6th Intercontinental Geoinformation Days

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Analyzing optimal routes to safe areas using OpenStreetMap and very high-resolution remote sensing imagery

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Keywords
Route analysis
Satellite images
OpenStreetMap
GIS
Remote Sensing

Abstract

This study presents a study on the practical application of an integrated system of OpenStreetMap (OSM), high-resolution imagery, and Geographic Information System (GIS) for route analysis. The research findings demonstrate the effectiveness of utilizing these technologies to assess earthquake damage, evaluate transportation accessibility, and plan optimal routes to safe areas. By comparing pre- and post-earthquake images and extracting spatial data from OSM, the study accurately identifies the extent and nature of the damage, highlighting the crucial role of high-resolution imagery in resource allocation, route planning, and relief efforts. Furthermore, the research emphasizes the significance of high-resolution imagery and OSM data in urban planning and disaster preparedness. By incorporating up-to-date road networks from OSM and detailed visual information from high-resolution images, the system performs route optimization, identifies obstacles or hazards, calculates distances and travel times, and supports informed decision-making for transportation planning, logistics, or emergency response. For determining the shortest, fastest, and recommended routes to safe areas, the system considers factors such as road networks, distances, travel times, land use, and potential obstacles or hazards. These findings have significant implications for disaster preparedness, urban planning, and effective communication with government agencies and aid organizations.

1. Introduction

Natural disasters, such as earthquakes, have the potential to cause widespread devastation and disruption to communities. Understanding the extent of the damage, identifying critical areas, and facilitating effective disaster response and recovery efforts are essential for minimizing the impact on human lives and infrastructure (Erden and Karaman, 2012). In recent years, advancements in geospatial technologies and open-source data availability have revolutionized how researchers and decision-makers approach disaster management (Kamran and Saeed, 2019).

This study focuses on utilizing a methodology based on secondary data analysis to assess the impact of an earthquake and inform disaster management strategies. The methodology integrates spatial data from OpenStreetMap (OSM) and satellite imagery obtained from reliable sources. By harnessing the power of these datasets, the study aims to provide valuable insights into spatial patterns, damage distribution, and safe routes within the affected area. The primary objectives of this research are to identify blocked road segments, collapsed buildings, and changes caused by the earthquake. This information is crucial for prioritizing relief efforts, coordinating rescue operations, and planning evacuation procedures (Jaiswal and Mukherjee, 2016). Additionally, the study aims to analyze the integration of OSM spatial data and satellite imagery to create comprehensive maps and visualizations that facilitate decision-making processes in disaster management.

2. Data and Methodology

2.1. Study Area

An earthquake-affected region of Kahramanmaraş was chosen as the study area. Kahramanmaraş, commonly known as Maraş, is a province located in the Mediterranean region of Turkey. According to the Geographical Regions of Turkey, it is bordered by Sivas to the north, Adıyaman and Malatya to the east, Adana and Kayseri to the west, and Osmaniye and Gaziantep to the south. Its geographical coordinates lie between

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Cite this study

Safi, O., & Atik, M. E. (2023). Analyzing optimal routes to safe areas using OpenStreetMap and very high-resolution remote sensing imagery. Intercontinental Geoinformation Days (IGD), 6, 117-120, Baku, Azerbaijan

37°35′ N latitude and 36°56′ E longitude, encompassing an area of 14,525 km^2. On February 6, 2023, Kahramanmaraş and its surrounding region experienced two devastating earthquakes with magnitudes of 7.7 and 7.5. The Location of the study area of this research is shown in Figure 1.

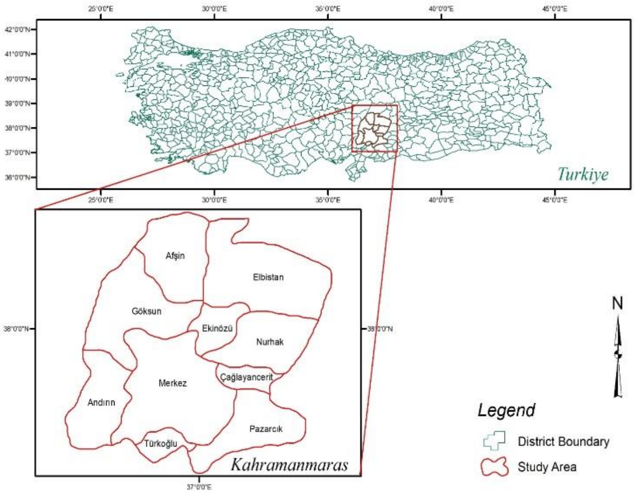

Figure 1. Location map of the study area

2.2. Data preparation and processing

The preparation and processing of spatial data from OSM and satellite images involved in this study are key components of the methodology. These steps were crucial for obtaining accurate and reliable information for analysis. To begin, the OSM spatial data was prepared by extracting relevant features such as road networks and building footprints. OSM is a collaborative project that aims to create a free and open map of the world (Haklay and Weber, 2008). It is built and maintained by a community of volunteers who contribute data on roads, buildings, and other features (Bertolotto et al., 2020). OSM data is used to create new routes and visualize road features (Mahabir, 2016). In the case of earthquake damage assessment, OSM data is used to identify blocked road networks and damaged buildings. One of the key advantages of using OpenStreetMap data is that it provides a detailed view of the road network in the affected area, including information about the width of each road and the presence of any obstacles such as buildings, trees, or other structures.

This information is overplayed on satellite imageries to determine which routes are most likely to be open and to identify any potential hazards that may need to be avoided. In addition to identifying which roads are open and which are blocked, the combination of OpenStreetMap data and high-resolution images is also used to identify safe areas where relief supplies can be delivered and where people can gather for shelter and medical assistance. This information is critical in ensuring that relief efforts are delivered efficiently and effectively, and that aid is directed to those who need it most.

This process involved filtering the OSM dataset to select the specific elements of interest within the study area. The selected features were then extracted and organized in a suitable format for further analysis. Figure 2 shows the road networks of the study area extracted for OSM and Figure 3 illustrates the building footprint of the surrounding region.

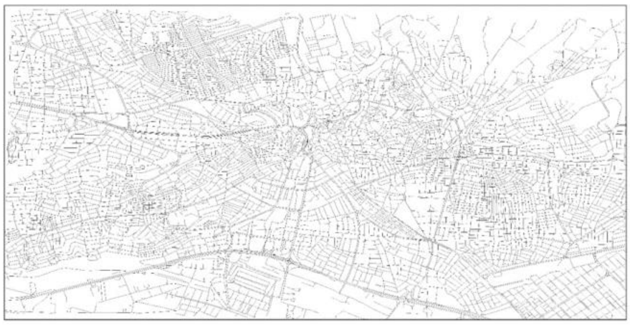

Figure 2. Road networks of the study area

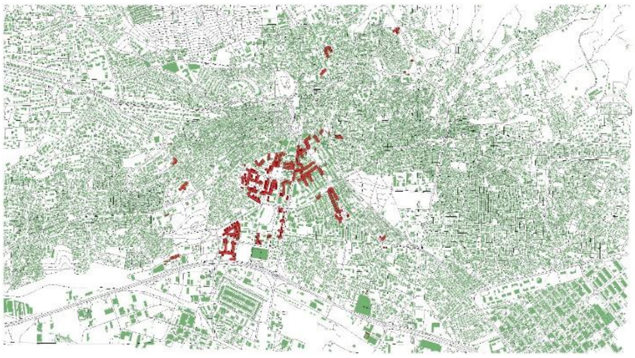

Figure 3. Building footprint of the study area

Simultaneously, the satellite images obtained from the selected source were subjected to thorough preparation and processing. The satellite images were taken from Planet SkySat satellite which has a spatial resolution of 50 cm. The images have RGB bands.

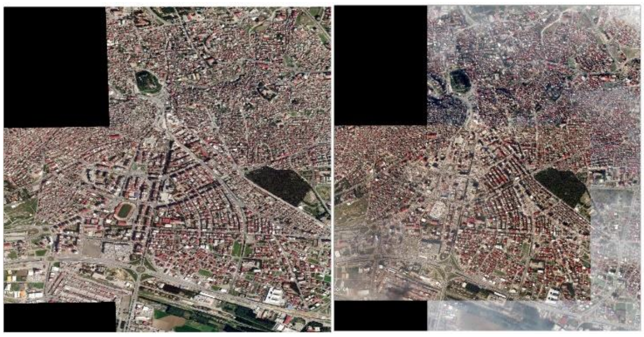

Figure 4. (a) Pre-earthquake high-resolution image
(b) Post-earthquake high-resolution image

2.3. Experiment

Following data preparation, the spatial data from OSM and the processed satellite images were integrated and aligned within a consistent coordinate system. This integration facilitated the overlay and comparison of the OSM features with the corresponding features extracted from the satellite images. The combined dataset was then subjected to further processing and analysis based on the research objectives. This involves tasks such as feature extraction, feature visualization, spatial analysis, and route analysis.

The methodology employed in this research involves a systematic approach. The initial step involves identifying blocked roads, safe areas, and collapsed buildings within the earthquake zone, enabling a clear understanding of the affected areas. Subsequently, a shortest path and fastest path analysis is performed to determine the optimal routes to safe areas, considering factors such as distance, time, and recommended routes. This analysis aids in coordinating evacuation and relief efforts by identifying the most efficient pathways for affected individuals and emergency responders.

3. Results and Discussion

The analysis of the collected data in this study not only provided insights into the immediate impact of the earthquake but also yielded significant findings that contribute to a broader understanding of the event and its consequences. The results obtained from the data analysis play a pivotal role in various domains, particularly in route planning, disaster management, and response strategies.

The examination of the satellite images before and after the earthquake enabled a detailed assessment of the extent of the damage. By comparing the pre and post-earthquake images, the study identified areas where buildings had collapsed or suffered significant structural damage. This information proved vital for prioritizing relief efforts and allocating resources effectively. The integration of OSM spatial data and satellite imagery allowed for the creation of comprehensive maps and visualizations. These visual representations facilitated a clear understanding of the spatial patterns, damage distribution, and safe routes within the study area. The maps provided valuable insights for decision-makers, aiding in disaster management and post-earthquake recovery planning. Figure 5 presents the visualization of the blocked road onto the road network of the study area and Figure 6 illustrates the visual display of collapsed buildings onto buildings' footprints.

Figure 5. Visualization of blocked road onto road network

Utilizing the shortest path analysis, the study identified the optimal routes from affected areas to safe zones. By considering factors such as distance, time, blocked roads, and debris, the analysis facilitated the planning and coordination of evacuation procedures. The results provided guidance for the safe and efficient movement of individuals and emergency response teams during and after the earthquake. Figure 7 presents the shortest route to the safe area. Figure 8 presents the shortest route from affected areas to safe areas.

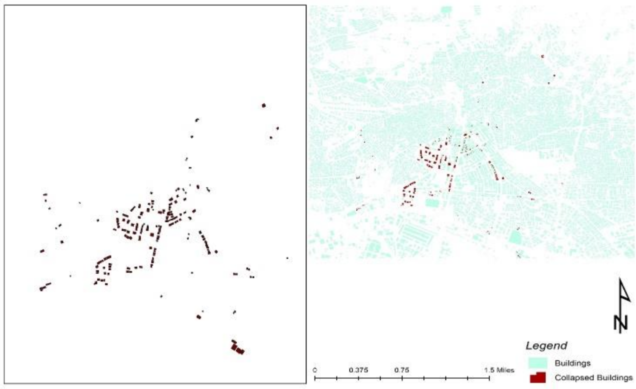

Figure 6. Visual depiction of collapsed building onto building footprint

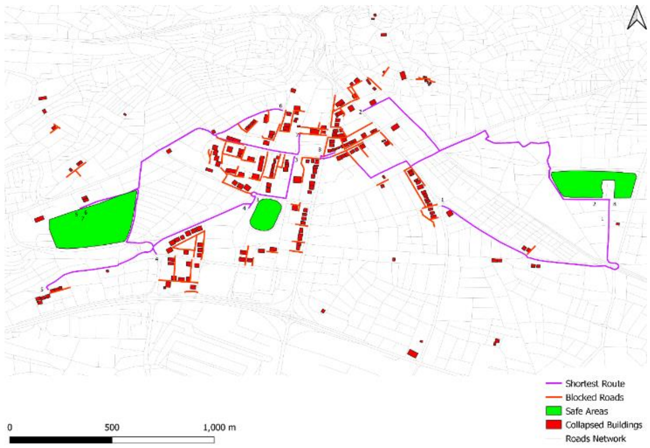

Figure 7. The shortest route to the safe zone

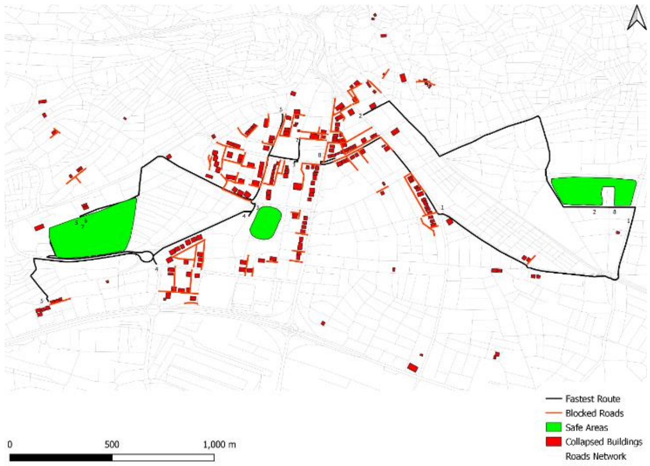

Figure 8. The fastest route to the safe zone

Recommended routes, in the context of post-earthquake scenarios, are meticulously evaluated to prioritize safety and efficiency for emergency evacuation and response efforts. While there may be instances where the recommended route coincides with the shortest or fastest route, the focus goes beyond mere distance or speed. The recommended route takes into account additional factors that can significantly impact safety, such as road conditions, potential structural damage, the presence of debris, and ongoing rescue operations.

The recommended route strikes a balance between efficiency and safety, guiding evacuees and responders through the safest and most feasible path. It may deviate slightly from the shortest or fastest route to avoid hazardous zones or blocked roads, thus providing a reliable and secure passage during the critical post-earthquake period.

Figure 9 provides an illustration of the recommended routes from the regions affected by the earthquake to the designated safe zone. This figure showcases the optimized paths that prioritize safety and efficient evacuation. By following these recommended routes, emergency responders and individuals can navigate through the affected areas with a higher level of safety and reduced risks.

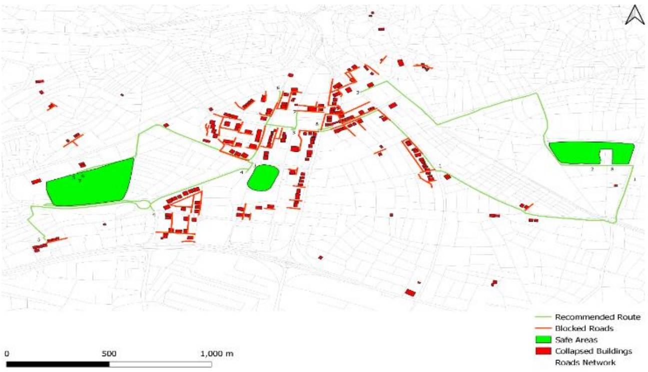

Figure 9. The recommended route to the safe areas

4. Conclusion

In conclusion, this study successfully employed a methodology based on the integration of OSM spatial data and satellite imagery to assess the impact of an earthquake and support disaster management and response efforts. The identification of blocked road segments and collapsed buildings provided crucial information for prioritizing relief operations and allocating resources efficiently. The detailed assessment of damage through pre- and post-earthquake satellite images enabled effective planning and resource allocation.

The integration of OSM spatial data and satellite imagery allowed for the creation of comprehensive maps and visualizations, enhancing the understanding of spatial patterns, damage distribution, and safe routes. These visual representations proved valuable for decision-makers involved in disaster management and post-earthquake recovery planning. In summary, the findings of this study provide valuable insights into the impact of the earthquake, supporting decision-making processes and informing strategies for disaster management and post-earthquake recovery.

Acknowledgment

Thanks to Planet Labs for providing VHR SkySat satellite images of the earthquake zone.

References

Bertolotto, M., McArdle, G., & Schoen-Phelan, B. (2020). Volunteered and crowdsourced geographic information: the OpenStreetMap project. Journal of Spatial Information Science, 20.

Erden, T., & Karaman, H. (2012). Analysis of earthquake parameters to generate hazard maps by integrating AHP and GIS for Küçükçekmece region. Natural Hazards and Earth System Sciences, 12(2), 475–483.

Haklay, M., & Weber, P. (2008). OpenStreetMap: User-Generated Street Maps. IEEE Pervasive Computing, 7(4), 12–18.

Jaiswal, A., & Mukherjee, A. (2016). Geospatial analysis of earthquake-induced damage using high-resolution satellite imagery. Natural Hazards, 81(2), 1095-1118.

Kamran, A., & Saeed, U. (2019). Advancements in geospatial technologies for disaster management: A review. Geomatics, Natural Hazards, and Risk, 10(1), 1690-1710.