

Research Article

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Security and surveillance application in 3D modeling of a smart city: Kirkuk city as a case study

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Abstract: Smart cities use information and communications technology to offer a wide range of applications targeted for improving the quality of life and perfecting urban services. However, the integration of security and surveillance technologies into the fabric of smart city infrastructure is a largely unexplored area. This research investigated the incorporation of security and surveillance applications into three-dimensional (3D) modeling in the context of smart city development in Kirkuk city/Iraq. The research assessed the effectiveness and potential benefits of incorporating security and surveillance systems into the 3D modeling framework of urban areas through the existing literature as well as the analysis of approaches and technology. The study emphasized on the importance of geomatics in smart cities, specifically the function of 3D geographic information system technology. The research highlighted the importance of addressing security and crime prevention concerns in the current discussion about smart city development. The study computed visibility percentages for observer locations between iterations, revealing an improvement from the first to the second iteration, with visibility percentages of 91.91 and 92.91%, respectively. Furthermore, the findings revealed a few outcomes: (1) creating a 3D land-use environment, (2) figuring out a proper spatial distribution of observer points, and (3) building a geodatabase for observer points comprising information about the field of view, vertical angle, horizontal angle, observable distance, and 3D coordinates. Hence, the study shows the relationship between security, surveillance, and 3D modeling in smart city development

and provides useful insights for politicians, urban planners, and researchers alike.

Keywords: smart cities, security, surveillance, 3D modeling, geomatics, urban planning, visibility analysis

1 Introduction

Over 50% of the global population lives in urban areas, and this unprecedented urbanization trend is expected to continue growing. Recently, geomatic techniques have been adopted for building a geo-database using the geographic information system (GIS), which can help planners and decision makers to control this urbanization [1,2]. The rapid urban development has helped many individuals; however, the increasing urban population has led to widespread issues in several regions globally. In order to tackle these challenges, governments are progressively utilizing information and communications technologies (ICTs) to create ‘smart’ cities [3].

Currently, satellite images play a crucial role in generating and updating cartographic and geographic data. Geomatic engineering uses GIS techniques to effectively achieve rapid findings by employing satellite images for feature extraction [4,5].

Using the GIS for satellite image classification is a crucial method used in various research endeavors. This technique is widely researched in the context of image processing, specifically in the analysis of remote sensing data pertaining to land use [6,7].

Integrating the global positioning system (GPS) within smart city applications offers substantial benefits by enhancing urban infrastructure and improving the overall quality of life. It facilitates traffic management, provides parking options, and aids emergency response services. Wearable devices embedded with GPS technology have the capability to consistently track and document an individual’s exact whereabouts, guaranteeing their security and welfare through the provision of up-to-date data.

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GPS technology is employed for urban planning to analyze traffic patterns, assess the air quality, enhance public security, and improve the infrastructure. In summary, GPS technology is crucial for the progression of efficient, environmentally friendly, and enjoyable urban environments [8].

Advanced digital technologies, including processing software, regional databases, along with satellite receivers, may be utilized to produce comprehensive field data as well as digital maps supporting engineering and planning inquiries. These solutions primarily address the problems that develop in spatial geodatabases as a result of frequently occurring along with overlapping for land-use (LU) data [9].

Smart cities offer excellent infrastructure for building a wide range of applications. These applications can aid citizens and governments in improving the quality of life and streamlining the services provided by local authorities. Furthermore, some of the ecosystems around us contain intelligent objects that cannot communicate with other objects and technologies. Smart city techniques can support several applications, including transportation, healthcare, smart environments, public security, and personal/social domains [10].

To highlight the importance of geomatics in smart cities, the three-dimensional (3D) simulation management system is gradually using realistic 3D GIS technology, which has become an essential tool for governmental organizations to accomplish spatial space management and enable lifestyle services in smart cities [11,12]. Effective smart city management systems recognize the importance of a city's visual landscape. These systems leverage high-performance data scheduling and diverse geospatial data to create highly detailed 3D models [13].

The growing of urbanization and developments in ICT can be considered the key elements affecting urban security planning and governance [14]. The ongoing discussion on smart city development often overlooks issues such as security and crime prevention.

The purpose of this research is to investigate the use of security and surveillance applications within the context of 3D modeling in the development of smart cities. This article aims to evaluate the effectiveness and potential benefits of incorporating security and surveillance systems into the 3D modeling framework of urban environments. Therefore, the 3D scenes are crucial to figure out the obstacle objects and their impact on the effectiveness of observer points unlike the two-dimensional (2D) views. This has been achieved by analyzing the existing technologies, methodologies, and case studies, ultimately contributing to a better understanding of the role of technology in improving urban safety and management.

2 Related works

This review aims to examine earlier research on novel security technologies related to the smart city concept. This involved the examination of the impact of technology on urban planning and governance through analyzing related articles. Cities are full of pedestrians and people, which entail high-level city management by monitoring and planning for security surveillance that can help construct smart cities [15]. The growing requirement for public security has created new obstacles to perfecting camera placement in urban environments. This entails creating detailed parameters such as position, azimuth, and observable distance for camera deployment. Proper camera placement and setup can result in cost savings, improved video analysis, and fewer blind spots in specific areas [16,17].

Video surveillance camera positions are related to their role in smart cities, *e.g.*, for traffic jam and accident monitoring, these types of cameras are placed on roads and major intersections, while the public safety cameras are placed in public areas, including streets, parks, cross areas, stations, and commercial districts, to detect criminal, theft, or any suspicious human activity [18]. These systems can use edge devices, applications, datasets, along with future trends, to analyze environmental data like rain, snow, and fog, providing valuable insights for meteorologists and forecasters. The fastest possible detection of even low-level flames is crucial for early fire detection techniques [19]. Al-Hmouz and Challa indicated that selecting optimal locations can take advantage of using the same surveillance system to serve multiple applications such as traffic monitoring and structural bridge monitoring [20].

Heyns has discussed about developing and enhancing surveillance systems to cover three zones with four goal checks by maximizing visibility detection to perfect the system for day and night coverage. These types of multiple surveillance systems lead to the reduction of the number of cameras, contributing to minimizing costs and future maintenance [21]. This can improve the safety and quality of life, support traffic management, prevent abnormal behavior, and check occurrences.

Security management requires extensive study and development, including theoretical models, simulation tools, and other support systems [22]. Many studies have discussed the best methods to improve data collection in smart cities using different types of sensors or cameras depending on different purposes. For example, Laufs *et al.* [23] discussed video surveillance systems, with an emphasis on modern technology and video analysis.

Surveillance cameras are increasingly becoming more important in public security and urban administration

around the world. There is a lack of camera positions, which complicates quantification, space management, and building status analysis. A technique for predicting the position and orientation of outdoor security cameras was proposed, using spatial segmentation and a quick survey device. The approach evaluated each camera's true location and determined the azimuth angle of the camera orientation, resulting in an average accuracy of 1.78 m between the estimated and actual locations based on the binary space partitioning (BSP) principle [24].

The surveillance system uses a multi-camera coverage modeling approach to optimize placement, enabling offline sensor planning. This system computes camera coverage in a 2D scene, calculates camera overlapping, and computes realistic camera effective range and blind zones to demonstrate versatility [25].

3 Visibility analysis

In the context of security and surveillance in smart cities, the concept of “visibility” is crucial for ensuring effective communication and unobstructed visibility. This is particularly

important for the deployment of surveillance cameras, drones, and other monitoring equipment. Research in this area often focuses on predicting the geometric FOV (field of view) probability in different urban environments, which is essential for optimizing the placement of surveillance devices and maintaining reliable communication links [26].

In summary, “visibility analysis” considerations are fundamental for the effective deployment of security and surveillance infrastructure in smart cities, and the ongoing development of 5G and 6G technologies is expected to play a significant role in advancing the capabilities of such systems.

4 Study area

The study area is Kirkuk province, which is one of the provinces of Iraq. It is located between longitudes 42°30'00" and 45°00'00" east of Greenwich and latitudes 34°00'00" and 36°00'00" north of the Equator with a total area of 5,099 km², as shown in Figure 1. This article focuses on the city center of Kirkuk province, which covers approximately 2.5 × 2.5 km². The diversity of land use of Kirkuk city is the main reason for choosing it as the study area.

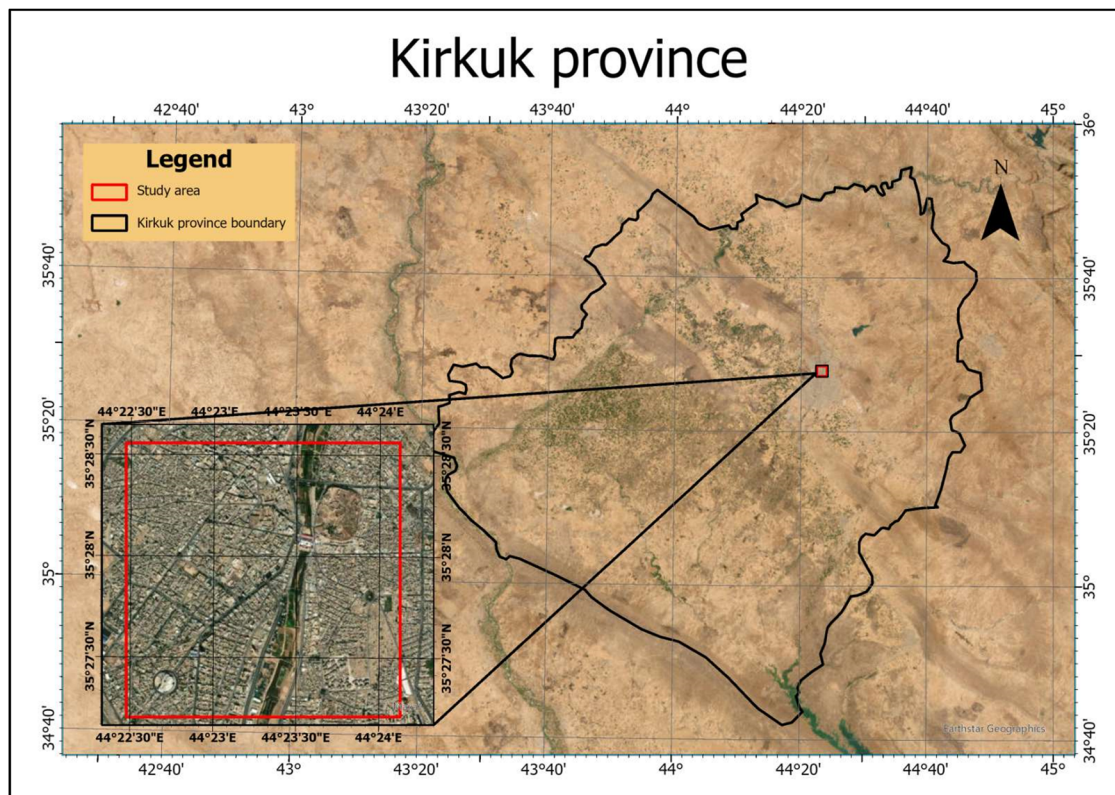


Figure 1: Study area.

5 Methodology

In a 3D urban management system, spatial distribution for the security and surveillance devices is usually used to achieve visibility, which is considered a crucial factor for ultimate object detection. Figure 2 illustrates the flowchart of methodology.

5.1 Data acquisition and software

1. The study used an orthorectified satellite image from the Buckeye system with a spatial resolution of 10 cm. The image was collected on 22 December 2018 and used to extract 2D feature data.
2. The digital elevation model (DEM) obtained from NASA's Earth Observing System was used for this analysis. Table 1 illustrates the specification of DEM.
3. The non-spatial data (attribute data) for the study area were collected by utilizing mobile data collection.
4. The point feature class of height was extracted from a 3D model by analyzing a pair of stereopanchromatic satellite images from a GeoEye-1 sensor, by applying the aerial triangulation process using ERDAS imagine software.
5. ArcGIS Pro 3.2 and ArcGIS online were adopted to create a 3D geodatabase of features and then applying 3D analysis.

5.2 Mechanism of operations

1. ArcGIS Pro 3.2 software
 - Adding satellite images to create a 2D geodatabase, which is designed and built using the editing process.
 - Applying data connection to adding feature height and attributing data to the 2D geodatabase. This process is considered a vital step which converts 2D data into 3D data.
 - Applying experimental spatial distribution for observer points based on choosing the highest buildings as a proposal location of security and surveillance observer points. This process involves applying the iteration method to achieve the best location of observer points.
 - Applying visibility analysis to figure out the visible and nonvisible pixels of DEM raster for each observer point depending on the DEM raster and feature data set.
 - Applying viewshed analysis to create a geodatabase of observer points, including the vertical angle, horizontal angle, maximum and minimum distances, heading and tilt values, and 3D coordinates.
2. ArcGIS online
 - Creating paper and interactive maps of 3D LU and 3D spatial distribution of observer points.

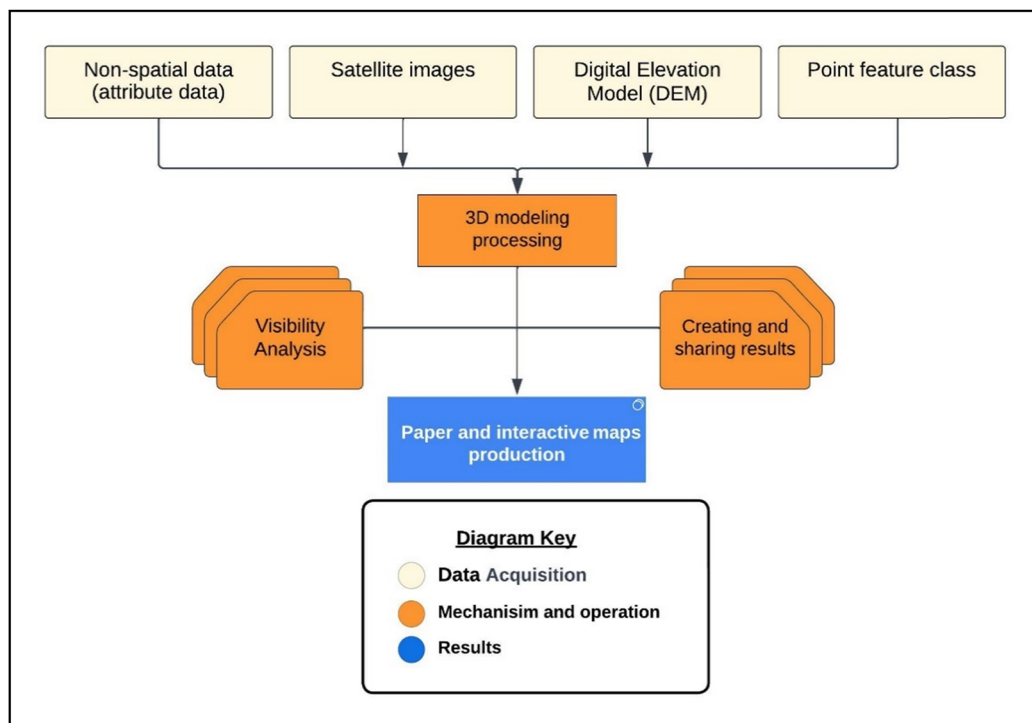


Figure 2: Methodology flowchart.

Table 1: DEM specification

Sensor	Source image ID	Pixel size	Acquisition date/time	Off-Nadir angle	Cloud cover	Clarity
ALOS PALSAR	ALPSRP087630700-RTC_HI_RES	12.5 m	09/16/2007 19:29:20Z	43.3°	0%	Better than 95%

6 Results and discussion

The findings of this investigation advocate a couple of outcomes.

6.1 3D LU

A 3D scene for LU built-up area for the study area was created based on 2D spatial data (Figure 3) and an interactive map was created and published, as illustrated in the link (3D land-use). The 3D LU was used to achieve a lot of urban planning studies.

6.2 Visibility analysis

This section discusses the main findings of the visibility analysis to figure out the efficiency of observer point location to enhance the security and surveillance in smart cities. The findings involved are as follows:

1. Determination of proper spatial distribution of observer points. This distribution depends on choosing the highest building in the study area to achieve the best coverage, Table 2 refers to the first iteration. Using this technique, the best places will be selected to place observer points to ensure the best coverage, as the main factor in the distribution is the height of buildings along the study area.
2. Applying observer point analysis, the finding involved a raster surface, showing exactly which observer points are visible from each raster surface location where value 1 refers to visible and value 0 refers to invisible. Figure 4 displays the results of observer point analysis, the "Count" field refers to the number of pixels in the study area that are detected or not detected by observer points, and another field of table involved the values (1) and (0), which refer to visible and invisible, respectively, according to each observer point.

Figure 5 explains the spatial distribution of observer points and visibility of the surface raster.

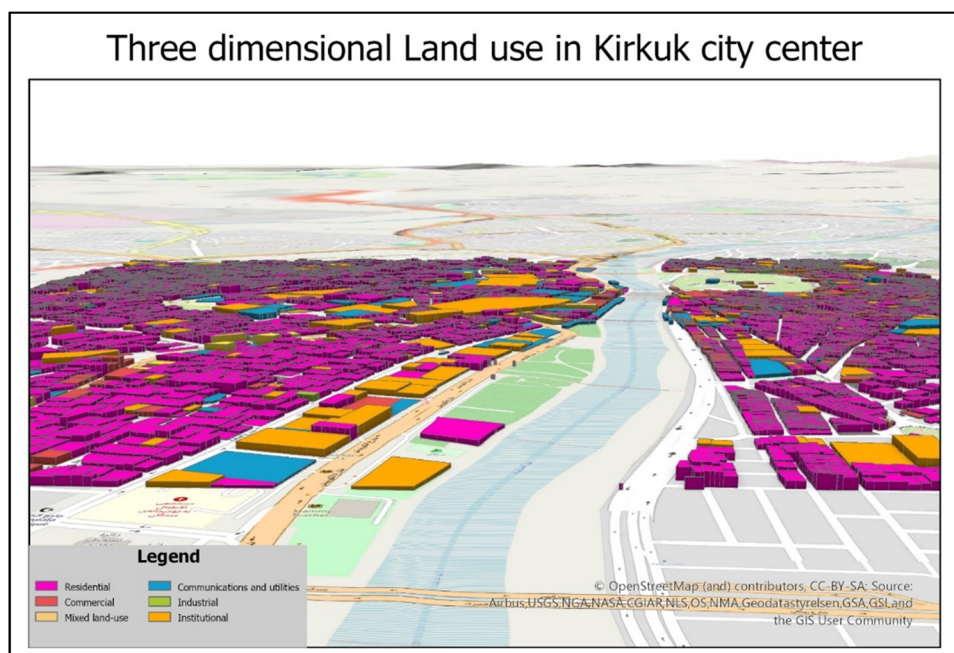
**Figure 3:** 3D scene of LU.

Table 2: 3D coordinates of observer points in the first iteration/Create from a practical aspect

Observer	X (E) m	Y (N) m	Z (elevation) m
obs1	444527.42	3924703.66	366.00
obs2	444460.36	3924651.90	360.00
obs3	444397.60	3924600.94	358.00
obs4	444320.11	3924543.02	361.76
obs5	444254.63	3924489.37	355.37
obs6	444184.82	3924434.42	359.51
obs7	444136.66	3924395.48	356.56
obs8	444092.02	3924361.98	364.04
obs9	444026.18	3924308.63	354.00
obs10	443996.63	3924343.85	363.78
obs11	444068.92	3924397.40	356.33
obs12	444105.70	3924426.86	358.10
obs13	444161.20	3924471.79	359.57
obs14	444210.12	3924506.72	350.51
obs15	444340.43	3924605.10	357.98
obs16	444430.74	3924677.33	356.01

- Applying a statistic process to calculate the number of visible pixels for each observer point. Figure 6 illustrates the statistics of observer point 1.

The same process has been applied for another 15 observer points.

- Calculating the visibility percentage for each observer points for the first iteration to figure out the suitable location of observer points to achieve the best coverage with minimum obstructions, by applying the following equation, and the results are shown in Table 3.

$$\text{Visibility\%} = \frac{\text{Sum of visiblepixels}}{\text{Total pixels in the study area}} \% \quad (1)$$

The summation of visible pixels for each observer point was calculated as shown in Figure 7, while the total pixels were calculated from the total area of interest divided by DEM pixel size (12.5×12.5) m² as follows:

$$\text{Total pixels} = \frac{110,259 \text{ m}^2}{(12.5 \text{ m} \times 12.5 \text{ m})} = 705 \text{ pixels.}$$

	OBJECTID *	Value	Count	OBS1	OBS2	OBS3	OBS4	OBS5	OBS6	OBS7	OBS8	OBS9	OBS10	OBS11	OBS12	OBS13	OBS14	OBS15	OBS16
1	2	1	55	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	7	65	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
4	17	961	1	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0

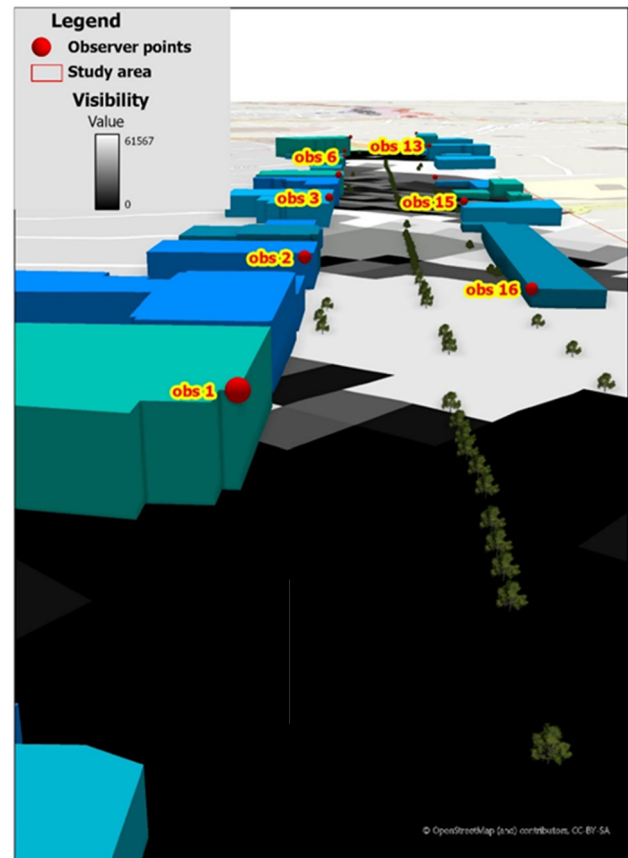
Figure 4: Sample of the results of observer points analysis/Create from a practical aspect.**Figure 5:** Spatial distribution of observer points and visibility of the raster surface.

Table 3 illustrates the number of visible pixels for each observer point, and the total visibility percentage of first iteration is equal to 91.91%.

5. Viewshed analysis

Interactive viewsheds were employed to find the observable regions of a three-dimensional perspective from a specified vantage point. The calculations were performed based on the content currently being shown in a scene, which included the ground surface and symbolic elements like buildings and trees. The extracted analytical parameters involved the observable distance, FOV angles, and directions, which can be used to simulate real-world

	OBJECTID *	OBS1	FREQUENCY	SUM_OBS1
1	1	0	89	0
2	2	1	53	53

Figure 6: Statistics of observer point 1/Create from a practical aspect.

Table 3: Visibility analysis of observer points in the first iteration/Create from a practical aspect

ID	Number of visible pixels	Visibility %
obs 1	53	7.52
obs 2	53	7.52
obs 3	28	3.97
obs 4	56	7.94
obs 5	42	5.96
obs 6	34	4.82
obs 7	52	7.38
obs 8	25	3.55
obs 9	23	3.26
obs 10	28	3.97
obs 11	19	2.70
obs 12	19	2.70
obs 13	77	10.92
obs 14	25	3.55
obs 15	70	9.93
obs 16	44	6.24
	648	91.91

objects. The results of analysis can be converted to feature class involving azimuth, tilt, offset, horizontal angle, vertical angle minimum range, 3D coordinates, and maximum range. Figure 7 illustrates the viewshed for two observer points, which show the visible, not visible, and multiple coverage areas.

Table 4: 3D coordinates of observer points in second iteration/Create from a practical aspect

Observer	X (E) m	Y (N) m	Z (elevation) m
Obs 1	444527.42	3924703.66	366.00
Obs 2	444460.36	3924651.90	360.00
Obs 3	444374.09	3924584.39	360.70
Obs 4	444320.11	3924543.02	361.76
Obs 5	444254.63	3924489.37	355.37
Obs 6	444184.82	3924434.42	359.51
Obs 7	444136.66	3924395.48	356.56
Obs 8	444078.32	3924352.44	364.34
Obs 9	444026.18	3924308.63	354.00
Obs 10	443996.63	3924343.85	363.78
Obs 11	444057.63	3924388.97	356.33
Obs 12	444105.70	3924426.86	358.10
Obs 13	444147.30	3924459.20	364.73
Obs 14	444210.12	3924506.72	350.51
Obs 15	444340.43	3924605.10	357.98
Obs 16	444430.74	3924677.33	356.01

In Figure 7, the color of visible areas was green and the color of invisible areas was red, which refer to obstacle features, such as trees and buildings; multiple coverage area is shown in green color, which refer to overlap coverage between observer points; the colored axis offers the ability to change FOV, vertical and horizontal angles, and other parameters.

- Depending on the first iteration, the visibility of the study area according to the locations of observer points showed that there are out of coverage areas for observer 3 and observer 13. Therefore, to improve the visibility of observer points, change of locations were applied for observer points 3 and 13, as shown in Table 4, which involved the 3D coordinates of second iteration comprising two highlighted points.
- Calculating the visibility percentage of each observer point for the second iteration, as shown in Table 5.

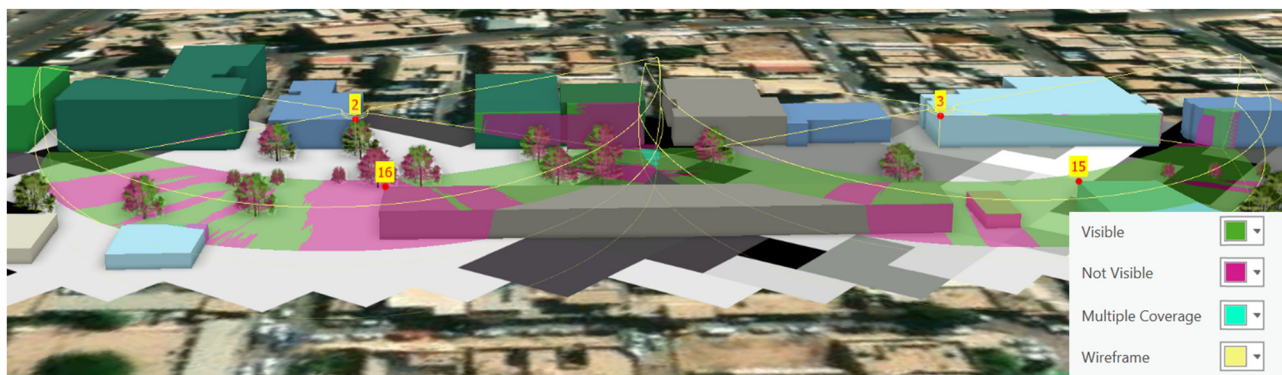


Figure 7: Viewshed analysis.

Table 5: Visibility analysis of observer points in second iteration/Create from a practical aspect

ID	Number of visible pixels	Visibility percentage (%)
obs 1	56	7.94
obs 2	50	7.09
obs 3	29	4.11
obs 4	56	7.94
obs 5	42	5.96
obs 6	38	5.39
obs 7	53	7.52
obs 8	27	3.83
obs 9	25	3.55
obs 10	32	4.54
obs 11	19	2.70
obs 12	21	2.98
obs 13	70	9.93
obs 14	26	3.69
obs 15	68	9.65
obs 16	43	6.10
	655	92.91

Table 5 shows the visible pixels of each observer point, and the total visibility percentage of second iteration was 92.91%. After analyzing the visibility using the raster surface to determine hidden observer points, it was found that the first distribution of observer points covered 91.91%. By adjusting the positions of observer points 3 and 13 in the round, visibility increased to 92.91%. Therefore, enhancing visibility requires more iterations. This slight enhancement carries implications for surveillance by reducing blind spots, potentially leading to quicker responses, during security incidents, and enhancing the overall situational awareness.

In real life situations, placement of observation points could boost safety in crowded locations. For example, during an emergency, the enhanced visibility could lead to detection and handling of danger. This might be especially helpful in areas with heavy pedestrian flow or critical zones that need surveillance.

8. The results involved interactive mapping with spatial data of observer points for second iteration, as shown in the link (Geodatabase of observer points).

7 Conclusions

This research explored the relationship between security, surveillance, and 3D modeling in the context of smart city development in Kirkuk provenance.

This study highlighted the significant impact of security and surveillance applications on shaping future

urban environments. This was achieved by comprehensively examining the existing literature and conducting a deep analysis of methodologies and technologies. Some of the mentioned literature utilized a 2D environment to figure out manually the distribution of observer points, and other utilized automative method to distribute the observer points by apply BSP, while in this article, the author utilized a 3D environment with GIS tools, such as viewshed analysis and iteration methods, to find out the best distribution of observer points to achieve the best visibility.

Researchers have drawn attention for the importance of geomatics in improving the quality of life in smart cities and for easing efficient management of urban space, especially about 3D GIS technology. The results of this study highlight the importance of incorporating cutting-edge surveillance systems into the framework of smart city infrastructure and the important issues related to urban security planning and governance. Cities can strategically utilize surveillance cameras and employ advanced technologies like visibility analysis and video analytics to improve public safety and discourage criminal activity.

The study's relevance in Kirkuk city proved its pragmatic worth in actual circumstances. By meticulously collecting data, utilizing software, and implementing operational processes, the authors want to gain a comprehensive picture of the distribution of observer positions and their impact on urban security. Additionally, the authors will conduct visibility analysis to assess the success of these measures.

Furthermore, this study highlighted the practicability of employing interactive viewshed analysis to detect observable areas from certain vantage points and to replicate real-world perspectives. By harnessing the potential of geospatial information, cities may enhance community safety and resilience through strategic resource allocation and urban design.

Essentially, this study contributed to the increasing volume of research on smart city development by providing valuable insights into the integration of 3D modeling techniques with security and surveillance systems. Future generations can reap the advantages of intelligent, secure, and environmentally friendly urban areas that will be established through the utilization of advanced technologies and the promotion of multidisciplinary cooperation.

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Conflict of interest: The authors state no conflict of interest.

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References

- [1] Hashim AH, Jasim OZ, Salih MM. The establishing of geospatial database for agricultural lands of islamic WAQF in Iraq: Case study Babil Province. *IOP Conf Ser: Earth Environ Sci.* 2022;961(1):012025.
- [2] Husain Hashim A, Zakariya Jasim O, Mejbil Salih M. Developing and establishing a geospatial database of the religious endowments in Hilla, Iraq. *IOP Conf Ser: Earth Environ Sci.* 2021;754(1):012026.
- [3] Saad FH, Jasim OZ, Albayati MM. E-government based on geodatabase of industrial services: Baghdad city as a case study. *AIP Conf Proc.* 2023;2793(1):012025. <http://aip.scitation.org/doi/abs/10.1063/5.0162985>.
- [4] Rehak D, Senovsky M, Balog K, Dvorak J. Analytical tool for risk assessment of landscape and urban planning: Spatial development impact assessment. *Cent Eur J Eng.* 2011;1(2):202–9.
- [5] Jassim FN, Humood SH, Malik HS, Alshareef TQ. The main impacts of a managed aquifer recharge using AHP-weighted overlay analysis based on GIS in the eastern Wasit province, Iraq. *Open Eng.* 2023;13(1):20220484.
- [6] Nashait AF, Jasim OZ, Ismail MM, Saad FH. Integrating various satellite images for identification of the water bodies through using machine learning: A case study of Salah Adin, Iraq. *IOP Conf Ser: Mater Sci Eng.* 2020;737(1):012223.
- [7] Jasim O, Hassoon K, Hussein M. Preparing a comprehensive geodatabase for Iraq geodetic networks systems. *MATEC Web Conf.* 2018;162:03030.
- [8] Hilal AH, Jasim OZ, Ismael HS. Determination of the optimum number and distribution of the ground control points in stereo imaging to achieve precise positions. *J Phys: Conf Ser.* 2021;1973(1):012191.
- [9] Husein H, Jasim O, Mahmood S. Proposal of building a standard geodatabase for urban land use. *MATEC Web Conf.* 2018;162:1–5.
- [10] Saad FH, Jasim OZ, Albayati MMA. Literature review of mobile spatial data collection and related to reality as a basis for the geomatics applications. *IOP Conf Ser: Earth Environ Sci.* 2023;1129(1):012009.
- [11] Hilal AH, Jasim OZ, Ismael HS. Accuracy assessment for points coordinates surveyed using low-cost Unmanned Aerial Vehicle and Global Positioning System with 3DSurvey and 3DF Zephyr software. *IOP Conf Ser: Earth Environ Sci.* 2022;961(1):012046.
- [12] Kalogianni E, Van Oosterom P, Dimopoulou E, Lemmen C. 3D land administration: A review and a future vision in the context of the spatial development lifecycle. *ISPRS Int J Geo-Inf.* 2020;9(2):107.
- [13] Habibzadeh H, Qin Z, Soyata T, Kantarci B. Large-scale distributed dedicated-and non-dedicated smart city sensing systems. *IEEE Sens J.* 2017;17(23):7649–58.
- [14] Gohar M, Muzammal M, Rahman AU. SMART TSS: Defining transportation system behavior using big data analytics in smart cities. *Sustain Cities Soc.* 2018;41:114–9.
- [15] Lee RJ, Sener IN, Mullins JA. An evaluation of emerging data collection technologies for travel demand modeling: From research to practice. *Transp Lett.* 2016;8(4):181–93.
- [16] Liu J, Sridharan S, Fookes C. Recent advances in camera planning for large area surveillance: A comprehensive review. *ACM Comput Surv.* 2016;49(1):1–37.
- [17] Han Z, Li S, Cui C, Song H, Kong Y, Qin F. Camera planning for area surveillance: A new method for coverage inference and optimization using Location-based Service data. *Comput Environ Urban Syst* [Internet]. 2019;78(Aug):101396. doi: 10.1016/j.compenvurbysys.2019.101396.
- [18] Ezzat MA, Abd El Ghany MA, Almotairi S, Salem MAM. Horizontal review on video surveillance for smart cities: Edge devices, applications, datasets, and future trends. *Sensors.* 2021;21(9):1–28.
- [19] Myagmar-Ochir Y, Kim W. A survey of video surveillance systems in smart city. *Electronics (Switzerland).* 2023;12(17):3567.
- [20] Al-Hmouz R, Challa S. Optimal placement for opportunistic cameras using genetic algorithm. *Proceedings of the 2005 Intelligent Sensors, Sensor Networks and Information Processing Conference.* Vol. 2005(Jan 2006). 2005. p. 337–41.
- [21] Heyns AM. Optimisation of surveillance camera site locations and viewing angles using a novel multi-attribute, multi-objective genetic algorithm: A day/night anti-poaching application. *Comput Environ Urban Syst* [Internet]. 2021 Jul;88:101638. <https://linkinghub.elsevier.com/retrieve/pii/S0198971521000454>.
- [22] Gaur A, Scotney B, Parr G, McClean S. Smart city architecture and its applications based on IoT. *Procedia Comput Sci.* 2015;52(1):1089–94.
- [23] Laufs J, Borrión H, Bradford B. Security and the smart city: A systematic review. *Sustain Cities Soc.* 2020;55(July 2019):102023.
- [24] Lan X, Zhou L, Lin B, Li J, Lv G. Rapid survey method for large-scale outdoor surveillance cameras using binary space partitioning. *ISPRS J Photogramm Remote Sens* [Internet]. 2024 Jan;207:57–73. <https://linkinghub.elsevier.com/retrieve/pii/S0924271623003222>.
- [25] Altahir AA, Asirvadam VS, Hamid NH, Sebastian P, Saad N, Ibrahim R, et al. Modeling multicamera coverage for placement optimization. *IEEE Sens Lett.* 2017;1(6):2–5.
- [26] Al-Hourani A. On the probability of line-of-sight in urban environments. *IEEE Wirel Commun Lett.* 2020;9(8):1178–81.