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Mini Review

GIS, an Essential Technology for Civil Engineering Education in Developing Countries

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ISSN: 2639-0574

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Submission: October 19, 2021

Published: November 09, 2021

Volume 4 - Issue 5

How to cite this article: Kithsiri Perera, Ryutaro Tateishi, Steven Goh. GIS, an Essential Technology for Civil Engineering Education in Developing Countries. Adv Civil Eng Tech. 4(5). ACET.000599. 2021. DOI: 10.31031/ACET.2021.04.000599

Abstract

GIS (Geographic Information Systems) plays a crucial role in designing multi-source information based civil infrastructure plans. The present study evaluates the status of GIS in civil engineering education in developing countries. A comparative study to investigate the status of GIS education at universities was published in 1995 by the present study's authors, which identified the need for GIS in civil engineering in developing countries. Since the early 2000s, a revolutionary development in digital computing and the internet has transformed how major civil infrastructure projects are planned. Even though the advances on the internet share the benefits of electronic communication among nations, the barriers that developing countries faced 25 years ago seem still overshadowing to build a valid educational link between civil engineering and GIS. This study suggests several recommendations to increase the inclusion of a GIS in civil engineering education in developing countries through educators, social and political decision-makers.

Keywords: GIS; Civil engineering; Multidiscipline; Developing nations; Developed nations

Introduction

The infrastructure can be considered economic infrastructure, which includes a combination of basic facilities and services that directly benefit the people, such as irrigation, power, transportation, and communication [1]. In any economy, infrastructure is strongly connected to social development. The daily life requirements, including housing, transportation, food, parks and green spaces, issues of squalor, environmental justice, and the built environment intersect to affect the people's health in the respective environments [2]. Figure 1 uses a visual example to explain how the built environment, the result of civil engineering projects, relates to the spatial features.

Civil engineering in infrastructure has a history as long as human civilization, dating back to 4000 and 2000 BC in ancient Egypt [3]. Civil engineers have created various constructions for human society as far back as the Great Pyramids at Giza. Any infrastructure development to assist community needs the input of civil engineers. When it comes to the built environment's complete functionality, civil engineers, architects, surveyors, and town planners work together to plan and design the infrastructure and buildings [4]. Within the role of civil engineers in infrastructure development, GIS (Geographic Information Systems) provides vital contributions through the projects' space-related aspects. Figure 1 shows how information extracted from the earth surface links with the built environment, and GIS facilitates the connection of spatial data for this process.

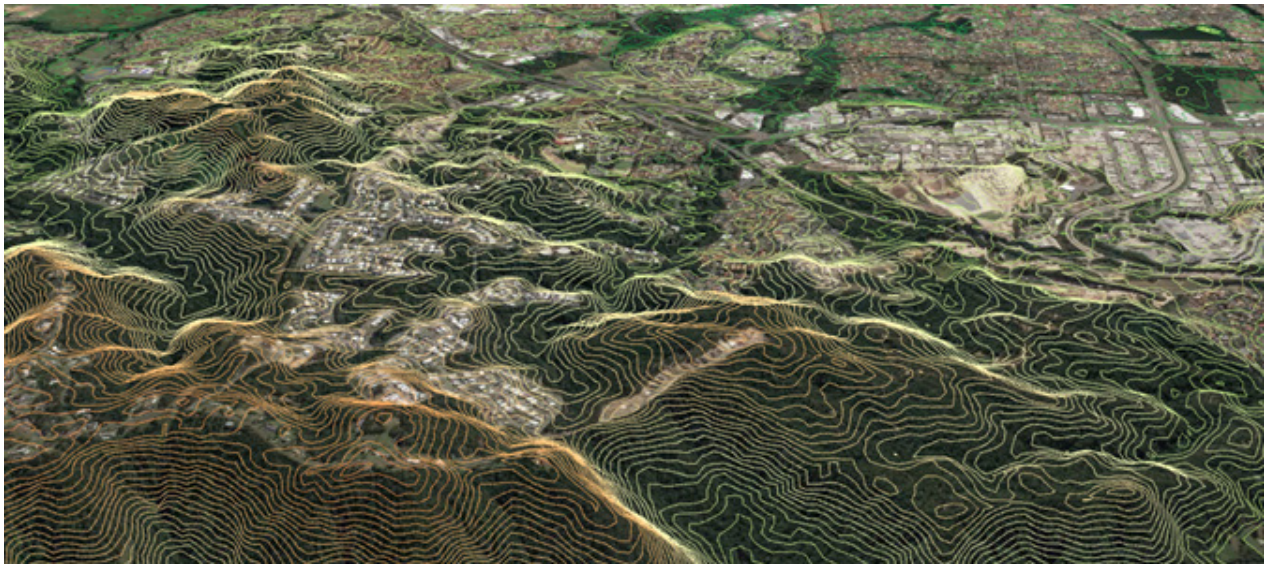

Figure 1: A 3D view of a Google Earth image of Gold Coast, Queensland, Australia, overlayed with 5m contours generated from SRTM DEM data. This is an ideal example to show how GIS data is behind the various components of the built environment.

The Value of GIS for Civil Engineers

A Geographic Information System (GIS) is a computer system that analyses and displays geographically referenced information [5]. GIS uses data that is attached to a unique location. Civil engineers need a vast amount of geographically referenced spatial data for their designs and decision-making process. For most civil engineering projects, the link between spatial data and engineering projects forms by GIS. Figure 2 shows the visualized definition of GIS, its main components, and how GIS provides an essential component in the built environment. In GIS, data provides the foundation for all analysis, and remote sensing can be counted as the most vital source to generate spatial data.

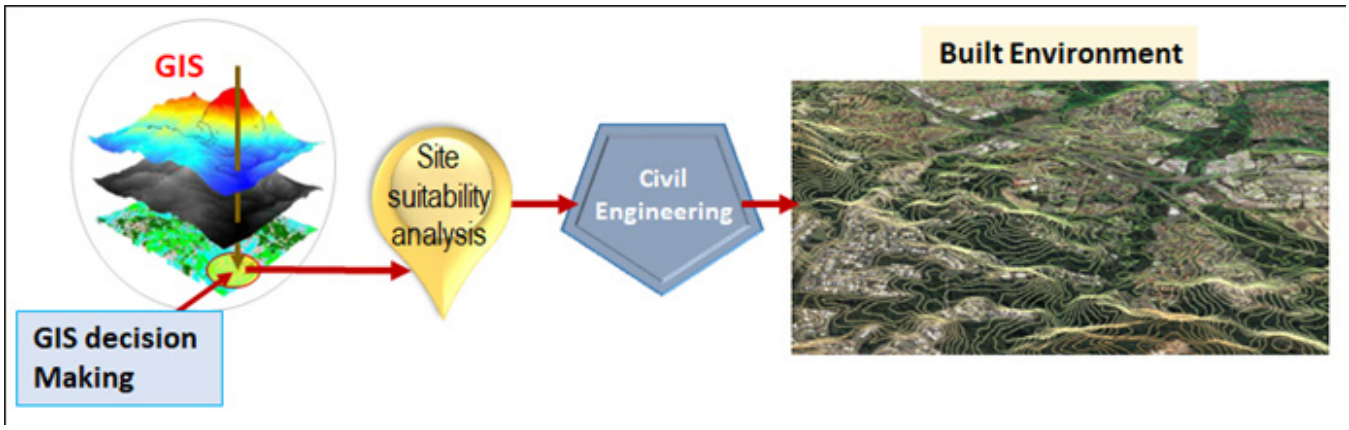

Figure 2: The link between GIS and civil engineering.

Due to the essential need for spatial information in their planning and assessments, civil engineers study GIS at various stages, from university education to on-job environments. ESRI, the market giant in GIS software, explains this link as; GIS software is interoperable, supporting the many data formats used in the infrastructure life cycle and allowing civil engineers to provide data to various applications while maintaining the core integrity of data [6]. The data component has various types, including the most recent and dynamic spatial data generated from remote sensing.

Perhaps the oldest branch of engineering, civil engineering, comprises many subdivisions such as surveying, construction, transportation, water resources, and environmental [7]. There are many GIS applications in those civil engineering fields, from building to environmental health [2]. In a paper published in 2010, Bartonek et al. [8] explain how GIS and cartography support civil engineering, particularly in the fields such as construction, capturing of mobile data, and using mobile GIS in water management. The schematic illustration in Figure 2 shows how GIS and civil engineering are

linked to executing projects in the built environment. In developed countries, from the 1980s, computer-based GIS has been linked with civil engineering to construct the built environment [9]. The invention of digital computer technology and the internet has strengthened the bond between these disciplines.

GIS Education in Developing Countries

A fact-finding survey was conducted in 1992 to investigate the status of GIS and remote sensing activities in universities worldwide [9]. A questionnaire was posted to 36 universities in 26 randomly selected countries, and 14 universities responded. The survey was aimed to collect information on financial strength, GIS activities, and the relationship with other departments or disciplines of the respective university. The 1992 study revealed that most developing countries did not sufficiently address the practical applicability of GIS technology in civil engineering. Low investments into the education system reflect an apparent setback in the total academic standard of the country. The per capita resource allocation for education and illiteracy in developing countries had a positive correlation. Sri Lanka, Indonesia, Bangladesh, and Nigeria allocate $US 13.73, 11.02, 2.90 and 0.65 as annual per capita education spending, and the illiteracy levels in these countries are 11.6%, 23.0%, 65% and 49.3%, respectively [10].

GIS is linked within the civil engineering and surveying disciplines in most higher education institutes in developed countries, if not established as independent entities to deal with multidiscipline higher education. The University College London (UCL), one of the world's highest-ranking universities, offers civil engineering MSc with GIS embedded in the degree [11]. In Australian universities, GIS (mostly together with remote sensing) is associated with civil engineering, science, or built environment disciplines. However, the situation is not much changed in developing countries. As an example, all GIS courses are included in the department of Geography in Sri Lankan universities. While there are some multidiscipline courses, GIS is still within Geography in Indian universities [12]. Table 1 presents where GIS is offered in some of the leading universities in selected developing countries. GIS courses are continued to offer under Geography without multidisciplinary opportunities for civil engineering students to follow those courses.

Table 1: GIS is not within the Civil Engineering discipline or in multidisciplinary higher education programs in developing countries (source: respective websites listed in references accessed in Oct 2021).

University	GIS under which Faculty or Department	Status of the University
University of Benin, Nigeria	Faculty of Environmental Science	Country rank 1
University of Lagos, Nigeria	Faculty of Social Science	Country rank 2
Kabul University, Afghanistan	Faculty of Environmental Science	Country rank 4
Herat University, Afghanistan	Department of Geography	Country rank 7
University of Colombo, Sri Lanka	Department of Geography	Country rank 1
University of Delhi, India	Department of Geography (Under BA degree)	Country rank 1
Sultan Qaboos University, Oman	Department of Geography	Country rank 1
University of Nairobi, Kenya	Department of Geospatial and Spatial Technology	Country rank 1
University of Sao Paulo, Brazil	Department of Geography (RS)	Country rank 1
Chulalongkorn University, Thailand	Geography and Geoinformation Research Unit	Country rank 2

Barriers for GIS to Include in Civil Engineering or Multidisciplinary Degree Programs in Developing Countries

While the developed countries are dealing with multidisciplinary courses robustly and fairly, developing countries are trapped in the vicious circle of poverty and traditional social ideologies. The economic factor is the most crucial barrier for GIS in university education in the developing world in the past. In the 1990s, GIS installation (hardware and software) cost about US$ ten thousand [13]. Now, open-source software, low-cost computers, and affordable software packages for developing countries have improved the situation. The lack of qualified human resources was once a critical issue for developing nations to establish GIS education, particularly in Asian and African countries [14]. However, skillful human resources have taken a new trend thanks to widely available internet resources, online forums, and free software. Yet, the recognition of the multidisciplinary approach is not well established in developing countries.

In most developing countries, students are categorized into different subject disciplines at the junior-high-school level, blocking students from changing the path of higher education afterwards. GIS is included in Geography departments in developing countries, and civil engineering students get no access to GIS. Traditionally, people and bureaucrats in developing countries have a perception that science and social science academic paths must be separate at the junior high school level. This attitude in society is a barrier to building productive multidisciplinary graduate courses in developing countries. Higher education is attributed to social status to a certain level, which is a critical factor that needs to be challenged. In Sri Lanka and most other developing countries, a student specializing in Geography cannot continue a higher degree in civil engineering. However, a student specialized in Geography

can be enrolled for a higher degree course in engineering faculty in Japan or other developed countries [9]. Governments and higher education authorities must realize the value of multidiscipline education in developing countries and facilitate students to change higher education paths. Developed countries have recognised the importance of multidiscipline higher education and considering the future of university education as an interdisciplinary environment [15].

The present-day open-source resources have resolved some of the technical barriers in developing countries, promising development. However, the poor economic capability and inadequate English language skills still have limitations to access freely available open-source data and software applications for students in developing countries. The disparity in internet facilities in developing countries can be witnessed in webinars or zoom technology-based international conferences. The global ranking of fixed broadband speeds gives evidence for inadequate internet facilities in developing countries, except China [16].

What Can Be Done from Now?

To promote GIS among civil engineering students in developing countries, universities in developed countries can proactively support it. Some significant actions to promote GIS in developing countries are

A. Promote multidisciplinary education at the undergraduate level in developing countries to study GIS under civil engineering graduate programs. For this goal, university management in developing countries must adopt such multidisciplinary courses available in developed countries.

B. Use online education to link developed and developing countries through direct government intervention.

C. Seek government funds to support GIS education in developing countries to link with civil engineering undergraduate programs.

D. Facilitate students at universities in developing countries to study GIS courses in leading universities of developed countries through remote access.

E. Offer online GIS courses at an affordable price.

F. Invite educational officers from developing countries for GIS workshops and training programs in developed countries.

G. Offer incentives for the students from NESB (non-English speaking background) countries to study in developed countries.

Civil engineering education and GIS can be linked in developing countries through the actions mentioned above or other appropriate decisions taken by relevant authorities [17-24]. Such initiations will help various aspects of built environment projects to improve with detailed spatial information input from GIS. When it comes to local and national level decision making for built environment projects, civil engineering and GIS's linked approach will help civil engineers to access the full benefit of spatial data such as satellite imagery, drawn imagery, and digital elevation data together with GIS data analysis capabilities. The next step of the present study will investigate the success of open-source GIS data and software applications and prospects of establishing multidiscipline graduate courses in developing countries [25-27].

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