterrence effect will only occur at locations where there is a CCTV camera (Farrington et al. 2007). Second, in order for a crime-detering effect to occur, offenders need to be aware

of the presence of a camera, and be concerned that it is operating and effectively monitored and that an appropriate response will follow (Farrington et al. 2007; Caplan et al. 2011). Moreover, cameras have limited lines of sight, which often creates blind spots (Caplan et al. 2011) that offenders can exploit. Previous research rarely acknowledged this in research designs and therefore overestimated the crime-detering effect of CCTV cameras.

Caplan et al. (2011) aimed to improve the previous research in three ways: by investigating the crime-detering effects of strategically placed and randomly placed CCTV cameras; by demonstrating a new technique for measuring the area that is actually monitored by a particular camera, the 'viewshed,' more accurately and realistically; and by evaluating the overall effectiveness of CCTV cameras for deterring particular types of crime at certain types of place. Their second aim constitutes an excellent example of how the availability of Google Maps allows criminologists to re-assess common research practices.

In order to correctly assess the crime-detering effect of CCTV cameras, the viewshed must be measured as accurately and as realistically as possible (Caplan et al. 2011). This implies that viewing distances and lines of sight should be measured correctly and that possible blind spots need to be identified and taken into account as well. Previously, researchers had to observe viewing distances and lines of sight on CCTV monitors in the police's camera control room and then subjectively transplant these onto a map in order to obtain a CCTV camera viewshed (cf. Ratcliffe et al. 2009). This method is time-consuming and the accuracy of the viewshed depends on the researchers' interpretation and ability to assess distances correctly on a two-dimensional monitor and transplant these interpretations onto a map (Caplan et al. 2011). Moreover, many researchers will not have access to the CCTV camera control room and therefore cannot replicate this method. To overcome these limitations, Caplan et al. (2011) propose a generally accessible and easy-to-replicate method for obtaining accurate viewshed measurements.

Caplan et al. (2011) created CCTV camera viewsheds by using aerial imagery from Google Maps. The viewing distance of CCTV cameras was initially set at twice the median length of a Newark block face (582 feet or approximately 177 meters), even though cameras might be able to zoom and view beyond this arbitrarily set viewing distance. Next, aerial imagery from Google Maps was used to create viewshed polygons for each CCTV camera included in the study. These aerial photographs allowed the researchers to take into account buildings and other barriers that limit the line of sight of a camera. To validate this alternative method, several cameras were randomly selected to ground-truth the Google Maps viewshed. This was done by observing viewing distances and lines of sight

on CCTV monitors in the police control room (as was done previously by Ratcliffe et al. 2009) and comparing these viewsheds with those obtained from Google Maps. Caplan et al. (2011) reported minimal deviations and concluded that the Google Maps method is equally robust, less time-consuming and more easily accessible for researchers.

The study by Caplan et al. (2011) is an interesting example of how the availability of online mapping technologies allows criminologists to reassess established research practices. While a great deal of effort had previously been involved in obtaining the information required to accurately measure CCTV cameras' viewsheds, the new method implementing Google Maps greatly reduced this while still obtaining accurate viewshed measurements. Although Caplan et al. (2011) did not use Street View in their research, they could have implemented it as well. For instance, the imagery could have been used as an additional means of establishing, verifying and improving the measurement of CCTV cameras' lines of sight.

Data visualization Finally, Google Maps has the power to be a useful tool to visualize environmental criminological research and make the results easily accessible to a broad audience. The Slovenian Krimistat.si project (Eman et al. 2013) is an example of this particular application.

The idea behind the Krimistat.si project was to combine police data with relevant economic and socio-demographic variables, present this in an easy-to-use mapping interface that uses the Google Maps environment, and make it publicly available (Eman et al. 2013). Slovenian citizens could then easily obtain information on the distribution of reported crimes and could see whether or not a particular type of crime had occurred in their home neighborhood. The Slovenian police would have access to the Krimistat.si project with additional crime mapping functionalities. The researchers expressed their hope that this project would make crime mapping analyses and the outcome of such analyses more comprehensible for the general public. Although no notable technical difficulties were encountered and the Slovenian law enforcement agencies were offered the chance to use the tool internally, the ultimate goal of the project was not achieved. Due to legal concerns surrounding the protection of personal data and potential violations of the privacy of victims, Eman et al. (2013) concluded that it is currently not a viable option in Slovenia to grant public access to this type of information and therefore the project was discontinued. Moreover, financial constraints prohibited the Slovenian police from acquiring the Krimistat.si program.

Regardless of the project's lack of success, it does illustrate how Google Maps could be an important part of criminologists' methodological toolkit. It can help to make

environmental criminological research and its findings more accessible, and possibly more comprehensible, to the general public by visualizing it in an environment with which many people are familiar.

When to use the method: strengths and weaknesses

While these online mapping technologies are useful additions to scientific research in general and create several new approaches to conducting environmental criminological research in particular, they have certain strengths and weaknesses that potential users should be aware of. This section aims to help criminologists to form an opinion on whether or not to use web mapping technologies in their own research project by discussing the major strengths and weaknesses of applying Google Maps and Street View in research.

Strengths

There are essentially three major strengths that will make researchers want to consider implementing Google Maps and Street View in their research design.

First, usability is a key element of these particular web mapping technologies, and new developments continuously aim to improve their usability and the user's experience (Nivala et al. 2008; McClendon 2012). Novice web users can make use of Google Maps and Street View, as they are not required to master specific technical expertise. Moreover, it is safe to assume that most people will have some familiarity with online mapping technologies, since many of us use these technologies in one way or another in our daily lives. Research subjects can focus on the tasks at hand, such as performing mapping tasks or browsing Street View imagery, instead of needing to figure out how to interact with the online environment. On a side note, advanced use, such as interacting with the API, does require some familiarity with the web mapping technologies. However, this is a task primarily set aside for the researcher, and research subjects in criminological research will rarely have to interact with the API.

Second, Google Maps and Street View can be accessed around the clock, as long as there is an internet connection^c. Researchers and research subjects are not required to purchase and install potentially expensive software. Nor are they limited to the location of a computer or laptop, since the mapping applications can also be accessed via smartphone. Similarly, if research results are disseminated through a Google Maps map, the general public can easily access these results as well.

Third, these web mapping technologies are inexpensive to use. In contrast to commercially available satellite imagery or street-level panoramic imagery, the use of Google Maps and Street View is essentially free of charge (Google 2014k). Although users will need to

make basic investments in a computer or smartphone with internet access, there are no significant additional costs that come into play afterwards.

Weaknesses

Researchers should also be aware that there are some major drawbacks to using these web mapping technologies in their research. First, Google's privacy policy (Google 2014i), terms of service (Google 2014f) and the additional terms of service applicable to the use of Google Maps and related services (Google 2012c) should be consulted prior to use, and the user should check whether the intended use violates any of the stipulations. Moreover, the user should understand what is being stipulated in the terms of service, and should be aware that these documents change over time. In particular, users should understand that Google collects personal information when you use any of their services, such as name, telephone number and credit card information (Google 2014i). Additional information that is collected includes device-specific information such as telephone number and unique device identifiers, log information such as telephone logs and internet protocol addresses, and actual or approximate location information. While this information is primarily used to improve Google products and user experience, it might be shared with partner companies, the general public, and upon request with law enforcement agencies and courts. This might be a particularly significant drawback in obtaining offenders' consent to participate in research that makes use of Google Maps or Street View. Moreover, while users retain the ownership of their intellectual property rights, under Google's terms of service uploading, storing, sending, or receiving content through any Google service grants Google a worldwide license to use, publish and distribute that content to improve or promote their services (Google 2014f). Finally, users need to obtain prior written authorization from Google to publish any of the content available in Google Maps and agree that they will not promote or provide instructional information about illegal activities (Google 2012c). Both stipulations could seriously limit the opportunities to implement Google Maps in criminological research.

Second, it is unclear how recent and accurate the information contained in these applications is. While Google aims to update the Maps and Street View content on a regular basis, update schedules are not publicly available. As a result, it is unclear whether Google's claim that the available imagery in Google Maps is not older than three years holds. Moreover, some of the available information will be inaccurate and reflect out-of-date situations. This is especially true for the Street View imagery, since Google focuses on expanding coverage and only intermittently updates

existing imagery. However, users can determine the approximate capture date of the available imagery either by using Google Earth when they wish to know the date of Google Maps' aerial imagery or by checking the status bar of the Street View imagery (Agarwal 2012). Moreover, the recently introduced 'time traveling' option (Shet 2014) allows users to see how certain areas have changed over time (or not). As Google expands its Street View database and repeatedly collects footage of the same area, this option could become a particular powerful tool for researchers interested in evaluating the impact of changes in the environment on crime and crime prevention.

Third, users will be confronted with missing information when using Google Maps and Street View. Obviously, a large number of countries have no Street View coverage at all^d. Other cases of missing information are subtler and relate to blurred-out areas in Google Maps, such as certain military installations, or pixelated houses in Street View. Moreover, users should be aware that the address information contained in the underlying database is not always accurate enough to allow some addresses to be identified; in particular, house numbers are sometimes missing or inaccurate due to 'noise' in the obtained images (Goodfellow et al. 2014). This might be an important drawback when assessing house features using Street View imagery. Instead of the actual address, images of the approximate address will be displayed. Moreover, the image quality is sometimes limited and will not always allow researchers to check the house number. However, a recently developed algorithm that is able to recognize house numbers in Street View imagery might solve this problem in the near future and improve address accuracy (Goodfellow et al. 2014).

How to use the method

Readers that plan to use Google Maps or Street View in their research and require some additional background information on how to use these tools, or simply want to browse the features that are available, can consult various sources.

The online Maps Help Center (Google 2014d) provides a comprehensive overview of the features that Google Maps and Street View offer, the many tools that are available and how to use them. Most users will find their questions answered by browsing through this database, which can also be quickly searched by using the search bar. The Maps Help Center covers a variety of subjects, including straightforward ones such as how to get started with Google Maps and how to search and explore a map, but also provides tips and tricks on how to create and share custom maps and what particular tools are currently available to customize a map in such a way that it suits your particular needs. Users who want to develop an application that taps into the power

of Google Maps or Street View should also consult the Google Maps Web API help site (Google 2014e), or related sites such as the Google Developers website (Google 2014a).

Additional information on the features and tools available in Google Maps and Street View can be found on the Google Lat Long Blog (Google 2013) and the Google Geo Developers Blog (Google 2012a). The Google Lat Long Blog is aimed at a general audience and regularly receives updates and highlights newly available features (e.g., McClendon 2014), recently implemented map or imagery updates (e.g., Rapoport 2014), or simply provides examples of how Google Maps is being implemented by researchers or is impacting the daily life of citizens (e.g., Erickson 2014). Users can either browse the blog or search its contents using the search bar. As the name suggests, the Google Geo Developers Blog is aimed at developers and expects its audience to have some understanding of how the underlying Google Maps API functions. It is updated on a regular basis and provides examples of how the Google Maps API can be used for a variety of applications.

Supplementary information and examples of how Google Maps is being used can be found on a number of blogs unaffiliated with Google, such as Maps Mania (Maps Mania 2014) and Google Earth Blog (Taylor 2014).

Future applications: international, comparative environmental criminological research

The availability of web-based mapping technologies could foster international, comparative environmental criminological research in the near future. The idea behind Street View is that it allows for the virtual exploration of the real world (McClendon 2010). It aims to bring the real world, or at least part of it, to the user's computer through a collection of immersive 360° panoramas. Researchers are no longer required to travel to far away or remote areas to experience and tour them. Moreover, promising results from public health studies that have used Street View to virtually audit the built environment suggest that it is a reliable, quick and cost-effective alternative to in-person, on-site audits. In other words, this creates new opportunities for conducting international, comparative environmental criminological research (cf. Badland et al. 2010; Griew et al. 2013; Taylor et al. 2011) since some of the logistical challenges and costs that are typical for such projects no longer come into play. For instance, criminological knowledge could be broadened by testing environmental criminological theories simultaneously in multiple neighborhoods in the same city or applying them in many cities on different continents without the researchers needing to undertake costly field trips or finding suitable observers in every relevant setting.

Data on the built environment of different neighborhoods and cities can easily be collected by browsing the

available Street View imagery in Google Maps. Since Street View brings the world to researchers' fingertips, this can all be done systematically from a single, convenient location, probably their office, but it might also be their home or any other location where they happen to be. Moreover, since the observers can be grouped at a single location, the lead researchers have the opportunity to check in on the data collection whenever they wish to (Clarke et al. 2010; Rundle et al. 2011) and can provide feedback to the observers when they feel it is necessary or when the observers require it. Furthermore, as already pointed out in several previous studies (Odgers et al. 2012; Badland et al. 2010; Clarke et al. 2010; Taylor et al. 2011; Rundle et al. 2011; Griew et al. 2013), the costs and time involved with traveling to the research location are significantly reduced and can be invested in other parts of the research project, such as data analysis.

An additional advantage is that the data can be collected in a controlled manner, and once collected it is likely to be more comparable across different settings (Badland et al. 2010). Google collects the Street View imagery in a more or less standardized manner, resulting in imagery that is consistent in terms of what is captured on camera and comparable in quality across different settings. Moreover, observers have direct access to geographic maps and aerial imagery of the surroundings, thanks to the link with the Google Maps environment (Taylor et al. 2011). This conveniently lets them get a feel of the layout of an urban area and helps them to collect environmental data on places that are harder to observe using street-level imagery alone.

However, it is unclear to what extent personal characteristics such as ethnicity and prior knowledge of the study area affect the outcome of virtual assessments (Odgers et al. 2012). In particular, does collecting data through Street View in different cities or countries by a group of observers that have not visited these locations before and have no established knowledge or experience with the country result in a reliable assessment of the built environment or not? It could be that observers with prior knowledge of the study area, because they live in the country or city of interest, are better at auditing such places than observers lacking this knowledge. In order to reliably collect international comparative environmental data this will need to be assessed in detail.

Conclusion

Online mapping technologies such as Google Maps and Street View have recently become available for a large audience, including offenders, law enforcement agencies and criminologists. Although offenders admit to using online mapping technologies and law enforcement agencies have expressed concern that their availability might alter existing offending patterns and habits, criminologists

have not yet fully embraced the possibilities these new technologies offer to conduct environmental criminological research. This paper articulated several of these possibilities and highlighted different aspects of Google Maps and Street View in relation to environmental criminological research.

First, the availability of these technologies triggers a number of substantive questions that could be addressed in future criminological research. Some of these have already been addressed in previous research (e.g., Van Daele et al. 2012) but there remain many questions to be answered. For instance, how does offenders' online searching behaviour on Google Maps affect their offline target decision process? What is the impact of homeowners' decisions to pixelate their house on Google Maps on the chance of burglary victimization. Are homeowners' decisions to pixelate their house in Street View a reaction to previous burglary victimization or a strategy to reduce the risk of becoming a victim? Does the introduction of Street View in an area result in a change in local crime figures, as has been suggested by police unions (cf. De Tijd 2011)? With the availability of a time-travelling option, other research questions also come to mind. For instance, do changes over time to features of houses, streets or neighbourhoods affect crime figures?

Second, online mapping technologies are a valuable methodological addition to environmental criminological research. They offer new ways to collect data on the physical environment in a cost- and time-efficient manner. Some of the drawbacks related to using conventional maps in offender interviewing (Summers et al. 2010) could be addressed by using Google Maps instead and Street View has the potential of becoming a helpful tool to remotely collect data on the built environment (Kronkvist 2013; Odgers et al. 2012). Over time and as Street View coverage increases, it might foster international, comparative environmental criminological research. At the same time, Google Maps and Street View are helpful tools that allow researchers to re-assess established practices in environmental criminological research (cf. Caplan et al. 2011). Google Maps in particular constitutes a helpful tool that allows to visualize environmental criminological data in a familiar mapping interface and disseminate research results to a broad audience (cf. Eman et al. 2013).

Suggestions for further reading

Apps (2012). *Residential burglary in Guelph: Looking at the physical and social predictors of break and enters. Guelph: The University of Guelph.*

The author examines the impact of physical and social features on burglary victimization. Assessments of private properties are conducted using Street View.

Caplan et al. (2011). **Police-monitored CCTV cameras in Newark, NJ: A quasi-experimental test of crime deterrence.** *Journal of Experimental Criminology*, *7*(3), 255–274.

This study serves as an interesting example of how Google Maps can be inventively implemented in criminological research to reconsider existing research practices.

Eman et al. (2013). **Crime mapping for the purpose of policing in Slovenia: Recent developments.** *Revija za kriminalistiko in kriminologijo/Ljubljana*, *64*(3), 287–308.

Part of this article discusses the Krimistat.si project. Although discontinued, the project illustrates how Google Maps could be used to make the results of criminological research more understandable and accessible to the general public.

Fujita (2011). **Why are older cars stolen? Examining motive, availability, location, and security.** Newark: Rutgers, The State University of New Jersey.

This is one of the first studies to examine the impact of variables measured using Street View on crime. This doctoral dissertation illustrates how Street View imagery can be used to measure environmental characteristics that exhibit a strong temporal variability such as number of cars parked on the street.

Kindynis (2014). **Ripping up the map: Criminology and cartography reconsidered.** *British Journal of Criminology*, *54*(2), 222–243.

Kindynis (2014) provides an elaborate and critical discussion of criminology's interest in mapping and cartography. Throughout the article, emergent digital mapping technologies and their impact on criminology are discussed. Several suggestions are provided as to how criminologists can harness the powers of these new technologies to come to new empirical insights and engage with the public.

Kronkvist (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.** Malmö: Malmö University.

This master thesis should not be overlooked by criminologists interested in replacing on-site audits with virtual audits should. It provides an in-depth discussion of the advantages and disadvantages of using Street View to collect information on the built environment in relation to environmental criminological research.

Odgers et al. (2012). **Systematic social observation of children's neighborhoods using Google Street View: A reliable and cost-effective method.** *Journal of Child Psychology and Psychiatry*, *53*(10), 1009–1017.

Similar to Kronkvist (2013), Odgers et al. (2012) examine the suitability of a virtual neighborhood audit to

collect criminologically relevant characteristics of the built environment, such as physical disorder and decay.

Rundle et al. (2011). **Using Google Street View to audit neighborhood environments.** *American Journal of Preventive Medicine*, *40*(1), 94–100.

Rundle et al. (2011) evaluate the feasibility of using Street View to audit the built environment. Their article is a good introduction to the literature on the matter and contains a comprehensive overview of the strengths and weaknesses related to using this method.

Summers et al. (2010). **The use of maps in offender interviewing.** In W. Bernasco (Ed.), *Offenders on offending: Learning about crime from criminals* (pp. 246–272). Cullompton: Willan Publishing.

Summers et al. (2010) focus on conventional maps rather than web-based mapping technologies. Nevertheless, this book chapter is a must-read since it provides essential background to the use of maps in general in criminological research.

Van Daele et al. (2012). **Technische hulpmiddelen en doelwitselectie bij woninginbraak: Een experimenteel onderzoek naar de invloed van Google Maps en Google Street View.** *Tijdschrift voor Criminologie*, *54*(4), 362–373.

This study has been discussed in this article. It is, to the author's knowledge, the only study to date that addresses substantive criminological questions related to the availability of Google Maps and Street View. Moreover, the authors implemented Google Maps and Street View in their research design. It is published in Dutch.

Endnotes

^aWhen available (indicated by a blue hue around the areas covered in Google Maps), Street View imagery can be viewed by zooming in beyond the highest zooming level available or by dragging and dropping the Street View icon, dubbed 'Pegman', into a location on Google Maps.

^bReaders that are using an Android smartphone or have installed a Google app on their phone, and have opted-in with sharing their location data for instance because they like to receive live updates on weather and traffic information, might want to check out Google Maps Location History (Google 2012b) to get an idea of the kind and amount of data that is currently being stored.

^cThe Google Maps app for smartphones and tablets offers users an offline viewing mode. Users can download some of the map information to their device and access it when no data signal is available. Although offline viewing mode is subject to several limitations (e.g., users cannot search an offline map, and offline maps expire after 30 days), it offers a solution for users that require access to map information when no internet connection is (temporarily) available.

^dMost countries in Africa, the Middle East and Central Asia are not covered in Street View.

Competing interests

The author declares that he has no competing interests.

Authors' contributions

CV is the sole author of this article. CV conceived of the study, performed the literature study and drafted the manuscript.

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