Journal of Sustainable Civil Engineering and Technology
e-ISSN: 2948-4294 | Volume 4 Issue 2 (September 2025), 105-115
https://joscetech.uitm.edu.my
https://doi.org/10.24191/jscet.v4i2.JSCET_ICoSCID2025_001

Utilizing Robotic Total Station Technology for Landslide Risk Mitigation in Urban Development

Othman Zainon [1*], Mohamad Taqiff Mohd Radzi [2]

[1] Geomatic Innovation Research Group (GnG), Department of Geoinformation, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia 81310 Johor Bahru, Johor. Malaysia
[2] Department of Geoinformation, Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia 81310 Johor Bahru, Johor. Malaysia

*Corresponding author: othmanz.kl@utm.my

Received: 10 July 2025 / Accepted: 08 August 2025 / Published online: 30 September 2025

Abstract

In Malaysia, landslides have resulted in significant damage to infrastructure and fatalities, highlighting the need for precise and continuous monitoring systems. Landslides are a critical geotechnical hazard that pose significant risks to urban development. Traditional slope monitoring methods, such as manual surveying and satellite-based remote sensing, often lack real-time capabilities and the accuracy required for early warning systems. To address these limitations, this study investigates the application of Robotic Total Station (RTS) technology in landslide risk mitigation. Assessing RTS's ability to accurately identify and analyse slope variations is the main goal of this study. The study was carried out in the landslide-prone region of Sireh Park, Iskandar Puteri, Johor Bahru, where two control stations and a network of thirteen monitoring points were set up. Geospatial displacement data was gathered over two epochs using a Topcon RTS GT-1001; measurements were processed using Magnet Field software. The findings showed different levels of slope deformation; MP9 showed the most displacement with 0.449 m, suggesting localized instability, while MP13 showed the least amount of movement with 0.007 m. These results validate that RTS offers high-precision, real-time monitoring, greatly enhancing early detection and response tactics for urban projects at risk of landslides. RTS is a useful tool for geotechnical risk assessment since it provides automated data gathering, lowers operating costs, and improves accuracy when compared to conventional geodetic methods. In conclusion, urban resilience against landslide risks may be greatly increased by combining RTS with early warning systems and predictive Geographical Information System modelling.

Keywords: Landslide, Monitoring, Robotic Total Station, Deformation

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1. Introduction

Urban expansion is a feature of modern civilization, fuelled by population increase, economic needs, and infrastructure ambitions. As towns expand into steep, mountainous, or formerly uninhabited terrains, the problem of ensuring safety and stability becomes more difficult. Landslides are one of the most destructive geotechnical hazards found in urban areas, capable of resulting in significant loss of life, property damage, and interruption of urban services.

Landslides are gravity movements of soil, rock, or debris down a slope caused by a variety of reasons such as rainfall, earthquakes, excavation, and human-induced landscape changes. Often, these catastrophes are particularly devastating in urban areas due to extensive infrastructure, essential transportation routes, and heavily populated regions located on or near unstable slopes. The increasing causes of landslides highlight the critical necessity to monitor and solve these issues. Deforestation is a significant and increasing factor to landslides (Aneesha et al, 2023). As forests are removed for various objectives, the removal of trees reduces

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slope stability, increasing susceptibility to landslides. The delicate balance of ecosystems upset by deforestation increases the likelihood of slope collapse. To protect against the increasing frequency of landslides, it is critical to monitor and control human activities, particularly those that lead to environmental deterioration. According to Kwan et al., (2022), a slope can collapse for a multitude of reasons, including geological, morphological, human, and physical variables, but only one causes the landslip to occur at the site of failure. A trigger is described as an external stimulation, such as heavy rain, storm waves, earthquake shaking, volcanic eruption, or fast stream erosion, that triggers a near-instantaneous reaction in the form of a landslip owing to a quick increase in stresses or a decrease in slope strength. In certain circumstances, landslides occur for no apparent reason owing to a variety or combination of variables, such as chemical or physical aging of materials, that progressively cause the slope to fail.

Ilah (2021) stated that there are three main causes of landslides. To begin, the instability of locations on steep hillsides has a vital role in the incidence of landslides. Second, the existence of surface water infrastructure, notably swimming pools, creates a possibility of undiscovered leakage difficulties. Finally, rivers with the ability to erode the base of the slope play an important part in weakening the hillside or slope, increasing the vulnerability to landslides. This extensive research highlights the diverse character of the elements that contribute to landslide occurrences, as stated by Ilah (2021).

Historically, landslide risk assessment and mitigation depended on traditional approaches including manual surveying, geotechnical instruments (e.g., inclinometers, piezometers), and remote sensing. While these approaches yield useful information, they frequently lack the frequency, precision, and real-time capabilities required to identify early indicators of slope instability efficiently.

In recent years, technological advances have transformed landslide monitoring. Among them, robotic total station (RTS) systems have gained popularity because to their high accuracy, automation, and flexibility. RTS technology enables continuous or periodic exact measurements of ground movement, allowing for the early discovery of slope deformation patterns. Its combination with Geographic Information Systems (GIS), remote sensing, and data analytics can improve prediction models and the effectiveness of early warning systems.

This research investigates how RTS technology might be strategically used in urban development projects to decrease landslide risk. It delves into the underlying concepts of RTS, its practical use in monitoring slope movements, and the crucial role it may play in protecting metropolitan people and infrastructure.

1.1 Causes and Mechanisms of Landslides

Landslides are complicated phenomena that occur when soil and rock masses slide downslope due to gravity. They can be caused by natural events such as heavy rainfall, quick snowmelt, earthquakes, volcanic activity, or by human actions like as excavation, building, and deforestation. These activities change the natural stability of slopes by eliminating support, raising pore water pressure, or introducing external stresses, all of which can lead to slope failure. Landslip motions are classified as slides, flows, spreads, topples, or collapses, each with its own features. Because tactics varied greatly, analysing these movements is crucial for developing effective strategies for detection and mitigation (Ar. Ankur, 2020). The mechanisms causing landslides include as shown in Figure 1:

(a) Rotational slides are curvilinear slips with concave failure surfaces.

(b) Translational slides are generally plane motions over surfaces parallel to the slope.

(c) Flow landslides occur when materials act fluidically, which is generally caused by saturation or persistent vibrations.

(d) Falls and topples are unexpected detachments of individual boulders or trees, typically from high cliffs.

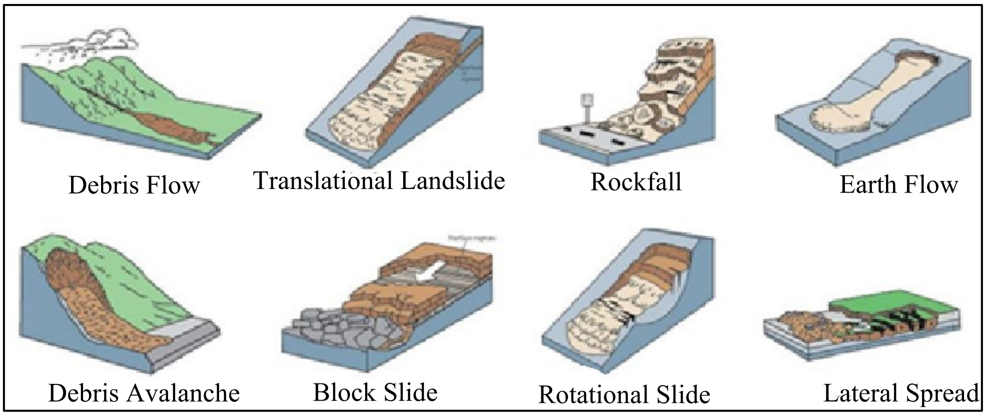

Figure 1. Landslides Typologies (Sources: Ar Ankur ,2020)

Slope stability is determined by a complex balance of pushing forces (downslope gravity component) and resisting forces (soil strength, friction, and cohesion). Disruptions to this equilibrium, whether from natural causes or human activities, can shift the balance toward instability. Soil composition, slope geometry, weather, and local geological stability are some of the variables that affect how much soil movement is deemed to be at high risk for landslides. Nonetheless, a displacement rate of more than 10 millimetres per day is frequently classified as high risk in standard geotechnical monitoring procedures, particularly if the movement exhibits acceleration. A slope failure may be imminent if there are rapid cumulative displacements of 30 to 50 millimetres or more, especially in normally stable locations. Rapid or abrupt changes in soil movement are also reliable markers of increased landslide risk, particularly after intense rains or seismic activity. It is usually advised to take rapid risk reduction measures, including evacuation or slope stabilization, when such thresholds are reached. Thus, it is essential to continuously and accurately monitor soil displacement in order to spot early warning indicators and stop disastrous landslide events.

1.2 Landslide Tragedies in Malaysia

Malaysia's fast economic expansion has resulted in the construction of several new roadways and skyscrapers. The Public Authority has categorized many places with the possibility for landslides, including Gua Musang (Kelantan), Bukit Kempas (Johor Bahru), Cameron Highlands (Pahang), Taman Bukit Permai, and Ampang (Selangor), as reported by Bernama (2022a) in Berita Harian 11 Mac 2022.

Other landslide catastrophes in Malaysia include the natural landslip tragedy in Tanjung Bungah, Penang, on October 21, 2017, which killed 11 persons, according to Bernama (2020a) - see Figure 2. According to Penang's Chief Minister, Chow Kon Yeow, landslides in Tanjung Bungah do not occur abruptly; rather, they occur gradually, with obvious warning signals visible in the surrounding environment. Unfortunately, these warning indicators are either ignored or poorly addressed and managed.

Figure 2. Landslide at Tanjung Bungah

The second catastrophe occurred on January 11, 2021; the distance between the landslide and the residential area is barely approximately 10 meters. The avalanche occurred due to the burst of an approximately 8-inch water pipe owned by Ranhill SAJ Sdn. Bhd. Upon investigation, the damaged pipe was discovered on the hill near Jalan Bukit Kempas 1/4. As a result, the fire service has issued instructions to evacuate residences in close proximity to the landslide region in order to reduce potential hazards and unanticipated accidents. Other tragedies in Malaysia include the burial of four deceased in Taman Bukit Permai in Ampang, Selangor, which also affected 20 residents. The occupants of the housing area were startled by loud booms from the landslide, which occurred twice amid heavy rain last evening. Furthermore, the public captured the incident's key moments.

Finally, a landslide occurred at Fraser's Hill Organic Farm Camping Site in Batang Kali, Selangor, on December 16, 2022, killing 48 persons, as seen in Figure 3 (Bernama, 2022b). It has attracted a lot of interest due to its unusual size. The Commander of the Malaysian Specialised Search and Rescue Team (SMART) revealed that the emergency call reporting the scenario shocked them, indicating that there were more than 100 persons involved. This material delves into the difficulties that SMART had in reacting to this unexpected catastrophe, emphasizing the significance of their efforts - see Bernama, (2022b).

Figure 3. Landslides at Batang Kali

2. Research Method

This study is organised into four phases, phase one is a literature review and research area review, phase two is data gathering, phase three is data processing, and phase four is conclusion and discussion. The research technique is linked between phases. Each phase in a sequential manner to ensure a systematic and organized approach.

2.1 Study Area

The study was conducted in Sireh Park, Iskandar Puteri, Johor, an area known for its diverse terrain and environmental significance. Given the region's susceptibility to geological and environmental challenges, it is essential to obtain detailed and comprehensive data for effective monitoring and analysis. The selected study area is shown in Figure 4, providing a clear representation of the research focus.

Figure 4. Sireh Park, Iskandar Puteri

2.2 Data Collection Using Topcon RTS GT-1001

This section presents and analyzes the data collected during two observation epochs to monitor ground displacement in the study area. The first epoch measurements were conducted on December 18, 2024, while the second epoch was recorded on January 20, 2025, with a one-month interval between them. Data collection was conducted from two occupied stations, referenced to one base station, covering 13 monitoring points in the study area. Each monitoring point was strategically positioned to maintain a clear line of sight from the occupied stations, with any obstacles removed or considered during the observation process. The monitoring points were divided between the occupied stations, where Occupied Station 1 captured Monitoring Points 1 to 5, while Occupied Station 2 captured Monitoring Points 6 to 13, ensuring full coverage of the site.

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During each epoch, check-in data was recorded five times to ensure accuracy and consistency in monitoring. Each monitoring session lasted approximately two hours, allowing for precise tracking of ground movement over time. The collected data was analyzed to assess slope stability, detect early warning signs of landslides, and improve risk management strategies. This structured approach ensures reliable monitoring, supporting safer construction practices and effective landslide mitigation efforts.

By comparing the coordinates from both epochs, displacement values were determined using ΔNorthing and ΔEasting, allowing for the calculation of displacement vectors. These vectors provide insights into the magnitude and direction of movement, which are crucial for assessing slope stability and identifying potential early warnings of landslide activity. The map view for each epoch is shown in Figure 5 for epoch 1 and Figure 6 for epoch 2.

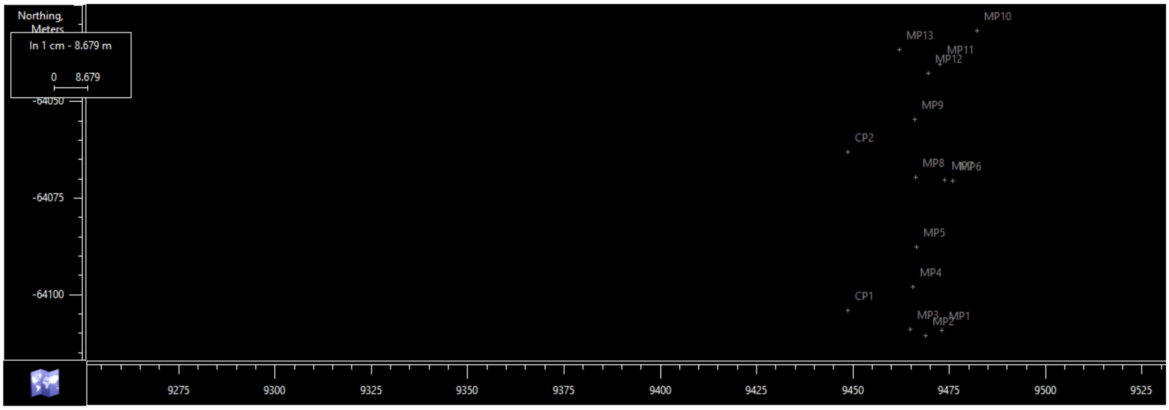

Figure 5. Map view for Epoch 1

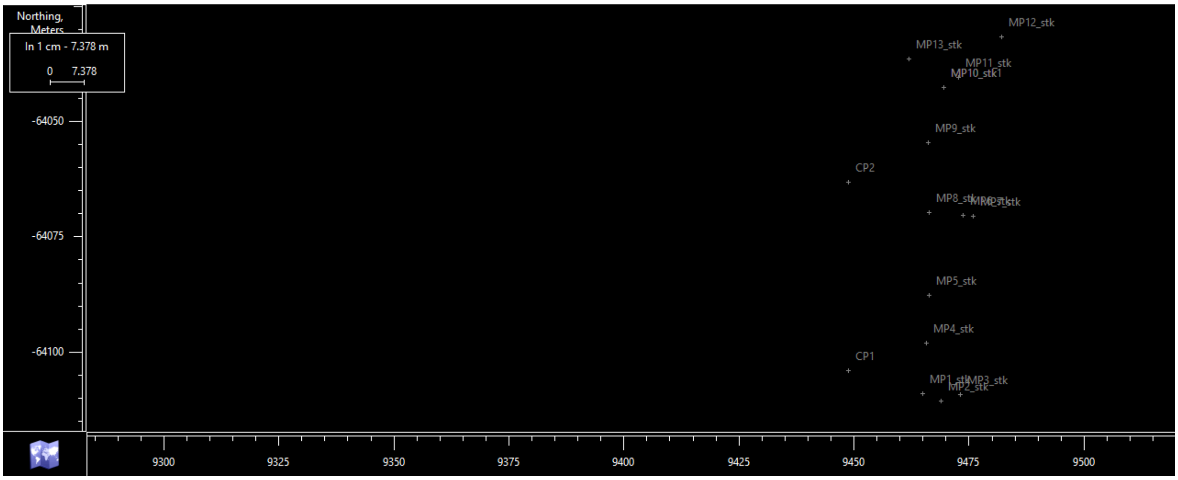

Figure 6. Map view for Epoch 2

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3. Results and Discussion

The static model is a deformation analysis approach that operates independently of time and external forces, focusing solely on the presence or absence of deformation. Its primary objective is to evaluate the magnitude and significance of ground movements. In this study, the geometrical positions of 13 monitoring points in the landslide-prone area were measured and recorded at two different epochs. The coordinates of the monitoring points recorded during Epoch 1 are presented in Table 1, while those from Epoch 2 are shown in Table 2. The difference in the geometrical positions of the monitoring points between Epoch 1 and Epoch 2 is presented in Table 3. The displacement components, ΔNorthing (mm) and ΔEasting (mm), are calculated using the formula (Epoch 2 – Epoch 1). The displacement vector is then determined based on these values, considering both magnitude and direction (azimuth). The results, including the magnitude of displacement and the direction of the vector, are also provided in Table 6 where the CP refer to Control Point and MP refer to Monitoring Point.

Table 1. Coordinate of Monitoring Points Epoch 1

Name	Northing (m)	Easting (m)	Elevation (m)	dN (m)	dE (m)	dHt (m)
CP1	-64104.100	9448.781	17.118	-	-	-
CP2	-64063.100	9448.781	15.893	-	-	-
MP1	-64109.304	9464.917	20.263	0.002	0.001	0.001
MP2	-64110.501	9468.927	22.909	0.002	0.001	0.001
MP3	-64109.300	9473.119	24.755	0.001	0.001	0.001
MP4	-64098.400	9465.670	20.574	0.002	0.000	0.001
MP5	-64087.703	9466.392	19.601	0.000	0.002	0.000
MP6	-64070.622	9473.808	22.363	0.004	-0.003	-0.003
MP7	-64070.354	9475.860	24.068	0.004	0.001	0.000
MP8	-64069.674	9466.320	18.786	0.002	0.002	0.001
MP9	-64054.500	9466.165	19.086	0.002	0.000	-0.001
MP10	-64031.727	9469.606	20.745	0.003	-0.002	0.003
MP11	-64040.300	9472.670	22.260	0.003	-0.002	0.002
MP12	-64042.716	9482.101	23.814	0.003	-0.002	0.000
MP13	-64036.496	9461.944	18.022	0.001	-0.002	0.003

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Table 2. Coordinate of Monitoring Points Epoch 2

Name	ΔNorthing (m)	ΔEasting (m)	Magnitude (m)	Direction of Displacement
MP1	0.000	-0.005	-0.154	North-West
MP2	0.000	-0.002	-0.203	North-West
MP3	-0.314	-0.009	-0.148	South-West
MP4	-0.375	-0.002	-0.079	South-West
MP5	0.000	-0.013	-0.204	North-West
MP6	0.000	-0.006	-0.123	North-West
MP7	0.000	-0.021	-0.156	South-West
MP8	0.000	-0.191	-0.047	South-West
MP9	0.065	-0.034	-0.449	North-West
MP10	0.000	-0.069	-0.117	North-West
MP11	-0.050	-0.01	-0.065	South-West
MP12	0.000	-0.588	-0.057	North-West
MP13	0.000	-0.002	-0.007	South-West

Table 3. Geometrical Displacement of Monitoring Points between Epoch1 and Epoch 2

Name	Northing (m)	Easting (m)	Elevation (m)	dN (m)	dE (m)	dHt (m)
CP1	-64104.053	9448.781	17.118	-	-	-
CP2	-64063.128	9448.781	15.893	-	-	-
MP1	-64109.304	9473.120	24.621	0.002	0.001	0.001
MP2	-64110.541	9468.925	22.706	0.002	0.001	0.001
MP3	-64108.986	9464.908	20.411	0.001	0.001	0.001
MP4	-64098.025	9465.654	20.653	0.002	0.000	0.001
MP5	-64087.703	9466.379	19.805	0.000	0.002	0.000
MP6	-64070.622	9475.842	24.220	0.004	-0.003	-0.003
MP7	-64070.354	9473.802	22.486	0.004	0.001	0.000
MP8	-64069.674	9466.312	18.833	0.002	0.002	0.001
MP9	-64054.565	9466.131	19.535	0.002	0.000	-0.001
MP10	-64031.727	9482.089	23.757	0.003	-0.002	0.003
MP11	-64040.350	9472.660	22.332	0.003	-0.002	0.002
MP12	-64042.716	9469.600	20.860	0.003	-0.002	0.000
MP13	-64036.496	9461.942	18.029	0.001	-0.002	0.001

Among the 13 monitoring points, MP9 exhibits the largest displacement magnitude, measuring 0.449 m in the north-west direction, while MP13 records the smallest displacement magnitude at only 0.007 m, moving towards the south-west. It is observed that monitoring points MP3, MP4, MP7, MP8, MP11, and MP13, primarily located on one side of the study area, show displacement towards the south-west direction. In contrast, monitoring points MP1, MP2, MP5, MP6, MP9, MP10, and MP12 exhibit movement towards the north-west direction. Additionally, MP12, located near the central region of the monitored area, experiences relatively minimal deformation compared to other points. The maximum displacement recorded among the monitoring points is 0.449 m.

The results indicate that among the 13 monitoring points, most exhibited minimal displacement, with the largest movement recorded at MP 9 is at 0.449m towards the northwest, suggesting localized instability. In contrast, MP 13 showed the smallest displacement is at 0.007m in the southwest direction, indicating minimal movement. The displacement analysis between Epoch 1 (December 18, 2024) and Epoch 2 (January 20, 2025) revealed a differential movement pattern:

a. Monitoring Points MP1, MP2, MP5, MP6, MP9, MP10, and MP12 moved towards the northwest.
b. Monitoring Points MP3, MP4, MP7, MP8, MP11, and MP13 moved towards the southwest.

These patterns suggest localized ground shifting, potentially influenced by geological conditions, soil properties, or environmental factors such as rainfall and temperature variations. Several factors may have affected the accuracy of measurements:

a. Environmental Conditions: The study area was exposed to direct sunlight and temperature variations, which could have impacted measurement accuracy, as temperature fluctuations between 25–30°C can affect electronic distance measurements (Arseni et al., 2015).
b. Measurement Distance: Some monitoring points were located farther from the control points, which may have slightly influenced precision.
c. Obstructions: The line of sight to certain monitoring points was occasionally blocked by moving vehicles, potentially causing momentary loss of RTS signal lock and minor data inconsistencies (Chua, 2004).

To verify the significance of the observed displacement, an error ellipse at a 95% confidence level was computed. The results indicate that most monitoring points exhibited displacements exceeding the error ellipse, confirming measurable ground movement. The findings suggest minor but detectable ground movement within the study area, particularly at MP9, which experienced the largest displacement. While no immediate landslide risk was identified, continuous monitoring is necessary to track potential long-term slope movements. The use of high-precision instruments such as the Topcon RTS GT-1001 provided reliable and accurate results for monitoring slope stability. These findings contribute to early landslide detection and improved risk management strategies in the area.

4. Conclusion

Growing urban expansion in geologically sensitive areas underscores the urgent need for innovative, accurate, and continuous slope monitoring technologies. A robotic total station (RTS) offers a transformative solution for mitigating landslide risk in urban areas. RTS stands out as a proactive tool for hazard detection and decision-making support due to its ability to perform high-precision, automated, real-time slope movement monitoring. RTS systems offer several advantages over traditional surveying techniques, including reduced human error, greater frequency of data acquisition, and remote monitoring, which is essential in inaccessible or hazardous terrain.

RTS systems have been demonstrated to be effective in integrating into landslide monitoring frameworks, both as standalone solutions as well as in conjunction with complementary technologies such as GNSS, inclinometers, and remote sensing. A number of case studies from various urban settings demonstrate RTS' versatility, adaptability, and measurable impact in reducing disaster risks, protecting infrastructure, and saving lives. Additionally, RTS-generated data play a vital role in early warning systems, emergency preparedness planning, and the enforcement of development controls in high-risk areas.

Nonetheless, successful implementation requires careful consideration of environmental factors, financial investment, technical expertise, and robust data management.RTS technology integration into policy, urban planning, and risk governance frameworks is not only strategically important, but also crucial as urban areas become increasingly susceptible as a result of uncontrolled growth and climate change.

In summary, a significant step toward resilient and sustainable urban development is the implementation of robotic total station technology in landslide-prone metropolitan areas. It provides a scientific basis and a useful toolkit for stakeholders from many sectors, bridging the gap between geomatics and catastrophe risk management. RTS is expected to become a key component of contemporary geotechnical risk reduction measures as a result of future advancements in AI, IoT, and smart city integration.

Acknowledgments

We would like to thank Sireh Park Organisation, for their invaluable support and contributions throughout this study. Special thanks to Mr Fadhlan for his assistance with data collection and analysis.

Declaration of Conflicting Interests

All authors declare that they have no conflicts of interest.

Author Contributions

Conceptualisation, Othman Zainon; Methodology, Validation, Analysis, Investigation, Mohamad Taqiff Mohd Radzi; Resources, Data Curation, Writing-Draft Preparation, Writing-Review & Editing, Visualisation, Supervision, Project Administration, Funding Acquisition, Othman Zainon. All authors have reviewed and approved the final version of the manuscript for publication.

References

Alkhasawneh, Mutasem Sh. et al. (2014), Modeling and Testing Landslide Hazard Using Decision Tree J. Appl. Math. 2014 (2014): 929768:1-929768:9.

Aneesha Rayalla, S Swaminathan, R Taneja (2023). Predictions for Landslides in the United States.

Ar. Ankur Gautam (2022). Landslides Typologies, Causes and Detection to Prone Areas. Gautam & Gautam Associates.

Artese, Serena, and Michele Perrelli. 2018. "Monitoring a Landslide with High Accuracy by Total Station: A DTM-Based Model to Correct for the Atmospheric Effects" Geosciences 8, no. 2: 46. https://doi.org/10.3390/geosciences8020046

Bernama, (2022a). Landslide occurrences in Malaysia since 2021, 11 Mac 2022 Available at: https://www.hmetro.com.my

Bernama, (2022b). The Batang Kali landslide is the second-largest incident involving fatalities. Available at: https://www.malaysianow.com.my

Butler, Matthew et al. (2019), “Efficient IoT-enabled Landslide Monitoring.” 2019 IEEE 5th World Forum on Internet of Things (WF-IoT): 171-176.

Casagli, N., Intrieri, E., Tofani, V. et al. Landslide detection, monitoring and prediction with remote-sensing techniques. Nat Rev Earth Environ 4, 51–64 (2023). https://doi.org/10.1038/s43017-022-00373-x

Chiara Del Ventisette, Giovanni Gigli, Veronica Tofani, Ping Lu, Nicola Casagli (2015), Radar Technologies for Landslide Detection, Monitoring, Early Warning and Emergency Management.; Part of the Springer Natural Hazards book series (SPRINGERNAT)

Eker R, Aydın A, Hübl J. Unmanned aerial vehicle (UAV)-based monitoring of a landslide: Gallenzerkogel landslide (Ybbs-Lower Austria) case study. Environ Monit Assess. 2017 Dec 19;190(1):28. doi: 10.1007/s10661-017-6402-8. PMID: 29256067.

Huang, G., Du, S. & Wang, D. (2023) GNSS techniques for real-time monitoring of landslides: a review. Satell Navig 4, 5. https://doi.org/10.1186/s43020-023-00095-5

Ilah Hafiz Aziz (2021) Three factors may be the cause of landslides in Kemensah. Akhbar Berita Harian, September 18, 2021, 37

Jing, Ce, Huang, Guanwen, Li, Xin, Zhang, Qin, Yang, Huan, Zhang, Kai, Liu, Guolin. (2023). GNSS/Accelerometer Integrated Deformation Monitoring Algorithm Based on Sensors Adaptive Noise Modeling. Measurement. 218. 113179. 10.1016/j.measurement.2023. 113179.

Kwan Ben Sim, Min Lee Lee and Soon Yee Wong (2022). A review of landslide acceptable risk and tolerable. in Sim et al. (eds) Geoenvironmental Disasters (2022) 9:3

Lerke, Otto and Volker Schwieger (2021). “Analysis of a kinematic real-time robotic total station network for robot control.” Journal of Applied Geodesy 15 (2021): 169 - 188. Maurizio Barbarella, Margherita Fiani and Andrea Lugli (2015) Landslide monitoring using multitemporal terrestrial laser scanning for ground displacement analysis, Geomatics, Natural Hazards and Risk, 6:5-7, 398-418, DOI: 10.1080/19475705.2013.863808

Mukhlisin, Muhammad et al. “Analysis of Rainfall Effect to Slope Stability in Ulu Klang, Malaysia.” (2015).

Onuwa Okwuashi , Inemesit Asuquo (2012) Basics of Least Squares Adjustment Computation in Surveying; International Journal of Science and Research (IJSR) ISSN (Online): 2319 7064

Othman Z., Jamilah J., Radin Jayakasuma R. S., Sakdiah B. (2006). The application of the geotechnical method and satellite tracking data for landslides studies. Universiti Teknologi Malaysia; RESEARCH VOTE NO: 71968 Ogundare, J. O. (2016). Precision Surveying. The Principles and Geomatics Practice.

John Wiley & Sons, Inc.: Hoboken, NJ, USA. Rajashree, Pati, Rajesh Dash, and Kanungo, D. (2021). Application of UAV for landslide mapping, modelling and monitoring. Pehlivan, Hüseyin. (2022). Identification of structural displacements utilizing concurrent robotic total station and GNSS measurements. 10.12989/sss.2022.30.4.411.

Ram R and Lazzari M (eds) (2020). A Landslides - Investigation and Monitoring. IntechOpen. Available at: http://dx.doi.org/10.5772/intechopen.78130

Rodriguez, Jorge & Hendry, Michael & Macciotta, Renato & Evans, Trevor. (2018). Cost effective Landslide Monitoring GPS System: Characteristics, Implementation and Results.S Psimoulis and S Stiros (2013), Using Robotic Theodolites (RTS) in Structural Health Monitoring of Short-span Railway Bridges, in: Joint International Symposium on Deformation Measurements (JISDM), Hong Kong, China, 2011. 38 TOPCON. (2015). MAGNET Field: User’s Manual. Tokyo, Japan: Topcon Corporation. TOPCON (2016) GT Series Robotic Total Station. Tokyo, Japan: Topcon Corporation

Wu, Q., Tang, H., Ma, X. et al. (2018), Identification of movement characteristics and causal factors of the Shuping landslide based on monitored displacements. Bull Eng Geol Environ 78, 2093–2106. https://doi.org/10.1007/s10064-018-1237-2

Xu Q., Guo C., Dong X., Li W., Lu H., Fu H., Liu X. (2021) Mapping and Characterizing Displacements of Landslides with InSAR and Airborne LiDAR Technologies: A Case Study of Danba County, Southwest China. Remote Sens. 2021, 13, 4234. https://doi.org/10.3390/rs13214234