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A volunteered geographic information system for monitoring and managing urban crimes: a case study of Tehran, Iran

Mohammadreza Jelokhani-Niaraki\textsuperscript{a}, Ramin Bastami Mofrad\textsuperscript{b}, Qiuomars Yazdanpanah Dero\textsuperscript{c}, Fakhreddin Hajiloo\textsuperscript{a} and Abolghasem Sadeghi-Niaraki\textsuperscript{d}

\textsuperscript{a}Department of Remote sensing and GIS, Faculty of Geography, University of Tehran, Tehran, Iran; \textsuperscript{b}Department of Remote sensing and GIS, Faculty of Environment and Energy, Tehran Science and Research Branch, Islamic Azad University, Tehran, Iran; \textsuperscript{c}Department of Political Geography, Faculty of Geography, University of Tehran, Tehran, Iran; \textsuperscript{d}Geoinformation Technology Center of Excellence, Faculty of Geodesy & Geomatics, K.N.Toosi University of Technology, Tehran, Iran

\section*{ABSTRACT}
Crime occurrence is an ever-increasing social problem of Tehran city. Crime management for this city requires social action, public participation or community-oriented policing. In this regard, Volunteered Geographic Information (VGI) systems can be of great support to community policing efforts. By employing such systems, members of the society can act as active, intelligent, responsible, location-aware, mobile, and distributed sensors in order to monitor and report local crimes and generate crime data. Analysis of such data can be substantially helpful in crime management within Tehran. Therefore, the objective of this study is to develop a VGI-based system as a means for crime management in District \# 22 of Tehran. Using this system, citizens and police departments can accurately report and analyze various information such as precise location, type, photo, date and time. Citizens’ feedbacks indicate that the system is easy-to-use (highly 55\%, very highly 31\%), suitable for reporting and presenting crime data (highly 90\%) and reducing crime rates (highly 40\%, very highly 35\%), all the while providing an attractive user interface (highly 25\%, moderately 45\%). However, most citizens stated that the system is highly dependent in its need for prior knowledge (highly 75\%). On the other hand, evaluation results by police departments show that the system facilitates the entire crime management process.

\section*{1. Introduction}
Public order and sense of security are essential requirements in both the personal and the social lives of all human beings, which to a great extent are subject to the occurrence of different urban crimes. As populations grow, cities are faced with a wide spectrum of offences and social abnormalities. Tehran, as the capital and the largest city of Iran, is subject to such abnormalities more than any other Iranian cities. Due to changes in the nature of threats to public security, as well as the geodiversity of crime mobility (Frank, Andresen, & Felson, 2012) in Tehran, it is difficult to manage urban crimes by only employing traditional models of police workforce and conventional criminal justice systems. These new and emergent threats stress the need for new and different crime control strategies. Nowadays, urban crime experts believe that centralized...
management of crimes is bound to fail and will be rendered unsuccessful without the citizens’ participation. An increase in public awareness of crime risks and the impact of crime on citizens’ life has accentuated the need for enhanced insight in voluntary and participatory crime monitoring. With the engagement of citizens in urban crime management, they will be able to shoulder the responsibility of public security and complement the duties performed by police officers in the city. Accordingly, a combination of citizens’ participation and police activities with the objective of solving crime-related problems and establishing security within the society would be more effective (Pattavina, Byrne, & Garcia, 2006).

Volunteered citizens can potentially be used as active, social, analytical, intelligent, responsible, context-aware, mobile, and distributed human sensors in order to monitor their environment, and report their findings and share a large quantity of real-time geospatial data of crimes that otherwise would have been difficult to collect using artificial sensors (Jelokhani-Niaraki, 2017a, 2017b). Realizing the value of information generated by human sensors, Goodchild (2007) coined the term Volunteered Geographic Information (VGI) ‘as a special case of the more general web phenomenon of user-generated content’ and referred explicitly to the notion of ‘citizens as sensors’. Actually, VGI is based on the concept that citizens, like artificial sensors or by far better, using their five senses can intelligently collect geographic information on urban crime in a more detailed and precise manner (Fatehian, Jelokhani-Niaraki, Kakroodi, Dero, & Samany, 2018; Goodchild, 2007).

Considering the current status of Tehran in terms of crime and antisocial behaviors as well as lack of accessibility to up-to-date crime data, the necessity of designing and implementing a VGI-based crime management system is increasingly sensed. This paper proposes an online VGI-based system for crime monitoring and management in district # 22 of Tehran. It integrates VGI and spatial analysis capabilities into the web platform, which provides appropriate analytical tools and platforms for direct involvement of the public in the crime monitoring and the decision-making processes. Citizen-generated data is a rich source of prevailing information that would result in more effective solutions compared with traditional methods. The system can utilize and analyze crime-related VGI to support well-informed and real-time decisions that will help ameliorate crime management.

2. Literature review

Public participation and voluntarism in policing has very deep roots in many country’s policing traditions (Britton & Callender, 2016). Several studies have emphasized the importance of community policing (Crowl, 2017; Friedman, 1994; Kearns, 2018; Lombardo & Donner, 2018). For example, Friedman (1994, p. 263) states that 'The whole criminal justice system and all the criminal justice scholars cannot, without an organized, informed community, make significant progress toward safer, friendlier neighborhoods.'

The need for accurate and integrated data of urban crimes on the one hand and their extent, dynamic nature, and changeability on the other hand emphasize more than ever the significance of citizens’ participation in crime data production. There are a number of studies that have focused on participatory crime mapping. Shy, Stimson, Western, Murray, and Mazerolle (2005) introduced a web-based GIS intended for producing crime and offence maps together with employment of spatial analysis of crimes. They argue that accessibility to web-based data could be a favorable approach for presenting large volumes of crime data and geographical information to the public. Aydin (2006) proposed a web-based data recording system aiming at collection of accurate spatial crime data through implementation of a participatory platform. This system enables real-time crime data production and accurate geocoding of point-based crime incidents, offenders and victims’ data. Lockyer-Cotter (2013) presented two web GIS-based application programs for recording crime reports in Toronto. Each program was designed to support interactive incident mapping, as well as anonymous incident reporting. The results showed that
there was a public tendency for voluntary participation in using these programs. Findings also indicated that web-based mapping programs had the potential for increasing volume and quality of the reported crimes. Vidal-Filho, Lisboa-Filho, de Souza, and Dos Santos (2013) developed the MossoróCrimes system for collection of voluntary information relating to public safety. The idea was to use MossoróCrimes as a tool for realization of a spatially enabled society in the context of public security, where the citizen and the police had access to user-generated crime data in real time. Zhou, Lin, and Ma (2014) developed and implemented a web-based system using open source software as a means for crime hotspot mapping and decision support. They used four hotspot mapping techniques, i.e., choropleth mapping, grid mapping, spatial ellipse mapping, and kernel density mapping.

Herrera, Sosa, and Delgado (2015) designed a VGI platform for reporting crime with a view to the interpretation of voluntary geospatial information. They showed how intelligent business analysis could improve productivity and effectiveness of data management in the case of high volumes of data. For this purpose, they considered crime reports in a VGI platform as an application program. Priya, Anand, and Thirumalai (2016) introduced a web and SMS-based GIS for monitoring theft in Tamil Nadu City, India, based on household locational information. In this study, home owners, as the main sources of data, provided the police with required information on the house status (e.g., locked or unlocked) via the web and cell phones, and the police, as the final users, adopted the necessary measures for preventing theft crimes. In addition to the above studies, a number of crime mapping tools have been introduced, including TriTech Software Systems in North America (https://www.crimemapping.com/), Halton local police in Canada (http://crimemapping. Edmontopolice.ca/), New York Map in United States (https://maps.nyc.gov/crime/), Kingston Police in Canada (https://www.kingstonpolice.ca/services/online/crime-mapping/), and Queensland Police in Australia (https://crimemap.info). However, in spite of various advances in crime mapping and application of many GIS-based crime analysis tools for crime management, there has been no VGI tool that supports community policing or citizen engagement in crime management in Tehran. Zhou et al. (2014) argue that timely mapping of crime locations and accurate detection of spatial concentrations of crime via web platforms help identify where crimes tend to agglomerate in space and time, and thus provides critical information for law enforcements and crime reduction efforts. VGI can be used to approximate citizens to political and administrative sectors, for instance, by helping map crime occurrences in a city (de Souza, Lisboa-Filho, de Sousa Câmara, Vidal Filho, & de Paiva Oliveira, 2014).

3. Methodology

3.1. Volunteered geographic information system

The proposed system integrates concepts and methods of four distinct areas of research including, crime management, public (citizen) participation, GIS and web technologies into a single unified framework for monitoring and management of urban crimes (see Figure 1). Crime management involves a wide spectrum of activities such as monitoring, recording, investigation, supervision, and administration of crime as well as crime-related analysis, forecasting, planning and decision making. Delegating part of the responsibilities and the decision-making processes in crime management affairs to citizens and giving heed to their recommendations, ideas and views concerning urban crimes is one of the most effective strategies for crime management. Citizens are aware of their environment and know their place of residence better than any other person and have local knowledge about criminal activities in their surrounding areas. One of the primary tenets of modern community policing is that residents and police work in cooperation to control and prevent crimes. Citizen participation is an essential element to a successful community policing system wherein the public can act as valuable sources of information regarding neighborhood problems and solutions. Considering the importance of the role of citizen involvement in
community policing, most police departments need to provide a new paradigm for citizens to actively participate, collaborate and interact with each other and with the police force in crime control efforts. One way of building this paradigm is to integrate web and GIS technologies, and provide a web-based volunteered geographic information system for concerned citizens to report reliable and updated spatial-temporal crime information. While GIS can be used as a powerful and integrated tool with unique capabilities for storing, manipulating, analyzing and visualizing geographically referenced crime data, the web platform provides an open, asynchronous, distributed, and active environment by which citizens can access relevant GIS data and tools anywhere (any location that has the Internet access), anytime (24 hours a day, seven days a week), and through any PC or handheld device (e.g., smart phones) and network (wired or wireless technologies).

This study involves a four-stage procedure of crime observation, reporting, analysis, planning and decision making in a cyclic process (see Figure 2). Volunteer citizens can potentially be used as human sensors to observe and monitor their environment. Contrary to artificial sensors (e.g., camera) which are only able to observe a limited number of crimes in certain circumstances and places, human sensors are able to observe and interpret the real and detailed context of criminal activities (e.g., robbery, house theft, etc.).

After observation of a crime, volunteered local citizens can report and share a large quantity of real-time geographic crime data via the proposed tools. At the most rudimentary level, three types of relations can be considered in a volunteered crime reporting process: citizen-citizen, location-location, and citizen-location (Zheng, 2011). The citizen–citizen relation shows a virtual community that brings people together in order to share their ideas and concerns. At a basic level of citizen–citizen relation, citizens communicate with each other to share and exchange ideas, concerns, viewpoints, and knowledge as an essential process of social interaction in community policing. The location–location relation implies that the locations of crime reported by citizens can be spatially related. The citizen–location relation means that a citizen can refer a particular type of crime to multiple locations and a location can be referenced by multiple citizens. This tool enables participants to use spatial objects (e.g., points, lines, and polygons) in order to report the
location, size, and shape of crime scenes and link these objects to videos, photos, or text (e.g., anonymous crime tips). The participants who view the same map at a later time are able to read crime tips and comments, and view the geographical locations to which they are linked, and can develop argumentations and discourse further with other participants, hence, creating a sort of citizen-to-citizen relation where certain discourses transpired amongst citizens during bodily meetings are more accurately approximated, with the added benefit of enabling citizens to pinpoint certain locations of interest in such discussion on spatial maps (Leahy, 2011).

Spatial analysis of crime examines the locations, attributes, and relationships of citizen-contributed crime data through GIS-based analytical techniques in order to address a question or gain useful knowledge for crime management or decision-making. These processes could encompass a variety of techniques to query and analyze crime VGI, detect and quantify patterns of crime spots, identify and measure spatial relationships between VGI, make predictions about criminal activities based on VGI, and so on. The results of these analyses are dependent on the locations of voluntarily reported crime objects. Eventually, the results of spatial analysis of urban criminal incidents are used to provide a crime analyst or police departments with more support in detecting crime-related problems and achieving higher effectiveness in crime-related decision-making processes. This is very convenient for designing, planning and implementing a variety of community-based crime prevention strategies.

3.2. Implementation issues

3.2.1. Study area

Tehran is the fastest growing city in Iran. It is divided into 22 municipal districts, each with its own administrative center. District # 22 of Tehran is used as the case study. The district is surrounded by the Central Alborz Mountain from the north, the Kan River from the east, the Tehran-Karaj freeway from the south, and the Vardavard forest area from the west (see Figure 3). The rapidly changing pattern of urban growth in this district, accompanied by increased population, has led to the rise of...
criminal activities. The proposed volunteered geographic information system has been used for monitoring and management of urban crimes in District # 22.

3.2.2. System implementation

The proposed VGI system was developed using the Google Maps Application Programming Interfaces (API) and MySQL database. Figure 4 depicts the architecture of the proposed system. User registration is the first stage of the crime reporting process. Each participant must complete and submit the registration form individually. The anonymous information that individuals provide in this page include age, education, region, and experience with GIS. Upon completing the form, citizens are redirected to the ‘instruction’ page. Returning citizens can log into the system using this web page. The instruction page describes the goal and objectives of the system. In addition, the page provides a step-by-step tutorial that familiarizes users with the system. It presents a walkthrough on how to use the website for reporting criminal activities.

Registered citizens can create and share their own spatial crime data using a single dynamic map-based interface; they can define different information markers or geometries (e.g., point, line, and polygon features) on the base map accompanied by a specific time and date; link these markers to videos, photos, or text. The Geo-referencing section for finding a specific location for those who need to report the exact location of crime incidents on the Google map involves panning and zooming or reading details on a map in order to find the exact location of the incident. Any citizen can mark the location of a crime scene on Google Map and record the
relevant descriptive information in the system. All of the citizen-contributed crime data can then be stored in a MySQL database. Goodchild (2007) describes the Google Maps phenomenon as the ‘democratization of GIS,’ due to its potential for introducing some of the more straightforward capabilities of GIS to the general public. Thanks to Google Maps, non-GIS experts are now able to ‘read, write, alter, store, test, and represent information in whichever ways that they desire and in formats and environments they understand’ (Miller, 2006, p. 188). This makes Google Maps a valuable tool to build the groundwork for the participation of citizens in an online crime report system.

Subsequently, citizen-contributed crime data can be analyzed to generate valuable information for crime prevention activities and decision-making processes. The system does not prevent and control crimes directly, but enables police officers/force to monitor the crime situation in different areas based on citizen-contributed crime information (i.e., VGI), and therefore, develop different specific and localized crime prevention/control strategies according to circumstances of the crime at hand in different neighborhood/areas. Specifically, a set of spatial analysis and query tools has been used for determining nearest police stations and crime hot spots as well as identifying the number and type of specific crimes in certain areas or certain police-divided regions with a particular number and type.

The workflow of the proposed system has been presented in Figure 5. The system includes the following web pages: ‘Crime reporting’, ‘Exploring crime data’, ‘Spatial analysis’ and ‘System evaluation’.

3.2.2.1. Crime reporting. As previously mentioned, the proposed tool helps citizens examine crime in an area and understand where within their neighborhood the crime is taking place, and voluntarily generate geographic crime data on Google Map. Each citizen-reported crime data is defined, represented and stored in the form of geometric shapes such as a point (coordinate), line and
polygon features (see Figure 5). Typically, citizens use points to represent single crime incidents, such as robbery, in a particular location. The line feature is used when citizens need to report the crime events with linear shape (i.e., the crimes that have length but no area). For instance, the criminal offenses of pickpocketing and the open illegal drugs trade along a street can be reported using a line feature. Spicer, Song, Brantingham, Park, and Andresen (2016) argue that crime patterns along major streets depend on the number and size of crime attractors (places that attract a large number of people such as a shopping centers or sporting venues) and generators (small places that are well-known for their criminal opportunities) they contain. Accordingly, these patterns can be reported using linear objects. Polygon features are used to report specific areas where criminal activities occur. For instance, citizens could specify areas where vehicle thefts are more highly concentrated. These data are then date and time stamped, and when reviewed, provide a picture of the urban crime situation. In addition, citizens could attach descriptions, photos, and videos to these features. Uploading photographs or video clips provide adequate grounds for accepting the reports. Consequently, in contrast to the traditional top-down authoritative process of geographic crime data production by police agencies, citizens could play an active role in producing crime geographic data through a bottom-up crowdsourcing approach (Sui, Goodchild, & Elwood, 2013).

Citizen-generated crime maps are, however, not available for public viewing. In other words, these maps do not present the public with direct information of where or what type of crimes occur or have occurred. Ratcliffe (2002) explains that victims of crimes and even sometimes offenders do not prefer their information portrayed to the public. For example, a victim of burglary does not wish their information and location to be released for public viewing as it could potentially showcase the property as vulnerable (Ratcliffe, 2002).

### 3.2.2.2. Exploring crime data

Up-to-date crime data produced by citizens are classified and symbolized for quick crime exploration according to the type of crime. Police agencies are able to query the data and extract certain types of crimes which have occurred in a specific time period.
(see Figure 5). For example, the system allows police officers to determine where and how many vehicle thefts have been reported from 20 April 2016 to 20 December 2016. As another case in point, the system enables police officers to find the type of crime(s) that occur frequently during night-time. These data and queries can be integrated into a data dashboard to provide at-a-glance outlooks of criminal statistics using a variety of graphs and charts.

3.2.2.3. Spatial analysis of crimes. Citizen-generated crime data can be further analyzed for the production of information and knowledge required for crime management. Spatial analysis of these data assists in better understanding urban crime status, and will ultimately help in prevention and controlling of crimes. The system provides a number of spatial analysis tools and functions in the context of urban crime management. The tools can be used to determine special features such as nearest police, crime hotspot, and perform area-based crime and crime rate analyses.

3.2.2.4. Closest police analysis. One of the most important requirements for prompt response to crimes is the accessibility to crime location at the shortest period of time possible. Considering the fact that crime rates are rather high in Tehran and timely response to crimes and reaching crime scenes is time-consuming, finding the nearest police force(s) or stations to a crime location is of utmost importance. Hence, the ‘Closest police analysis’ has been implemented in the system. Using this tool, Tehran’s police call center would be able to review online reports of crime incidents that have occurred in their respective areas and dispatch the closest police cars to these locations.

3.2.2.5. Crime hotspot analysis. This analysis identifies areas with high crime intensity based on citizen-generated crime data. Generating crime maps that contain hotspots are becoming a critical and influential tool for policing; they help develop the overall knowledge and understanding of different areas in a city and possibly why crimes occur there (Ratcliffe, 2004). Police forces could examine hotspots in certain regions and interpret why they happen. Wang et al. (2013) argue that precisely identified crime hotspots can significantly help the public by means of visualizing threat areas, more efficient allocation of police resources, identification of vulnerable areas, and crime prediction. Considering the geographic extent of Tehran and optimal distribution of facilities for a perfect crime control program, it would be necessary to place priority on high-risk neighborhoods or hotspots for better crime control and prevention. Through recognizing these areas for a specific type of crime(s), Tehran police officials can take the necessary actions for more effective crime prevention and control procedures. To observe hotspot areas, users are required to specify a particular type of crime and time frame for crime hotspot analysis (see Figure 5). For example, the tool can aggregate the locations of burglary incidents reported by citizens and easily identify areas that suffer from high rates of burglary.

3.2.2.6. Area-based crime analysis. Considering the fact that missions of Tehran police forces are assigned based on a set of police beats or districts, the need for accurate information and analysis of the crime status in each beat for optimal allocation of facilities and patrol teams seems obvious. This would help police centers to perform separate investigations of the crime status and the type of offences in their areas, and make decisions based on the results of the analysis. In the course of this analysis, the type of crime and the police beat is initially selected, and the number and the locations of reported crimes in that specific beat are then calculated and displayed on the map (see Figure 5). The results of this analysis facilitates the location-allocation process, where crime locations are assigned to one or more police stations/centers. Taking into account the condition of police forces and facilities that offer services and a set of crime points that need them, the goal of location-allocation is to locate police bodies in a way that supports the crime points
most efficiently. Typically, the goal is to make it possible for police forces to reach crime scenes within a defined time frame.

### 3.2.2.7. Crime rate analysis

One of the tools required in crime analysis is the classification of areas based on crime rate and identification of crime hot spots. If the police are to add facilities to their current sources in Tehran, it would require classification of the areas based on the crime rate to optimize the facilities’ allocation and deployment of more of such facilities to the more crime transpiring areas. Using this analysis, priority areas could be determined. For example, it would be possible to use this analysis to identify urban areas with highest rate of car theft. To accomplish this task, the system uses comparison operators (conditional statement) to determine whether the number of crimes of a certain type (e.g., car theft) in a beat or area is equal to, greater than, or less than a police-specified value. Consequently, those areas satisfying the conditions are displayed on the map (see Figure 5).

### 3.2.3. System evaluation

The usability of the proposed system for participatory monitoring and managing of urban crimes was evaluated by both citizens and police departments. Knowing the satisfaction level of the citizens and using their views, criticism, and recommendations can help further improve the system. An online survey tool was included in the system to gather citizens’ feedback during the course of time they used the system. The form included five evaluation questions regarding the suitability of the tool for reporting and presenting citizen-contributed crime data, the perceived need for prior GIS knowledge in using this system, easy utilization of the system, suitability of the system for reducing crimes, and attractiveness of the system’s graphical user interface (see Table 2). Moreover, a questionnaire was distributed to police officers at different police stations and departments in Tehran to find out how satisfied they were with the system (see Table 3).

### 4. Results

The residents of District # 22 were invited to use the VGI-based crime monitoring system. A total of 30 citizens participated in the crime monitoring program and reported crimes. A summary of the recorded crime data is presented in Table 1. Overall, a total of 63 offences were reported on the map. These crimes include gathering of miscreants, rallying of addicts and drug dealers, collision, bullying, car theft, burglary, battery, murder, and bag-snatching. The lowest and highest number of reports in the district are related to murder (0) and gathering of miscreants (14), respectively. Looking at the crime data, it is evident that the citizens tend to attach descriptions (i.e., texts) to the crime locations.

<table>
<thead>
<tr>
<th>Type of crime</th>
<th>Type of geometric shape</th>
<th>Descriptions</th>
<th>Multimedia file</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Point</td>
<td>Line</td>
<td>Polygon</td>
</tr>
<tr>
<td>Gathering of miscreants</td>
<td>12</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Gathering of addicts and drug dealers</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Collision</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bullying</td>
<td>7</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Car theft</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>House theft</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Battery</td>
<td>5</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Murder</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bag snatcher</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>53</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>
The results show that citizens prefer using points (53) rather than fine resolution line or polygons features (10) to report crime. This may be due to the fact that defining points is straightforward and takes less time. The citizens can easily determine the location of crime simply by clicking on the map instead of drawing complex line/polygon features. However, some of the citizens used polygon features to report ‘Gathering of miscreants’, ‘Gathering of addicts and drug dealers’ and ‘Bag-snatching’. Only a few multi-media files, including photos, videos, and sounds (2) were attached to the reports, which may be justified given the nature of the crimes. As shown in the table, people attached multi-media files only for ‘Collision’.

Table 2. Evaluation results by citizens.

<table>
<thead>
<tr>
<th>Question</th>
<th>Very Low</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is it a suitable tool for reporting and presenting citizen-contributed crime data?</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>90</td>
<td>0</td>
</tr>
<tr>
<td>Were you in need of previous knowledge in using this system?</td>
<td>0</td>
<td>25</td>
<td>0</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td>How easy and simple is the utilization of this system?</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>55</td>
<td>31</td>
</tr>
<tr>
<td>How did you like the system’s graphical user interface?</td>
<td>0</td>
<td>15</td>
<td>45</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>How suitable is the tool for reducing urban crimes?</td>
<td>0</td>
<td>0</td>
<td>25</td>
<td>40</td>
<td>35</td>
</tr>
</tbody>
</table>

Note: the numbers show percentages.

Table 3. Evaluation results by police officers.

<table>
<thead>
<tr>
<th>Question</th>
<th>Very Low</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the citizen’s contribution within the system beneficial to the police?</td>
<td>7</td>
<td>9</td>
<td>18</td>
<td>39</td>
<td>27</td>
</tr>
<tr>
<td>How much does the police want to use this system?</td>
<td>18</td>
<td>10</td>
<td>9</td>
<td>33</td>
<td>30</td>
</tr>
<tr>
<td>How much does this system help realize the concept of community policing?</td>
<td>7</td>
<td>9</td>
<td>18</td>
<td>30</td>
<td>36</td>
</tr>
<tr>
<td>How can this system speed up police response?</td>
<td>10</td>
<td>15</td>
<td>21</td>
<td>45</td>
<td>9</td>
</tr>
<tr>
<td>How effective is this system in helping find criminals?</td>
<td>7</td>
<td>21</td>
<td>45</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Can police solely trust citizens’ reports?</td>
<td>18</td>
<td>39</td>
<td>18</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>To what extent can this system facilitate the process of crime control for the police?</td>
<td>6</td>
<td>7</td>
<td>33</td>
<td>36</td>
<td>18</td>
</tr>
<tr>
<td>How useful is the analysis of the closest police station?</td>
<td>6</td>
<td>10</td>
<td>12</td>
<td>45</td>
<td>27</td>
</tr>
<tr>
<td>How useful is the crime rate analysis in the districts?</td>
<td>10</td>
<td>12</td>
<td>36</td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td>How useful is the area-based crime analysis?</td>
<td>4</td>
<td>24</td>
<td>36</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>How useful is the analysis of crime hot spot?</td>
<td>9</td>
<td>10</td>
<td>18</td>
<td>36</td>
<td>27</td>
</tr>
<tr>
<td>How easy is it for the police to use the system?</td>
<td>7</td>
<td>12</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Are the tools implemented in the system sufficient for controlling the crimes in this system?</td>
<td>10</td>
<td>18</td>
<td>45</td>
<td>18</td>
<td>9</td>
</tr>
<tr>
<td>Is this system able to connect to other police systems?</td>
<td>18</td>
<td>36</td>
<td>15</td>
<td>21</td>
<td>10</td>
</tr>
</tbody>
</table>

Note: the numbers are given in percentage.

The results show that citizens prefer using points (53) rather than fine resolution line or polygons features (10) to report crime. This may be due to the fact that defining points is straightforward and takes less time. The citizens can easily determine the location of crime simply by clicking on the map instead of drawing complex line/polygon features. However, some of the citizens used polygon features to report ‘Gathering of miscreants’, ‘Gathering of addicts and drug dealers’ and ‘Bag-snatching’. Only a few multi-media files, including photos, videos, and sounds (2) were attached to the reports, which may be justified given the nature of the crimes. As shown in the table, people attached multi-media files only for ‘Collision’.

Table 2 shows the responses of citizens to the evaluation questions. According to the citizens’ views, the system is: suitable for reporting and presenting the citizen-contributed crime data (highly 90%), simple and easy-to-use (highly 55%, very highly 31%), a useful tool for reducing urban crimes (highly 40%, very highly 35%), attractive in terms of graphical user interface (highly 25%, moderately 45%). However, most of the citizens stated that the use of the system requires loads of previous knowledge and skill (highly 75%).

Table 3 summarizes the evaluation results of this system from the perspective of the police. It consists of a 14-item questionnaire with five answers for police officers to evaluate the system. A total of 15 police officers from different administrative sections completed the questionnaire and expressed their opinions, suggestions, and solutions to improve the quality and the efficiency of the system. According to police officers, this system is well suited for citizens in regards to reporting crimes, and citizen-contributed information can be useful for preventing and controlling crimes (27% very high and 39% high). Police also tend to use these systems (30% very high and 33% high) and the development of such systems contributes to the realization of the concept of citizen-centered police or community policing (36% very high and 30% high). According to
their views, this system can accelerate the speed of police response in the face of crime (45% high). However, it may not effectively help police find the criminals (21.2% low and 45.4% moderate). This may be due to the fact that the system focuses more on crime scene (location) and not the offenders. Future systems might adopt more advanced and complex spatial analysis tools to detect criminals’ locations based on similar spatial patterns of crimes.

Based on the police’s opinion, volunteered crime information may not be very reliable, and does not completely ensure correctness, accuracy, and quality of data (39% low and 18% very low). Looking at the evaluation results, we note that the system facilitates the process of crime control for the police (36% high). The evaluation of the analyses embedded in the system shows the following features as useful and effective tools for crime analysis from the perspective of the police; closest police (45% high), crime hotspot (36% high), and crime rate analyses (36% average, 24% high). However, most of the police officers did not find the area-based crime analysis feature (36% average, 24% low) a useful tool to be used for crime management. As regards the simplicity of the system, most of them found it simple and easy to use (27% very high and 27% high). However, these tools are not adequate, and more mapping and analytical tools are needed to improve the performance of such systems, taking into account the citizen opinions and police information needs. In order to improve the system for both police and citizens, the usability and the human-computer interaction patterns of the system require evaluation (Meng & Malczewski, 2010). This encourages the employment of certain user-centered designs of the system where system goals, objectives, context, and environment are all aligned with preferences of both the police and the citizens. Central to the citizen-centric crime monitoring and management systems is the need for a user-friendly and easy-to-use interface. Finally, it can be seen from the table that the system has limited ability in connecting with other existing police systems (36% low). Therefore, police departments could redesign their systems and integrate them with the proposed volunteered geographic information system for effective managing of urban crimes. Police officers suggested developing an easy-to-use GPS-enabled mobile application for VGI-based crime monitoring and management system. GPS is the key technology here which could be used to determine the locations of crime scenes, and can be applied by the people to submit real-time reports based on their specific location determined by mobile devices. This is useful for those who need to use GPS-enabled smart phones to report the location of a crime incident.

5. Discussion

The proposed system shows significant potential for realizing the concept of community policing. It can reduce police workload, and increase community co-operation and police awareness of neighborhood problems as well as spatial-temporal crime analysis (Ratcliffe, 2002; Roth, Ross, Finch, Luo, & MacEachren, 2013). Findings on why the proposed map-based tool is suitable for reporting and presenting citizen-contributed crime data may be due to the fact that crimes occur within a geographical context that includes both space and time. Fitterer, Nelson, and Nathoo (2015) state that since the information required for intelligence-led policing are mainly in the form of map-based data, use of certain environments which allow the application of GIS as an added benefit can be profoundly effective (see also Chainey & Ratcliffe, 2005). The use of the map-based tool provides a more real, accurate, and faster way to report crimes. Furthermore, the issue that users need to have prior knowledge regarding how the system works provides an important clue for designers to develop simple crime mapping tools, where citizens are able to use the system without prior knowledge or experience. It is suggested that an effective participatory GIS ought to provide tools that allow non-specialist users to perform analytical tasks equal to those performed by specialists (Jankowski & Nyerges, 2001). In other words, the systems should be designed with easy-to-understand graphical user interface, yet good enough to satisfy all the needs and requirements of the users. The suitability of the proposed tool for reducing urban crime can be attributed to
its ability to provide detailed, local, and real-time observations of crime, and monitor different types of crimes in different areas, and thus allows for making well-informed decisions and creating proper strategies for crime prevention, enforcing the law, and maintaining criminal justice.

The result that volunteered crime information may not be very reliable is consistent with the VGI researchers’ views. According to most VGI researchers, although volunteered data provides a rich source of up-to-date information for scientific research and other applications, it may however not be of fine quality since most data are produced by non-expert citizens (Elwood, Goodchild, & Sui, 2012; Goodchild & Li, 2012; Ostermann & Spinsanti, 2011). For example, citizens may draw geometric features such as points, lines, and polygons for determining crime scenes at different zoom levels within the map. The higher the zoom level of the map, the more precise the input location data. Owing to the fact that non-expert citizens are not familiar with these issues and they may use different levels of map zooming, the accuracy, correctness, and quality of data may vary from one citizen to another. Ratcliffe (2002) indicated many adverse factors related to incorrect specification crime scenes. A case in point was regarding the decrease in insurance premiums and services provided in regions with high crime rates as well as other problems in terms of prices for both residential and commercial properties. This in turn might result in the unwillingness of employees towards working in such crime hotspots. Their results showed that distribution of crime hotspots within the maps can undeniably influence various socio-economic indices, specifically property prices, in a negative manner. Goodchild and Li (2012) suggest three approaches to quality assurance, including crowd-sourcing, social, and geographic approaches.

Another limitation is that citizens have a low or varying familiarity with VGI systems. The system requires a certain level of familiarity with online mapping tools. These challenges can be overcome by providing adequate Web-based learning material on the use of such tools. As stated by Sieber (2006), cooperative GIS projects are dependent on laws, culture, politics, and history of a community, city, region, or nation where they are implemented. While a VGI-based crime mapping tool may be broadly accepted by all stakeholders in one community, the same system may be entirely unacceptable in another community. Motivation for citizen’ engagement is another issue. Police departments should investigate motivational factors that drive volunteers to contribute crime data (Budhathoki, Nedovic-Budic, & Bruce, 2010).

6. Conclusion

In this study, a web-based VGI system for monitoring crimes in Tehran was designed and implemented. This tool allows citizens to create and share spatial crime data. The citizen-contributed crime data can be analyzed to better support crime control, prevention, management and decision-making processes. Evaluation results confirm that the proposed system provides an appropriate platform for involving citizens in monitoring and management of urban crimes. As for the future lines of research, the VGI-based crime management tool can be integrated with other technologies, such as Multicriteria Spatial Decision Support System (MC-SDSS) and social networks. While VGI provides a rich collection of dynamic, detailed, and local information about criminal activities in a geographic context, MC-SDSSs could offer powerful analytical tools for crime-related decision-making procedures. In the context of crime management, VGI-based MC-SDSS can be used, for example, to find the optimal locations for police stations or generate crime risk maps. Location-Based Social Networks (LBSN) have recently attracted millions of users by letting them share their location-related information and use location-based services via social networking tools. Future studies can develop an LBSN tool for citizens to report and share crime-related information in Tehran.
Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Dr. Mohammadreza Jelokhani-Niaraki is assistant professor at department of GIS and Remote sensing, faculty of Geography, University of Tehran, Tehran, Iran. His research area focuses on GIS and crime mapping processes.

Ramin Bastami Mofrad is M.Sc. student at department of GIS and Remote sensing, faculty of Environment and Energy, Tehran Science and Research Branch, Islamic Azad University, Tehran, Iran. His thesis focuses on volunteered crime mapping.

Qiuomars Yazdanpanah Dero is assistant professor at department of political geography, faculty of Geography, University of Tehran, Tehran, Iran. His research area focuses on criminology and crime mapping processes.

Mr. Fakhreddin Hajiloo is M.Sc. student at department of GIS and Remote sensing, faculty of Geography, University of Tehran, Tehran, Iran. His thesis focuses on volunteered crime mapping.

Dr. Abolghasem Sadeghi-Niaraki is assistant professor at Geoinformation Technology Center of Excellence, Faculty of Geodesy&Geomatics, K.N.Toosi University of Technology, Tehran, Iran. His research area focuses on GIS and crime-based decision support systems.

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