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The Assessment and Mapping of Urban Visual Pollution through an Assembly of Open Source Geospatial Tools

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1 ABSTRACT

Urban surroundings and spaces are losing their identity due to the visual pollution in the urban panorama of already densely populated cities in the developing countries. Quantitative assessment of visual pollution and its spatial mapping are very recent and relatively un-explored branches of urban studies. The diversity of visual pollution objects (VPOs) and their traits, the subjectivity of observers, the scale of urban space and dependency on subjective variables are the key challenges for quantification during visual pollution assessment (VPA). A paper-based score-card type VPA tool using Analytical Hierarchy Process to address these issues has previously been developed. However, considering the challenges associated with the deployment of paper-based tool for VPA (which include the inability to handle variety of data types such as text, numeric, geolocation, images, etc.), the natural progression is the development of a mobile-based solution which matches the fast-growing mobile penetration rate of urban centres and provides a turn-key solution to achieve efficiency and effectiveness in primary data collection. On the other hand, academic research on the spatial mapping of visual pollution has slightly progressed to explore its cartographic dimension. This research presents a spatial decision support system comprising of a combination of open source tools to collect, store and present VPA data for any urban space of any scale. The system employs Open Data Kit (ODK) to build its mobile-based VPA tool which can be used to collect VPO attributes using any Android device. The collected data is streamed to a web-based data management module of the system in real time which is built upon ODK Aggregate and PostgreSQL. Furthermore, the web-based visualisation module of the system is built upon some other major open source tools including OpenGeo Suite and PHP. The visualisation module presents the results of visual pollution index (VPI) in the form of a web-based dashboard containing real-time choropleth maps which can be filtered for any specific VPO.

This research demonstrates the strengths of open geospatial tools to solve challenges of primary data collection on a diverse range of VPOs along with the systematic capturing of their spatial location and visual images. Furthermore, it proves the ability of open source web mapping tools to display visual pollution assessments in most appropriate cartographic representation. Resultantly, it offers the practitioner urban planners a tested mechanism to assess and map the levels of urban visual pollution in an urban space and help them take effective measures to improve the visual image of the city.

Keywords: open source, geospatial tools, urban pollution, visual pollution, pollution assessment

2 INTRODUCTION

For the first time ever, over 50% of the world's population lived in urban areas in 2008 and is projected to rise to 70% by 2050. Additionally, it is predicted that most of this growth (at a rate of 2.27%) will occur in developing countries where there is already a paucity of basic needs and good governance (UN Habitat, 2016; Wakil, Hussnain, Waheed, & Naeem, 2016) The dimension of urban issues has drastically changed in the 21st century due to the complexity of urban environments. The urban challenges of today's world are not only related to service delivery and infrastructure but are more linked with urban governance and management. It is evident from the literature that contemporary urban governance methods to deal with the urban problems are insufficient, resulting into urban sprawls, peri-urban developments, visually unpleasant urban landscape, and disordered urban neighbourhoods and localities (UN-Habitat, 2009). The urban issues are of multi-fold and multi-dimensions. For example, pollution which was limited to air, water, land and noise, now includes visual pollution as a key area to be addressed (Mcmahon, 2011; Nagle et al., 2009).

The overall compound impression of disorder, clutter, blight and excess of any object which hinders human vision and affects aesthetic of urban landscape is termed as visual pollution (Allahyari, Nasehi, Salehi, & Zebardast, 2017; Principe, 2015). All those elements which create visual clutter including solid waste dumps, outdoor advertisements, wall chalking, communication poles and hanging wires, broken roads, dilapidated buildings, etc. are visual pollution objects (VPOs) and their concentration at any point defines the level of visual pollution (Chmielewski, Samulowska, Lupa, Lee, & Zagajewski, 2018; A. Portella, 2007).

The impact of exposure to visual pollution in urban settings is penetrating and vast including physical, mental and social. Studies reveal that it may be a distraction for drivers on a highways (Hasan, 2015), traffic chaos, loss of sense of place and aesthetics (Ogunbodede & Sunmola, 2014), psychological disturbances, and low quality of urban landscape(Chmielewski, Chmielewski, Tompalski, & Wężyk, 2011). Therefore, it ruins the whole living environment of urban neighbourhoods and communities. Moreover, literature also reports the escalating effect of visual pollution on children since they lose their sense of beautification and better surroundings since these qualities are usually associated with deteriorated visual settings, and consequently lose the urge to improve them (Jana & Sc, 2015). Various writers including Lynch, Cullen, Dandis, Carmona and Ashihara, in their books “Theory of the City”, “The Selection Landscape”, “Visual Literacy Principles”, “Public Places and Spaces”, “Aesthetic Landscape” respectively, emphasise the quality of the visual environment as it clearly defines urban spaces and urban centres (Nami, Jahanbakhsh, & Fathalipour, 2016). Further, it is quoted that humans perceive and are influenced by the imageability and legibility of the built environment they live and grow in (A. Portella, 2007). In a nutshell, it is an established fact that human perceptions and development are associated with the quality of the urban environment.

As the visual pollution is a recently emerged urban problem, its quantification and statistical measure have yet to mature (Allahyari et al., 2017; Aydin & Nianci, 2008; Chmielewski et al., 2011). Researchers from both developed and developing countries are contributing to exploring a number of aspects of this urban phenomenon but all those endeavours have some limitations to investigate the subject in terms of subjectivity, complexity, researchers’ biases, scientific quantification of the level of visual pollution, scale of area and VPOs coverage (Bankole, 2013; Nasar & Hong, 1999; V.A. Gokhale, Mayuri Raichur, n.d.). Due to such constraints, especially quantitative assessment of visual pollution, it is generally associated with soft elements of governance like policies, laws, guidelines, etc. rather than physical solutions like the other branches of pollution.

3 RELATED WORKS

3.1 Efforts on assessment of visual pollution and its cartographic presentation

As explained previously, most of the definitional work has been done during the last four decades. However, according to Portella’s work (A. A. Portella, 2007), many researchers have addressed the systematic assessment of various dimensions of visual pollution. For instance, Allahyari, H. and et.al worked on the evaluation of visual pollution in urban squares (Allahyari et al., 2017), Szymon et.al. used inter-visibility analysis and public surveys to measure visual pollution (Chmielewski, Tompalski, Chmielewski, & Wężyk, 2016), Karimipour, H., et.al assessed the visual impact of Tehran Towers using GIS (Karimipour, Mojtahedi, & Dehkordi, 2015), Jurate, at.el. measured the visual impact of billboards along the roads and presented a framework for their regulation (Kamicaityte-Virbasiene & Samuchovi, 2013), and Atta, at.el. worked on the statistical determination of visual pollution (Atta, 2013).

On the other hand, the work on the cartographic representation of visual pollution is at an embryonic stage. A review of cartographic representations offered by advanced GIS tools represents a long list of matching options including density, heat and cluster maps, auto-resizing symbols, and carto-diagrams. However, only a few have been adopted by researchers working on visual pollution. This concern has been raised by Syzmon et.al. in a recent publication where they summarised that only three methods of cartographic visualisation have been adopted for visual pollution mapping so far: i) the point symbol style referring to VPO locations, ii) the visibility map, and iii) the iconographic symbols representing streetscape visual pollution (Chmielewski et al., 2018). While presenting their promising work about the engagement of citizen science and WebGIS for VPA, Syzmon et.al. referred to the absence of visual pollution mapping in an online platform. However, the work by Wakil et.al. in 2016 has already responded to this concern where using online density maps, the accumulation of outdoor advertisements is represented (Wakil, Hussnain, Naeem, & Tahir, 2016)

3.2 Quantitative assessment of visual pollution; introduction to paper-based VPA tool

Recently, the authors have developed a scorecard type paper-based tool for the quantitative measurement of visual pollution in any location. The procedural details about the development of the tool, its contextual coverage and its reliability are in the publication process as a separate output. However, it is important to mention that the developed VPA tool is based on the findings of a two-tier analytical hierarchy process (AHP) exercise with a group of 20 professionals to enlist, classify and rank the VPOs. Additionally, the tool contains the attributes and characteristics of each VPO along with their rubrics values which are used to generate a quantitative value, ranging between 0 and 100, called visual pollution index (VPI) at any given point or node.

In its final shape, the tool offers the coverage of forty VPOs classified in ten broader groups. As far as the validity and reliability of the tools are concerned, the inter-observer reliability, also called inter-rater reliability (IRR), has turned out to be 83%.

3.3 Challenges of using paper-based VPA scorecard in the field

Despite its strengths, the administration of the paper-based VPA tool has resulted in some challenges. The major one has been its inability to handle the variety of data types such as text, numeric, geolocation, images, etc. during the field survey. Typically, a survey enumerator must carry multiple devices along with the VPA scorecard which could help in capturing photos of VPOs and geographic location (GPS coordinates) of the site where visual pollution is being measured. Furthermore, it is difficult to keep all records properly tagged on various data sources. For example, assigning a unique site-code to paper-based VPA scorecard and replicating the same for GPS location and VPO images induces errors. The paper-based filled VPA tool has been shown in see Figure 1.

Figure 1. A picture of a filled paper-based score-card type visual pollution assessment (VPA) tool

Other challenges faced during the administration of paper-based VPA tools included the time and cost inefficiency. Furthermore, the data entry process exposes to human error. Hussnain et.al already explained

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how the similar challenges of paper-based data enumeration can be effectively resolved through a mobile-based or computer-assisted solution (Hussnain, Anjum, Wakil, & Tharanga, 2014).

4 SYSTEM ARCHITECTURE

This research presents a combination of open source tools to develop a system which offers the collection of urban visual pollution data through Android devices, manages the collected data through an online server, and develops quick on-the-fly analysis charts and density maps for various VPOs. The schematic diagram representing the system development flow is given in Figure 2. The system relies primarily on the Open Data Kit (ODK) ecosystem since most of its components are developed using various ODK tools. ODK is an open-source suite of tools initially developed at the University of Washington with the financial assistance of Google (Hartung et al., 2010).

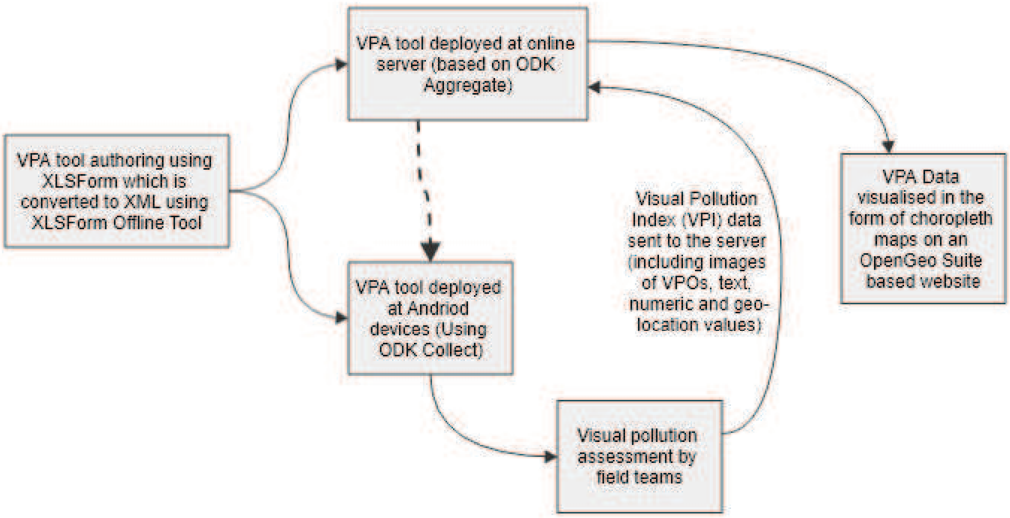

Figure 2. Schematic diagram representing the system development flow

In its simplest form, the system consists of two main components: i) mobile-based component operable on any Android device and ii) the server-side component to receive, store and manage data of various types. Although, there exists a wide range of tools under ODK suit to help and build the various dimensions of above-mentioned components, only the selected tools have been used which were relevant to the tasks at hand for various system requirements. Table 1 summarises the applied tools.

Stages	Task	Opensource tools applied
1. Paper to mobile form conversion	The paper-based scorecard must be translated to a digital form.	XLSform ODK XLSForm Offline v1.7.0
2. Mobile data collection in field	Using Android devices to collect attributes of VPOs, their pictures and their geographic locations	ODK Collect
3. Data management on online server	Receiving data sent from Android devices (via WiFi or other internet sources), management of VPA form, data management and visualization	ODK Aggregate
4. Mapping of visual pollution data	Presence of VPOs must be reflected on maps using symbols (which the density maps has to be developed) based on the VPI values	OpenGeoSuite PHP PostgreSQL

Table 1. Open source tools used at various stages of system development

In the first stage, the paper-based VPA tool has been converted to a digital format (commonly called form authoring). ODK tools require the form to be in XForm compliant XML format. Since direct XML writing turns out to be complicated for the lengthy VPA tool, XLSForm (https://docs.opendatakit.org/xlsform/) has been used for this purpose. XLSForm is a standard which simplifies the authoring of forms in Excel. In this process, an Excel workbook with a pre-specified worksheet, standardised column headings and keywords is prepared as shown in Figure 3. To convert the Excel base form to XML, ODK XLSForm Offline v1.7.0 (https://gumroad.com/l/xlsform-offline) has been used as given in Figure 3. Resultantly, the digital form of VPA tool is ready in ODK understandable XForm pattern.

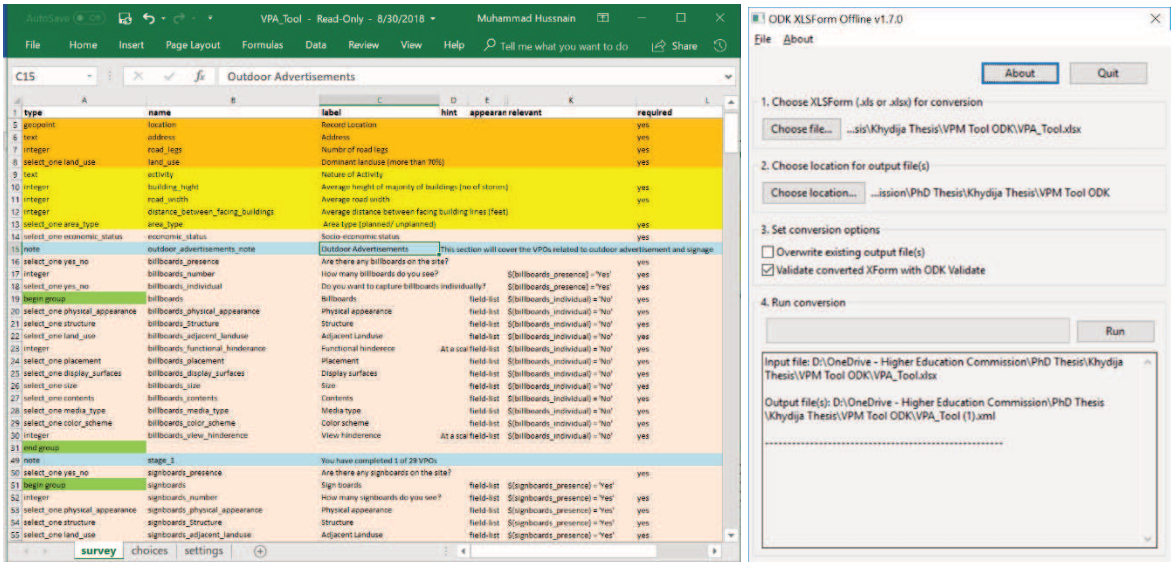

Figure 3. Screenshot of VPA tool in XLSForm format (left) which is then converted to the XML file using ODK XLSForm Offline (right)

In the second stage, the VPA tool is deployed on Android-based mobile devices for field use. For this purpose, ODK Collect (https://docs.opendatakit.org/collect-intro/) has been used. ODK Collect is also available as an open source application which can read an XForm and display the form into a series of input prompts, as exhibited in Figure 4. For every question, ODK Collect ensures form logic, entry constraints and repeating sub-structures at the time of data collection. Once data about all the VPOs is finalised, it is sent to the online server.

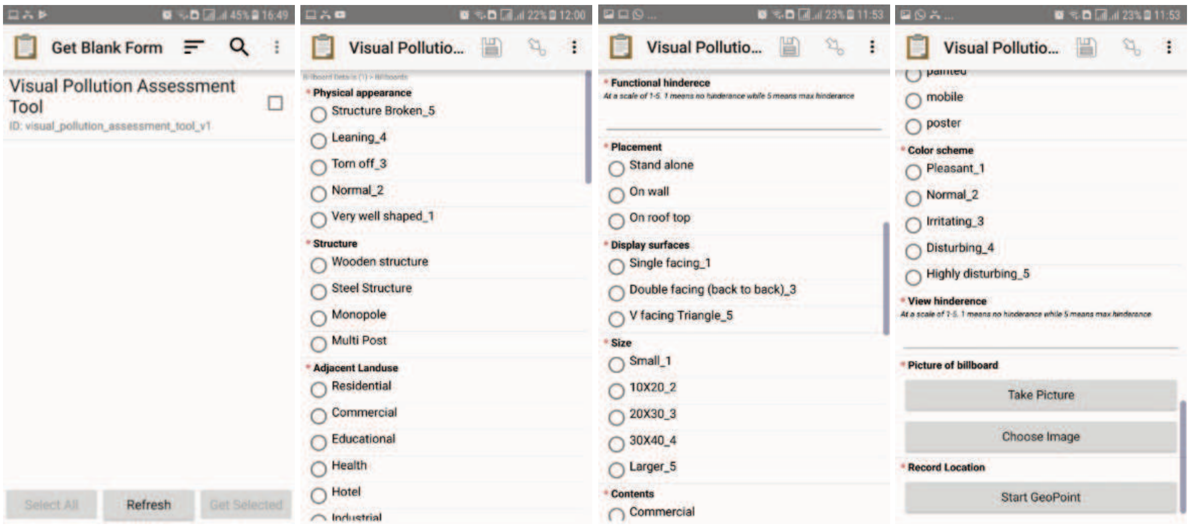

Figure 4. Screenshots of VPA Tool in ODK Collect; every close-ended question is presented with a predefined set of options

ODK Collect resolves the challenge of multiple devices handling in the paper-based survey since it allows the enumerators to collect text, numeric, date, multi-choice, images and geolocation data types which are required for VPA. In addition to that, it allows the real-time calculations and presents the results of the assessment immediately as shown in Figure 5.

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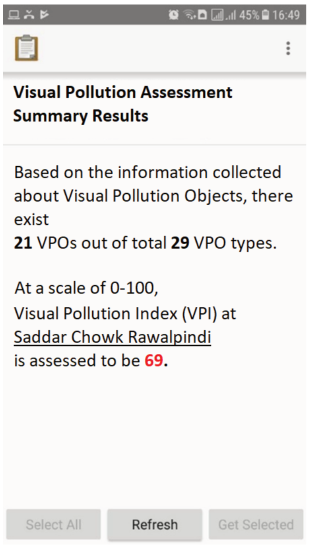

Figure 5. Summary results of Visual Pollution Assessment presented to the data enumerator in real time

In stage three, the digital form of VPA tool (XForm) has been deployed on the online server which is established based on the ODK Aggregate (https://docs.opendatakit.org/aggregate-intro/). ODK Aggregate uses PostgreSQL as its database and helps in server-side operations including form management, submissions management and user management as exhibited in Figure 6. The VPA data received from the field is presented as a list of submissions, similar to a spreadsheet view, such that the data for each node is displayed as a single and separate row.

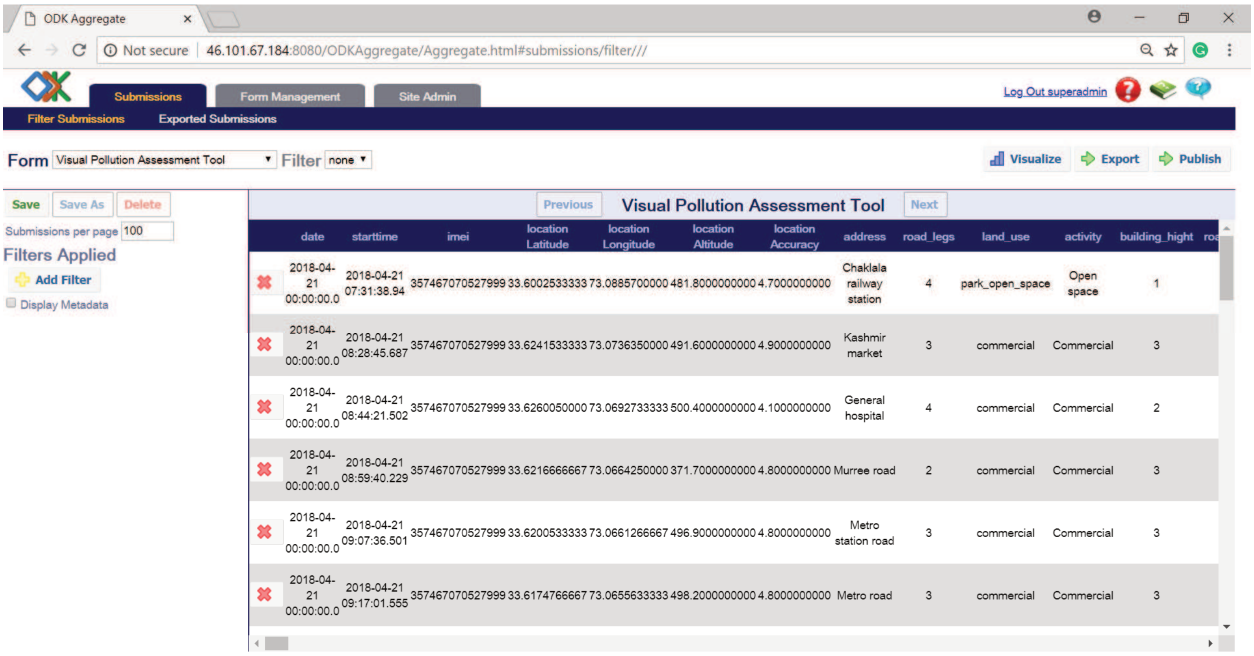

Figure 6. Screenshot of ODK Aggregate based server which allows the management of submissions received through ODK Collect

Furthermore, ODK Aggregate allows the quick visualisation of VPA data. The user can generate a pie chart or a bar graph for any selected column and see the patterns appearing from the collected data as given in Figure 7.

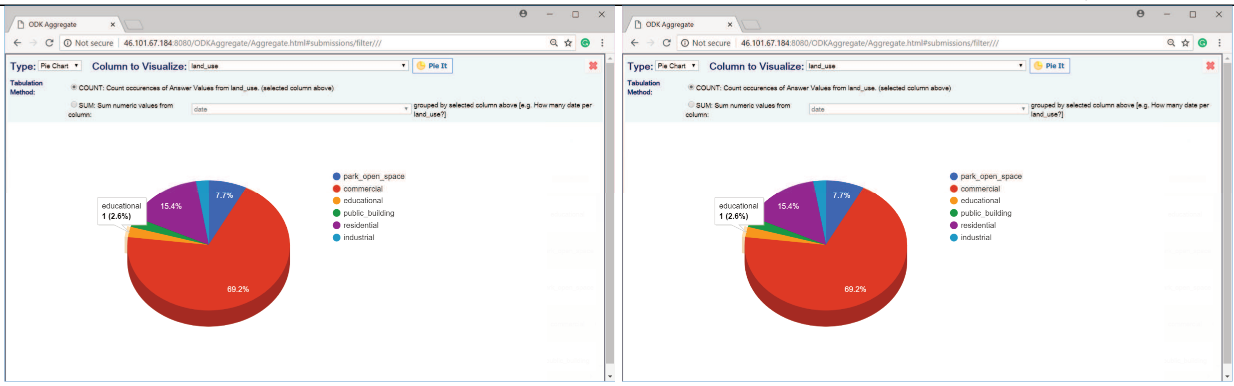

Figure 7. Screenshots of the online server which allows the visualization of VPA data in the form of pie charts or bar graphs

Finally, OpenGeo Suite (http://workshops.boundlessgeo.com/suiteintro/) and PHP are used to create a front-end interface to display VPA data in the spatial form. The front-end application reads the data from the PostgreSQL data of ODK Aggregate and uses geolocation columns to generate point data layers. To make the online map more meaningful, density map has been applied which uses the point location based VPI value to highlight areas containing various levels of visual pollution.

5 CONCLUSIONS AND FUTURE WORK

This research concludes that an efficient and effective quantification mechanism of visual pollution in terms of time and cost at any point of interest in an urban area is achievable with mobile-based and open data tools. The ODK entails the properties of transparency and speed to VPA process. However, the availability of capacitated human resources and institutional support, and setup is inevitable for the wider utilization of the tool. Thus, these are posed among a few of the major challenges for owning and operating the open source based VPA tool. So, it is highly recommended to have intensive training of the concerned professionals especially urban planners and managers to eradicate the reluctance in using the mobile-based VPA tool. Since the VPO categories are subject to increase as per area and location, further customization of the tool is suggested. It is expected that the mobile-based VPA tool development process will be refined as the subject of visual pollution will be better acknowledged, investigated and tested by the city managers especially in the developing countries.

6 REFERENCES

Allahyari, H., Nasehi, S., Salehi, E., & Zebardast, L. (2017). Evaluation of visual pollution in urban squares, using SWOT, AHP, and QSPM techniques (Case study: Tehran squares of Enghelab and Vanak). Pollution, 3(4), 655–667. https://doi.org/10.22059/POLL.2017.62780

Atta, H. A. (2013). Visual pollution and statistical determination in some of Karrada district main streets / Baghdad. Journal of Engineering, 19(3). Retrieved from https://www.researchgate.net/publication/308749604_Visual_pollution_and_statistical_determination_in_some_of_Karrada_district_main_streets_Baghdad

Aydin, C. C., & Nianci, R. (2008). Environmental harmony and evaluation of advertisement billboards with digital photogrammetry technique and GIS capabilities: A case study in the city of Ankara. Sensors, 8(5), 3271–3286. https://doi.org/10.3390/s8053271

Bankole, O. (2013). Urban Environmental Graphics: Impact, Problems and Visual Pollution of Signs and Billboards in Nigerian Cities. International Journal of Education and Research, 1(6), 1–12.

Chmielewski, S., Chmielewski, T. J., Tompalski, P., & Wężyk, P. (2011). Geo-spatial problem of advertising billboards in urban landscape: Lublin (Poland) case study, 1–3. Retrieved from http://visualpollution.pl/files/Evaluating-Spaces_Chmielewski-et-al..pdf

Chmielewski, S., Samulowska, M., Lupa, M., Lee, D., & Zagajewski, B. (2018). Citizen science and WebGIS for outdoor advertisement visual pollution assessment. Computers, Environment and Urban Systems, 67(January), 97–109. https://doi.org/10.1016/j.compenvurbsys.2017.09.001

Chmielewski, S., Tompalski, P., Chmielewski, T. J., & Wężyk, P. (2016). Measuring visual pollution by outdoor advertisements in an urban street using intervisibilty analysis and public surveys. International Journal of Geographic Science, (April). https://doi.org/10.1080/13658816.2015.1104316

Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W., & Borriello, G. (2010). Open data kit: tools to build information services for developing regions. In Proceedings of the 4th ACM/IEEE international conference on information and communication technologies and development (p. 18).

Hasan, A. (2015). Hazardous attraction: External-to-vehicle distraction caused by billboard advertisements in Lahore. Global Media Journal: Pakistan Edition, 8(2), 1–9. Retrieved from https://liverpool.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=ufh&AN=114636172&site=eds-live&scope=site

Hussnain, M. Q., Anjum, G. A., Wakil, K., & Tharanga, P. H. T. D. (2014). Improving Efficiency in Data Collection for Urban Development Plans through Information and Communication Technology. In International Conference on Town Planning and Urban Management (ICTPUM). Lahore.

Jana, M. K., & Sc, M. (2015). Visual pollution can have a deep degrading effect on urban and sub- urban community: a study in few places of bengal, india, with special reference to unorganized billboards, 7881(June), 1–14.

Kamicaityte-Virbasiene, J., & Samuchovi, O. (2013). Free Standing Billboards in a Road Landscape: Their Visual Impact and Its Regulation Possibilities (Lithuanian Case) Júrate Kamicaityté-Virbasiené, Ona Samuchoviené. Environmental Research Engineering and Management, 4(4), 66–78. Retrieved from file:///C:/Users/Khydija/Downloads/5320-19549-1-PB (2).pdf

Karimipour, H., Mojtahedi, M., & Dehkordi, F. A. (2015). Introduction to a quantitative method for assessment of visual impacts of Tehran Towers. Journal of Soil Science and Environmental Management, 6(6), 132–139. https://doi.org/10.5897/JSSEM12.046

Mcmahon, E. T. (2011). Billboards: The Case for Control. Planning Commissioners Journal, (81), 1–4. Retrieved from http://plannersweb.com/wp-content/uploads/2012/07/402.pdf

Nagle, J. C., Adler, B., Appel, P., Barrett, A., Bellia, A. J., Bellia, T., … Vandenbergh, M. (2009). The Idea of Pollution. Environments, 43(November), 1–78. Retrieved from https://lawreview.law.ucdavis.edu/issues/43/1/articles/43-1_Nagle.pdf

Nami, P., Jahanbakhsh, P., & Fathalipour, A. (2016). The Role and Heterogeneity of Visual Pollution on the Quality of Urban Landscape Using GIS; Case Study: Historical Garden in City of Maraqeh, 2016(January), 20–29.

Nasar, J. L., & Hong, X. (1999). Visual Preferences in Urban Signscapes. Environment and Behavior, 31(5), 671–691. https://doi.org/10.1177/00139169921972290

Ogunbodede, E. F., & Sunmola, R. (2014). Posters, Banners and Billboards Visual Pollution in Nigerian Urban Environment: Challenges to Urban Managers.\n. IOSR Journal of Humanities and Social Science (IOSR-JHSS), 19(6), 56–64. Retrieved from http://www.iosrjournals.org/iosr-jhss/papers/Vol19-issue6/Version-4/I019645664.pdf

Portella, A. (2007). Evaluating Commercial Signs in Historic Streetscape; Chapter 1-5. Oxford Brookes University.

Portella, A. A. (2007). Evaluating Commercial Singns in Historic Streetscapes: the Effects of the Control of Advertising and Signage on User's Sense of Environmental Quality. Oxford Brookes University. Retrieved from http://discovery.ucl.ac.uk/10817/1/10817_Front.pdf

Principe, D. (2015). Understanding Pollution Visual Pollution is More than Just a Bad View. Retrieved June 15, 2016, from https://understandingpollution.com/category/types-of-pollution/visual-pollution/

UN-Habitat. (2009). Planning sustainable cities: Global Report on Human Settlements. 2009. Earthscan, London. London, Sterling. https://doi.org/10.1007/s13398-014-0173-7.2

UN Habitat. (2016). Urbanization and Development Emerging Futures. Nairobi.

V.A. Gokhale, Mayuri Raichur, I. R. (n.d.). Examining Impact of Visual Pollution on City Environment: Case Study of Pune, India. Retrieved from https://scholar.google.com.pk/scholar?hl=en&q=Examining+Impact+of+Visual+Pollution+on+City+Environment:+Case+Study+of+Pune,+India&btnG=&as_sdt=1,5&as_sdtp=

Wakil, K., Hussnain, M. Q., Naeem, A. M., & Tahir, A. (2016). Regulating outdoor advertisement boards; employing spatial decision support system to control urban visual pollution. In 8th IGRSM International Conference and Exhibition on Geospatial and Remote Sensing. Kuala Lumpur: IOP Conference Proceedings.

Wakil, K., Hussnain, M. Q., Waheed, A., & Naeem, A. M. (2016). Contextual Review of Outdoor Advertisements: Impacts and Regulatory Practices. Science International, 1(1), 531–535. Retrieved from http://www.sci-int.com/pdf/17789059681 a 64 531-535 Khydija Wakil, -+++REVIEWED -SS--NUST--ISD--30-1-15.pdf