Integrating advanced technologies for enhanced demographic research and urban planning

Recent technological advancements in optical, thermal, and Synthetic Aperture Radar (SAR) satellite imagery, Light Detection and Ranging (LiDAR) point clouds, and Unmanned Aerial Vehicle (UAV or drone) imagery have significantly impacted demographic research. These technologies facilitate detailed mapping and monitoring of environmental features crucial for understanding vector-borne diseases, predicting socio-economic outcomes in urban areas, enhancing geo-demographic studies, and supporting real-time population estimation, significantly reducing time and costs compared to traditional methods. Models developed using these technologies integrate various factors to assess and manage public health risks, aiding the authorities and decision-makers (Catry et al. 2016; Potić et al. 2023; Singh and Sisodia 2019; Stevenson, Mues, and Bravo 2022).

Remote sensing technologies via satellite and aerial aeroplane/UAV imagery are transforming urban planning and demographic studies, offering tools that significantly surpass traditional methods in scope and capability. LiDAR technology provides detailed three-dimensional elevation maps and is pivotal in capturing urban and rural areas' complex topography and structure. This high-resolution data is crucial for planning infrastructure and housing developments, enhancing socio-economic analysis. Moreover, integrating LiDAR data with other demographic features affords a more comprehensive view of urban environments, which aids informed decision-making and policy development.

Similarly, UAVs provide detailed aerial views and high-resolution data essential for urban modelling and planning, greatly enhancing spatial planning and knowledge of territories. UAVs facilitate rapid data collection over areas of interest, significantly reducing the time and costs associated with traditional survey methods. This technology is beneficial for creating detailed 3D models of urban areas, supporting large-scale urban planning and studies (Tenedório et al. 2016). Additionally, the UAV technology supports the dynamic monitoring of urban development, allowing for real-time insights into demographic changes and urban extension, making it an invaluable tool in urban planning and development measures (Preethi Latha et al. 2019). This technology also facilitates enhanced population dynamics mapping, critical for urban management and planning in rapidly changing environments, and offers insights into the evolving legal and regulatory framework concerning its use, ensuring that urban planning integrates the latest technological approaches and complies with local and international standards (Noor and Rosni 2017; Zhao et al. 2021).

Modern remote sensing technologies offer broader coverage, higher frequency, and potentially lower costs than traditional population census methods. These technologies provide broader spatial coverage for population estimation, which is especially beneficial in remote areas, or where conducting traditional census surveys is challenging. Using high-resolution satellite imagery to estimate population densities in the regions with poor transportation and communication infrastructure enables effective planning and resource allocation without the high costs and logistical complexities associated with door-to-door survey methods. This approach is particularly crucial in rapidly urbanising regions, or in contexts requiring up-to-date demographic data for emergency response and development planning (Yagoub et al. 2024). Furthermore, the integration of machine learning with remote sensing data for population estimation shows promising results, offering detailed insights comparable with traditional census data, but with added granularity and frequency (Robinson, Hohman, and Dilkina 2017).

Integrating remote sensing data with traditional census data can further enhance demographic analyses and resource management. Such integration can be effectively implemented by using a multi-criteria spatial decision support system, where satellite imagery integrated with census data aids in land use planning and conflict resolution (De Marinis et al. 2018).

When applied to population estimation, remote sensing data demonstrate an enviable accuracy comparable to traditional methods, and offer the advantage of more frequent and cost-effective updates. High-resolution remote sensing data can enable a detailed analysis of population distribution on a fine scale.

Integrating remote sensing data with traditional census data allows policymakers to significantly improve urban planning, census operations, and resource allocation. Combining the data facilitates the creation of more detailed and dynamic urban models, thus improving urban planning decision-making. By merging data from various sources, such as satellite imagery, mobile data, and traditional surveys, policymakers can enhance the planning of infrastructure projects, urban renewal, and land use changes, thereby supporting sustainable urban development (Hensel and Bier 2022).

In the context of emergency response in urbanisation, demography, and population protection, spatial information is crucial, primarily through remote sensing and advanced GIS processing. Identifying and integrating informal structures into urban planning processes significantly enhances risk management and sustainable development. Mapping informal settlements in the areas susceptible to natural hazards, including floods, landslides, and forest fires, allows urban planners and demographers to anticipate and mitigate risks effectively, ensuring a safer and more resilient urban environment (Šimunić and Potić 2021). Similarly, detecting, mapping and analysing unexploded ordnance's (UXO) effects on the environment using optical satellite imagery and digital terrain models via complex GIS analysis, facilitate targeted demining operations and resource allocation. This approach enables authorities to first address the most hazardous zones, reducing risks to human populations. GIS analyses reveal high-risk areas with a concentration of hazardous zones, supporting effective prioritisation of protection efforts. Environmental impact assessments further evaluate potential contamination of soil and water sources by UXO components, including depleted uranium. This comprehensive evaluation aids in understanding long-term environmental risks and informs strategies for environmental remediation and protection (Potić et al. 2023).

However, remote sensing technologies are not without limitations. They often face challenges such as spatial and temporal resolution limitations, which can restrict the effectiveness of the data for dynamic population analysis and urban planning (Liu et al. 2023). Accuracy and reliability issues may arise due to atmospheric conditions such as cloud cover and lighting, which can obscure and distort the imagery used in population estimates. Additionally, the reliance on ancillary data for calibration, such as ground truth data from surveys, may not always be up-to-date or available, particularly in remote or conflict-affected regions (Yang et al. 2019). The need for advanced analytical techniques and software also poses a barrier in the regions lacking technological infrastructure or technical expertise.

CONCLUSION

Combining advanced remote sensing technologies with traditional demographic methods offers transformative potential for urban planning and public health. By enabling high-resolution mapping and dynamic monitoring of demographic changes, these technologies provide policymakers with robust tools for making informed decisions. However, challenges such as data integration, resolution limitations, and the need for specialised skills must be addressed to fully leverage these technologies in demographic research. Future efforts should focus on developing interdisciplinary approaches and enhancing data integration frameworks to support sustainable urban development and effective resource management.

This review not only highlights the capabilities of modern remote sensing in demographic research, but also underscores the necessity for continued innovation and integration of technological advancements in urban planning processes.

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