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Employing digitization and spatial analysis tools in GIS to manage educational institutions: The College of Engineering at Mustansiriya University as a case study

Ali Dhafer Abed [1*], Rhowena J. Ramdeen[2], Ryan C. Rampair[3], Nasir Ahmad[4], Mir Bintul Huda[5]

[1*] Assistant Professor, Water Resources Engineering Department, College of Engineering, Mustansiryah University, Baghdad- Iraq, Email: ali.dhafer@uomustansiriyah.edu.iq
[2] Research Scholar, Faculty of Engineering, The University of the West Indies, St. Augustine, Trinidad, Email: Rhowena.Ramdeen@my.uwi.edu
[3] Research Scholar, Faculty of Engineering, The University of the West Indies, St. Augustine, Trinidad, Email: Ryan.Rampair@my.uwi.edu
[4] Assistant Professor, Faculty of Engineering, Baba Ghulam Shah Badshah University, Rajouri, Jammu and Kashmir, India Email: nasirr3@gmail.com
5 National Institute of Technology Srinagar, Jammu and Kashmir, India
Email: dr.mirhuda@gmail.com

Abstract

Geographic Information Systems (GIS) are one of the most important tools for organizing the development of integrated spatial databases for educational institutions. These databases support infrastructure analysis, resource management, expansion planning, and improve planning and decision-making efficiency. Therefore, this research aims to use corrected satellite imagery to produce an integrated digital map of the study area (College of Engineering/Al-Mustansiriya University) within a GIS environment. This map will then be linked to an integrated database and spatial analysis will be

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conducted on this data. Field surveys will be used to collect the database for each department within the College of Engineering. This data will be linked to its geographic location on the digital map. Spatial analyses will be conducted to arrive at the final results, which will serve as an integrated database for department management and forecasting future plans for expansion of faculty, students, and staff. This analysis will also produce multiple strategies for decision-making regarding the required number of undergraduate, graduate, and evening students, and linking these numbers to the facilities, laboratories, and infrastructure that will accommodate the acceptable number of students.

Keyword: GIS, Spatial Analysis, Mustansiriyah, Bab Al-Moazam, Symbology.

1. Introduction

Geographic Information Systems (GIS) are among the most important modern digital tools that allow for the collection, analysis, and presentation of spatial data visually and interactively, linking the site to an integrated database (Abed & Sabtu, 2024). The most important feature of GIS is its ability to handle massive amounts of data resulting from the development of databases and graphical technologies, which have enhanced GIS's analytical capabilities within complex spatial environments (Akl et al., 2024). Precise spatial

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analysis is what distinguishes this system, providing two- and three-dimensional maps and visual representations that effectively support decisions, especially in institutions where decision-making relies on geographic infrastructure, such as educational institutions (Sasongko et al., 2024).

Through the integrated spatial database that is being built, educational institutions can manage their resources and track their facilities and departments. It can also improve academic planning and service delivery, including the distribution of buildings and colleges, laboratory locations, and their relationships with departments, and monitoring urban expansion in the area surrounding or adjacent to the institution (Almansi et al., 2024). The basic GIS tools for input, display, analysis, and querying are among the most powerful tools for managing data accurately and effectively, especially when spatial information from geometrically corrected satellite and aerial images is combined and analyzed within the framework of spatial systems, map projections, and coordinates, which enhance the accuracy of geographic information (Ying, 2021).

One of the most important studies that used GIS in education management is the study conducted by Calantropio et al. (2021), which developed a three-dimensional model for university department management using an

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integration between GIS and BIM systems (Calantropio et al., 2021). The study methodology relied on three sequential stages: creating digital models, integrating and updating them with accurate information, and developing a building management application through MDPI. The study concluded that functional integration between GIS and BIM improves the efficiency of educational facility management, facilitates the maintenance of buildings and laboratories, and facilitates future planning for institutional needs. The study conducted by Brown et al. (2022) relied on spatial analysis using GIS tools to analyze the distribution of school infrastructure in urban areas, focusing on the impact of population density and the geographical distribution of schools within the study area. Their study concluded that there is a lack of easy access to schools due to the disparity in the geographical distribution of schools. It is recommended that future planning in the city's master plan improve school distribution based on geographical data and accessibility criteria (Brown et al., 2022). Another study conducted by Blázquez et al. (2023) developed an interactive system using GIS to distribute students according to educational districts, to reduce overcrowding and improve spatial distribution. The system contributed to improving student distribution, reducing pressure on schools, and providing accurate data to support decisions regarding expansion and reduction of school hours (Blázquez et al., 2023).

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In the study by Yoo & Kim (2021), an educational database was built based on digital maps of educational institutions to improve future expansion plans for educational institutions within the city. The study demonstrated that the use of GIS analysis tools contributes to improving strategic education planning, identifying suitable locations for new educational institutions, and providing accurate data to support decision-making (Yoo & Kim, 2021).

Haedrich et al. (2023) relied on remote sensing techniques using satellite imagery to track changes in the urban area around academic institutions. The study demonstrated trends in the expansion of educational institutions and accurately tracked their urban changes, contributing to future planning for educational institutions (Haedrich et al., 2023).

These studies demonstrate the importance of using GIS in improving the management of educational institutions and developing future plans for them. Based on an integrated spatial database linked to educational facilities, educational institutions can improve resource allocation and management, plan future expansion trends, and enhance the efficiency of administrative processes. Therefore, this research aims to employ the spatial analysis tools of geographic information systems (GIS) to design and develop an integrated spatial database for the educational institution in the study area, represented by the College of Engineering at Al-Mustansiriya University, which is

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considered one of the most important and highest-ranked engineering colleges in Iraq. The database will contribute to improving future decision-making in the interest of students, planning the college's resources, and supporting administrative and educational processes.

2. Area of Study

The College of Engineering, located in the capital, Baghdad, in Bab Al-Moazam, belongs to AL Mustansiriyah University. The study area is defined between two latitudes (33.353290° - 33.390159°) and two longitudes (44.383218° - 44.387766°), respectively (Abed & Maythem, 2021), as in Figure 1.

The College of Engineering contains nine departments, including civil, architectural and others departments, It contains initial studies, represented in four stages, in which students are taught in everything related to their departments gradually, and it also contains higher studies, represented by masters and doctorates, and its importance to provide specialized engineers with high competence and experience, students who graduate from them become engineers and highly qualified because of the efficiency of the teaching staff and being qualified with all modern technologies that will be useful to students (Abed, 2018).

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A digital map of the College of Engineering will be produced using the GIS program and a corrected satellite image of the study area, and then the digital map will be linked to a database based on field surveys, as it is possible to continuously add and update these data in the future in line with the needs of the college and researchers to conduct any of the spatial or statistical analyzes that have great benefit for the College of Engineering and its employees (Alatta et al., 2023).

Figure 1: Location of the College of Engineering, Mustansiriya University, relative to the city of Baghdad.

3. Methodology

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A digital map was produced for the College of Engineering, Mustansiriyah University, using ArsMap 10.7, according to the following sequential steps:

1- A satellite image of 2025 for the study area with a resolution of 60 cm was used. The coordinate system for the satellite image was defined to conform to the study area coordinate system (WGS84-UTM-Zone 38 North). The Arc Catalog window was used for the purpose of creating layers through which the study area will be defined and linked to a database. The following layers are created:

A- Boundary of college Layer: the type of this layer is Polygon, it was created with the name "boundary of college", then its coordinate system was defined WGS84-UTM-Zone38N, and then the attribute table for this layer was created to contain the following data (Name, area, perimeter).

B- College Buildings Layer: In the same way as the previous method, a layer was created for buildings of the polygon type, named Building and with WGS84-UTM-Zone38N coordinate system, and then the attribute table was created for this layer to contain the following data: (the name of each Building, area, number of teachers, number of engineers, number of first-stage students, number of second-stage students, number of third-stage students, number of fourth-stage students and number of postgraduate students).

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C- College Paths Layer: Also, in the same way, a Layer of College Paths and Streets was created from the polyline type, named Road and with the same coordinate system, and then the attribute table was created for this layer to contain the following data: the length of the road, the type of road, the name of the road.

3- The Editor toolbar was used in ArcMap to draw the three layers (college boundaries, buildings, roads) based on the geometrically corrected satellite image. Through the use of the Start Editing and Snapping command, all layers were drawn and defined characteristics in terms of color, thickness, and appearance. Drawn layers can be observed through Figure 2.

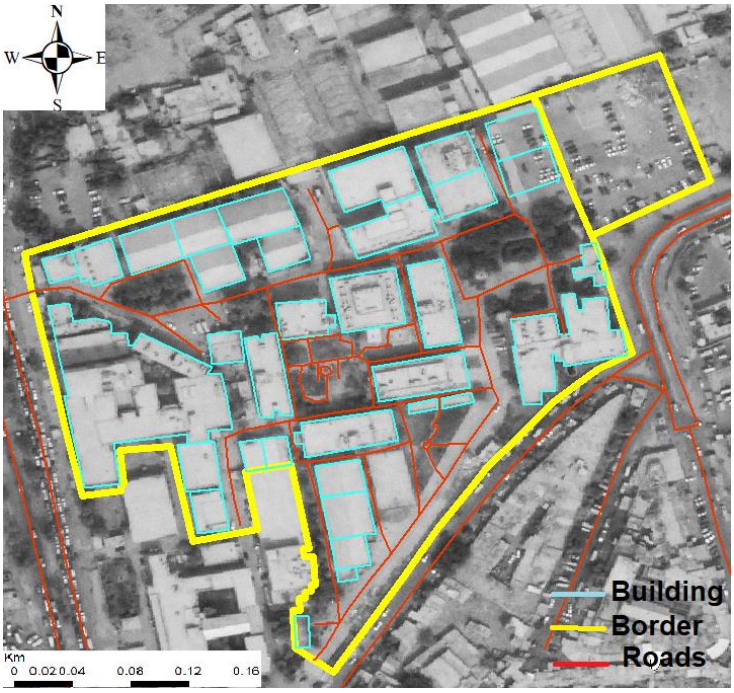

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Figure 2: Boundary, building, and paths for the study area.

4- Field surveys were conducted within the College of Engineering for the purpose of gathering the required database for each layer, represented by the data in the tables for each layer. As the required data for each department was collected with the help of department heads and rapporteurs, and this information was used to fill in the tables of the three layers, as each piece of information was entered in its layer within its field.

With regard to the geometric data in the tables, such as lengths, areas, coordinates, and perimeter, they are geometric data that have been accurately calculated by the program of ArcMap, and the accuracy of the calculations depends on the accuracy of the satellite image and the accuracy of the Shapefiles.

Now that an integrated database is available for each layer of the college, this database will be used to conduct spatial analyses.

3. Results and Discussions

Spatial analyzes of the three layers' foe the study area was performed as follows:

A. Spatial analysis of the buildings layer: The Symbology analysis tool was used to perform the spatial analysis according to the feature of area

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and number of employees as in the illustrated in Figure 3 and Figure 4. It's clear that that the largest area is found in the directorate for girls followed by the Hydraulic Laboratory, Registration and the Internet, Deanship of the College of Engineering, respectively, and the least area is found in Fluid mechanics lab. From noted Figure 4, the largest number of employees is in the Deanship of the College of Engineering, followed by Registration and the Internet, dormitories directorate for girls, Services Division, College of Engineering inquiries, Construction materials lab, Surveying lab, Soil lab, Construction lab, Transportation lab, Hydraulic lab, Fluid mechanics lab, Traffic engineering lab, Electrical power lab, microbiology lab, student activities, Power lab, Sanitary lab, Programming lab, High voltage lab, center of continuing education, respectively.

An analysis of the significant disparity in the spaces allocated to the units and departments of the College of Engineering indicates:

- The primary function of the space: The nature of its use determines its size. Female dormitories are considered service units that require ample space to accommodate the number of students and the infrastructure they require.
- Laboratory infrastructure and equipment requirements: Most of the College of Engineering laboratory equipment requires safety and

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operating distances, which necessitates providing ample space for these laboratories, especially if they require the installation of large-scale equipment, such as the hydraulics laboratory and the construction materials laboratory.

- The structural age of the buildings: Some of the College of Engineering buildings are considered heritage buildings that give a symbolic dimension to Mustansiriya University. These include the Civil Engineering Department and the Electrical Engineering Department, which are among the first departments built within the college. These departments were built to limited standards, appropriate to the period in which the college was built in the 1960s, which limits their future expansion.

An analysis of the disparity in the number of staff and faculty members within the college's deanship, laboratories, and departments indicates:

- Administrative and organizational nature: The deanship of the College of Engineering and the Registration Department manage the affairs of all current and former students at the college. Therefore, they require a large number of staff to coordinate between students and academic departments.

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- Laboratory specialization or technical uniqueness: Some college laboratories are understaffed due to the uniqueness of each laboratory in a specific area of study or testing, such as the health laboratory, which specializes in environmental testing only, and the soil laboratory, which specializes in soil testing only. Therefore, these laboratories require specialized staff and do not require a large number of employees.
- Administrative priority for college units: The deanship has priority in recruiting administrative staff and supporting their needs from administrative units within the deanship. This explains the concentration of a larger number of staff in these units compared to the rest of the college's departments and centers.

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Figure 3: Spatial analysis according to the feature of area

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Figure 4: Spatial analysis according to the feature of number of employees

B. Spatial analysis of the department layer: The Symbology analysis tool was used to perform the spatial analysis according to the feature of: Area, Number of lecturer, Number of employees, Number of students for

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1st year, Number of students for 2nd year, Number of students for 3rd year, Number of students for 4th year, number of Postgraduate students as in the Figures 5 to Figure 13.

It is clear from Figure 5 that the largest area is in the Roads and Transportation Engineering Department, followed by the Mechanical Engineering Department, and the least area is in the Environmental Engineering Department. Figure 6 shows that the largest Number of lecturers was found in the Civil Engineering department and the least is in the Architecture Engineering department. From Figure 7, it became clear that the largest number of employees was found in the Electrical engineering department (including engineers and secretarial staff), followed by the Mechanical engineering department, and that the least number of them is found in the Water resources engineering department.

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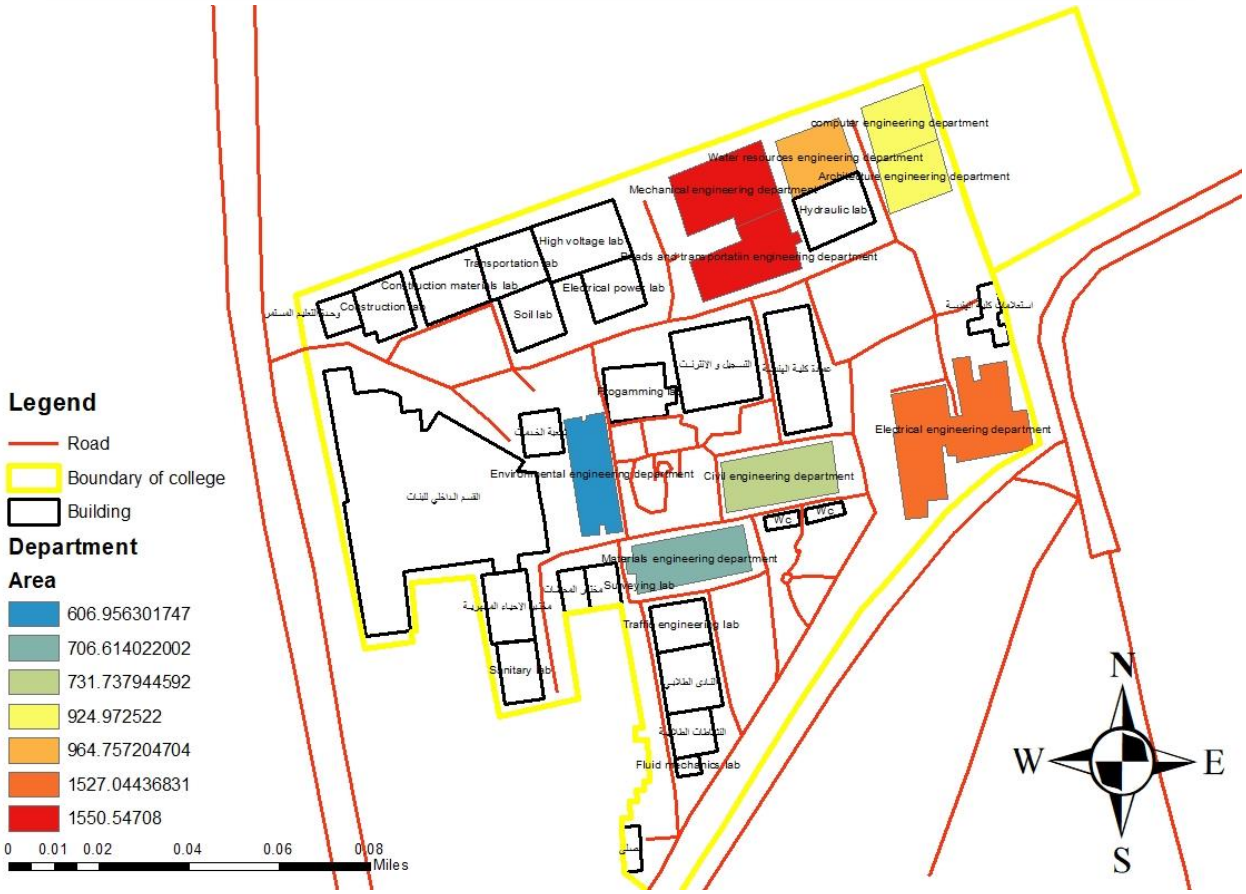

Figure 5: Spatial analysis according to the feature of area.

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Figure 6: Spatial analysis according to the feature of Number of lecturers.

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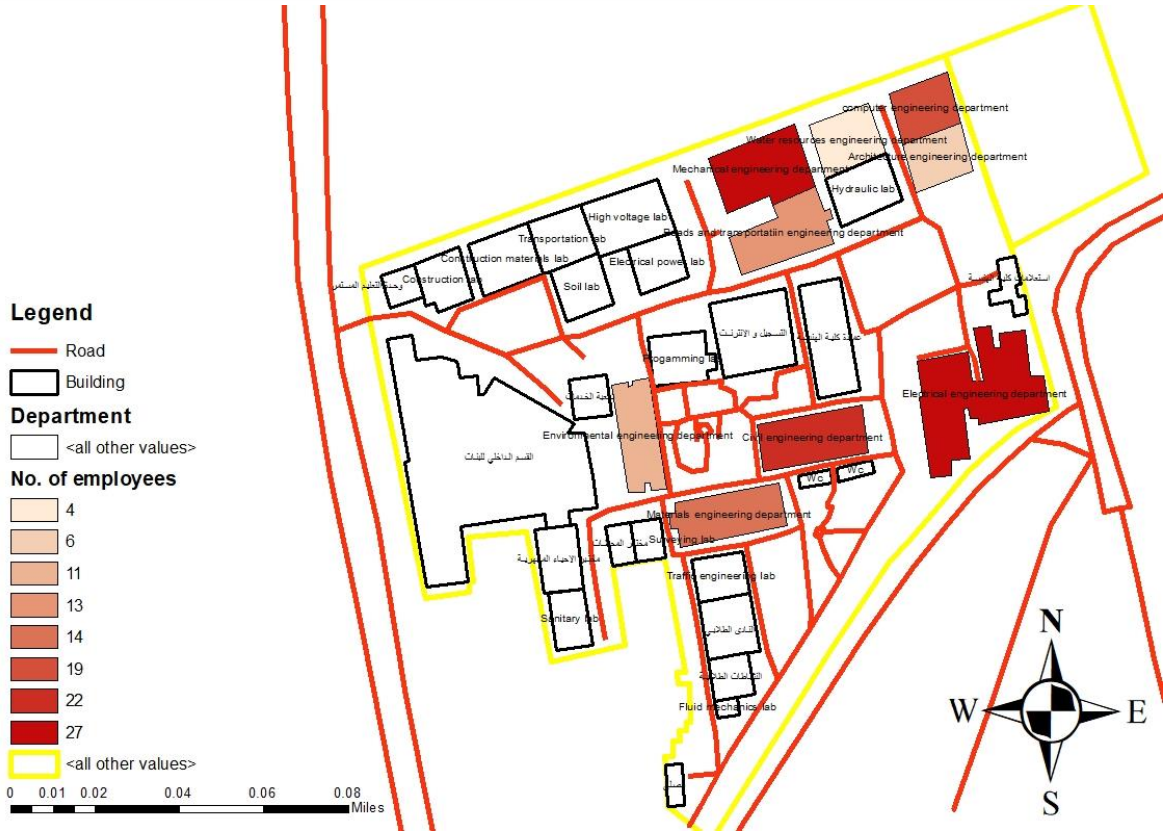

Figure 7: Spatial analysis according to the feature of Number of employees.

As shown in Figure 8, the least number of students for the 1st year is found in the Architecture engineering department, and the largest number of students for the 1st year was found in the Roads and transportation engineering department. From Figure 9, the largest number of students for the 2nd year was found in the Electrical Engineering department, followed by the Civil

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Engineering department, and the least number of students was found in the Environmental Engineering department. As shown in Figure 10, the largest number of students for the 3rd year is in the Mechanical Engineering department, and the least number of them in the Architecture Engineering department. As shown in Figure 11 that the largest number of students for 4th year is in the Electrical Engineering department, followed by Civil Engineering department, and the least Number of students for the 4th year in the Water Resources Engineering department. As shown in Figure 12 that the largest number of postgraduates (master's) is in the Electrical Engineering department, and the least Number of them is in the Water Resources Engineering department and the Architecture engineering department. As shown in Figure 13 that the largest number of post-graduation (doctorate) students is in the Mechanical Engineering department, followed by the Electrical Engineering department, and ends with the Architectural Engineering department with no postgraduate students.

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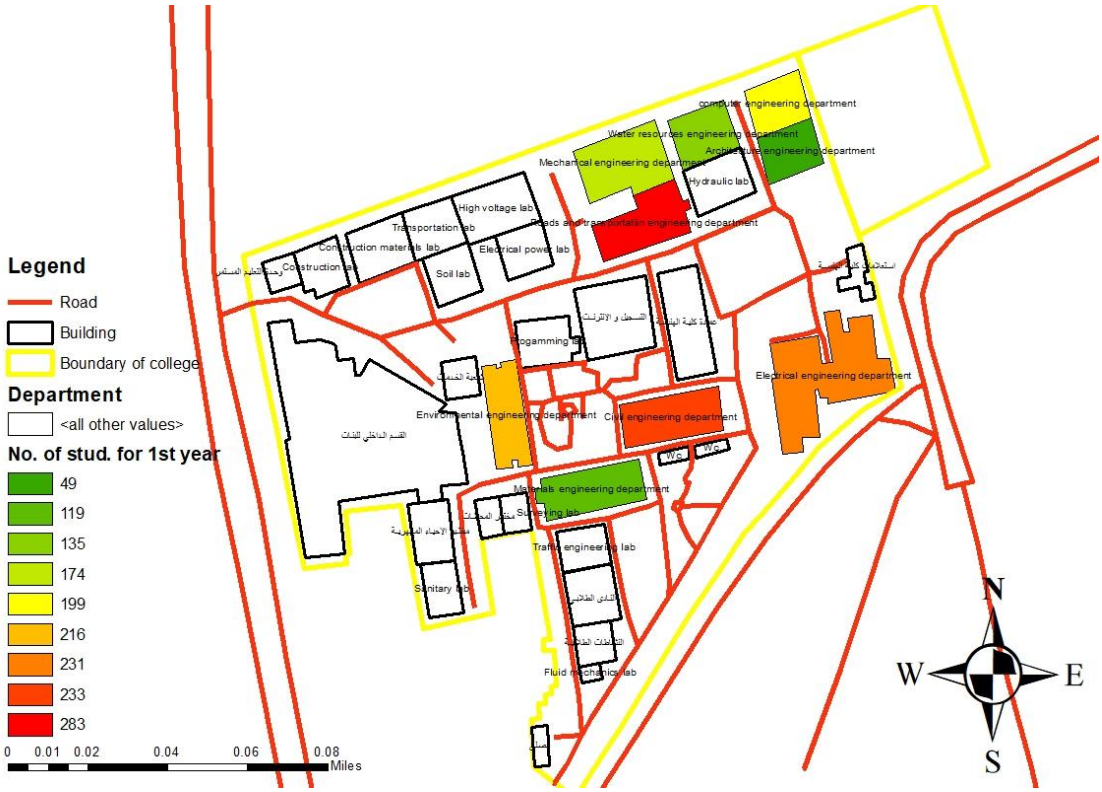

Figure 8: Spatial analysis according to the feature of student's number for 1st year.

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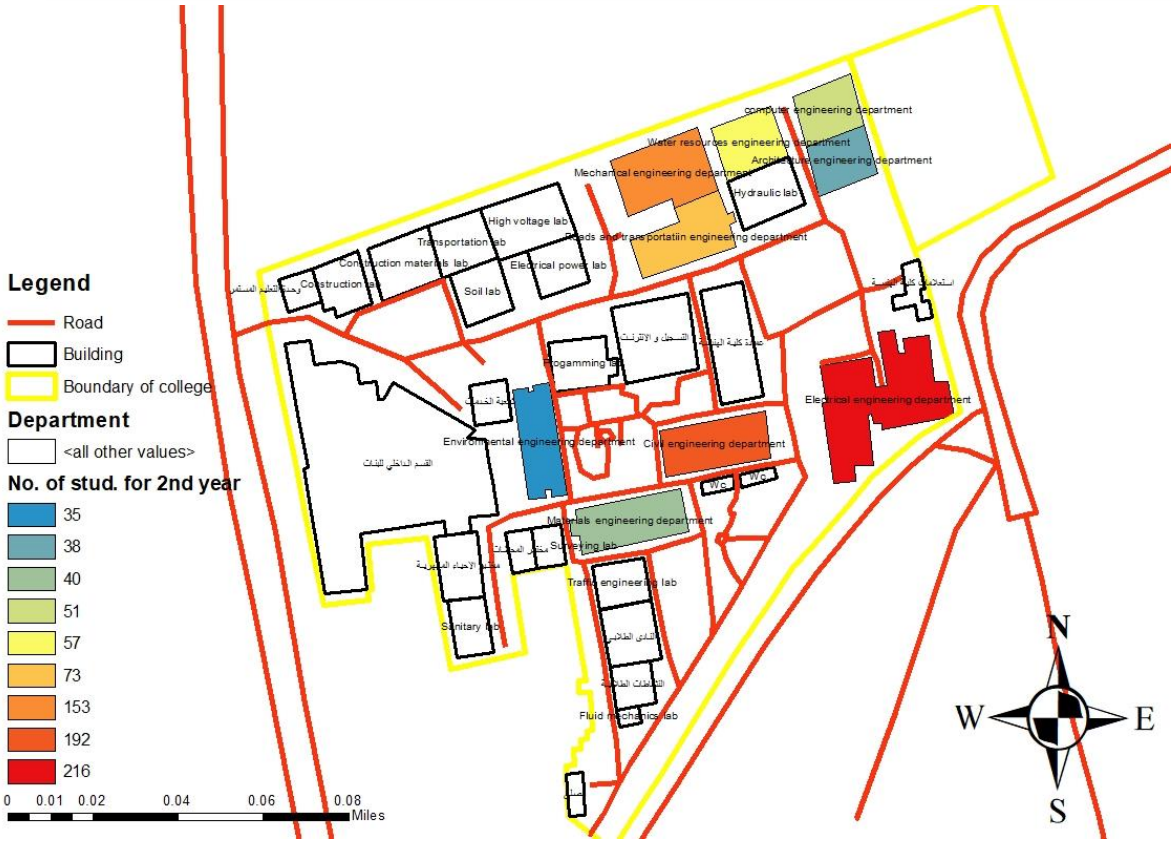

Figure 9: Spatial analysis according to the feature of student's Number for 2nd year.

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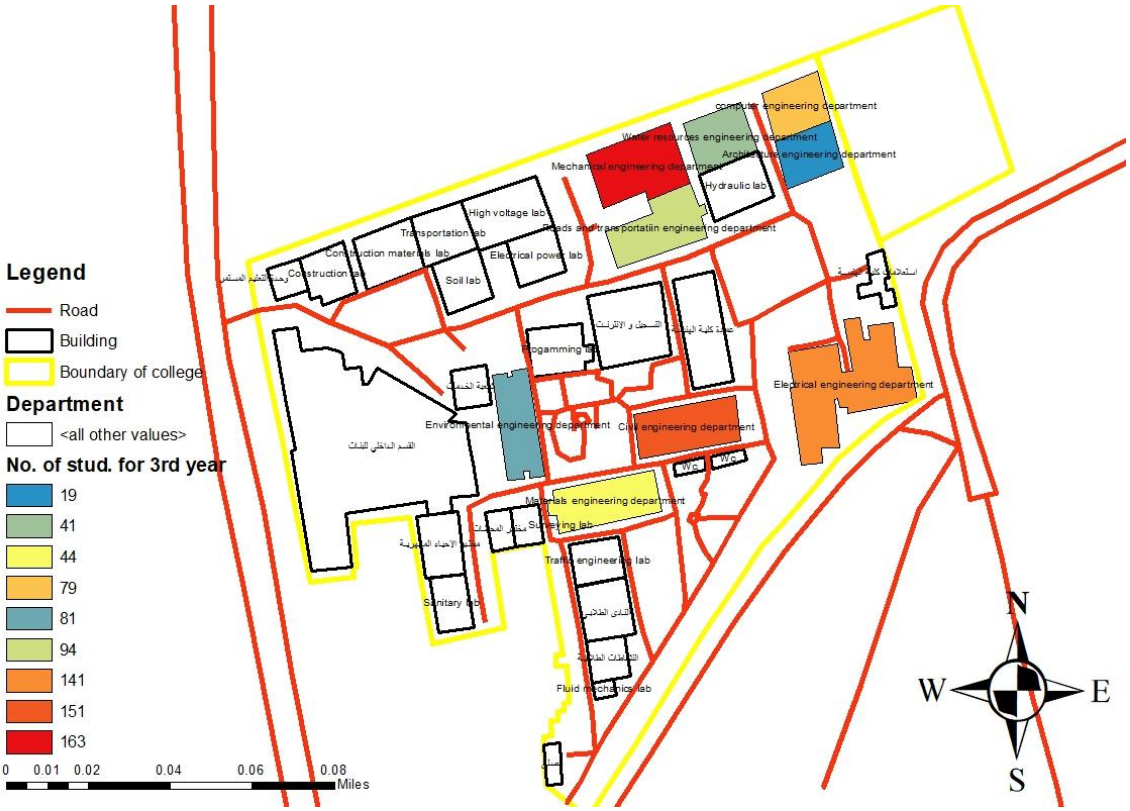

Figure 10: Spatial analysis according to the feature of Number of student for 3rd year

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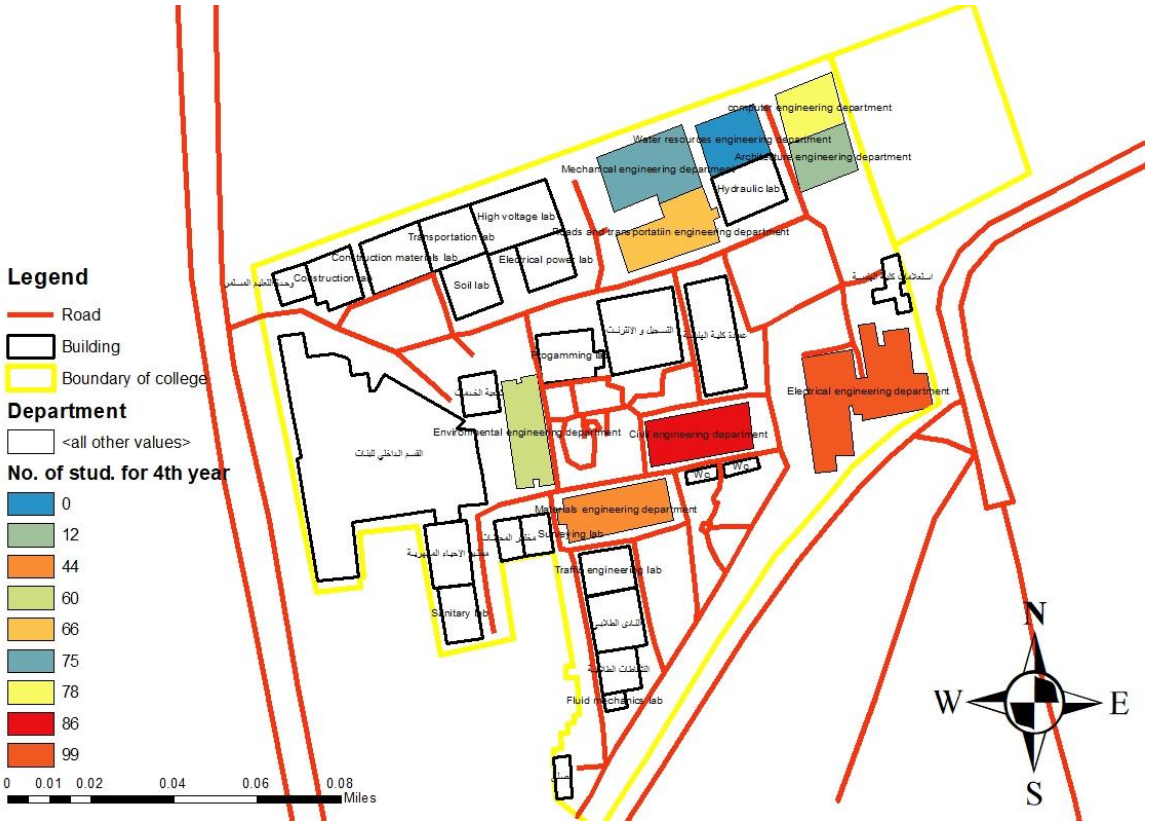

Figure 11: Spatial analysis according to the feature of Number of student for 4th year.

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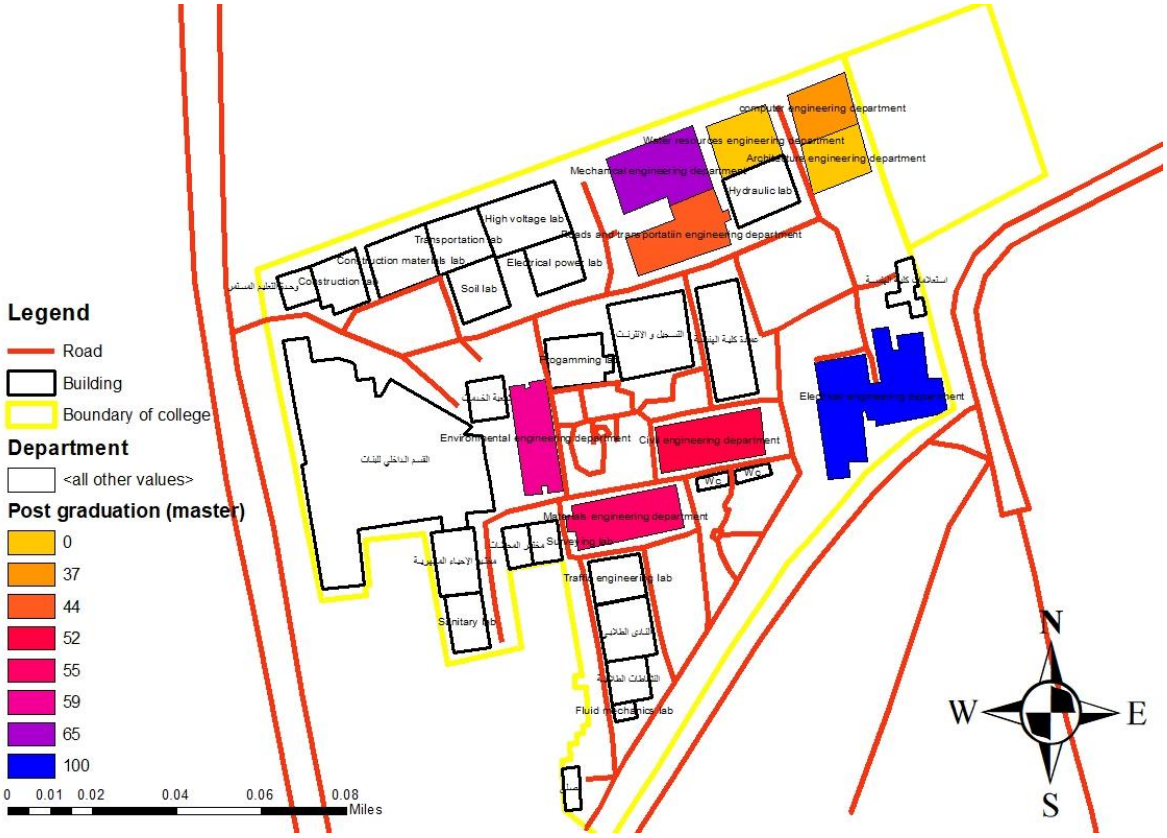

Figure 12: Spatial analysis according to the feature of Number of postgraduate students (Master).

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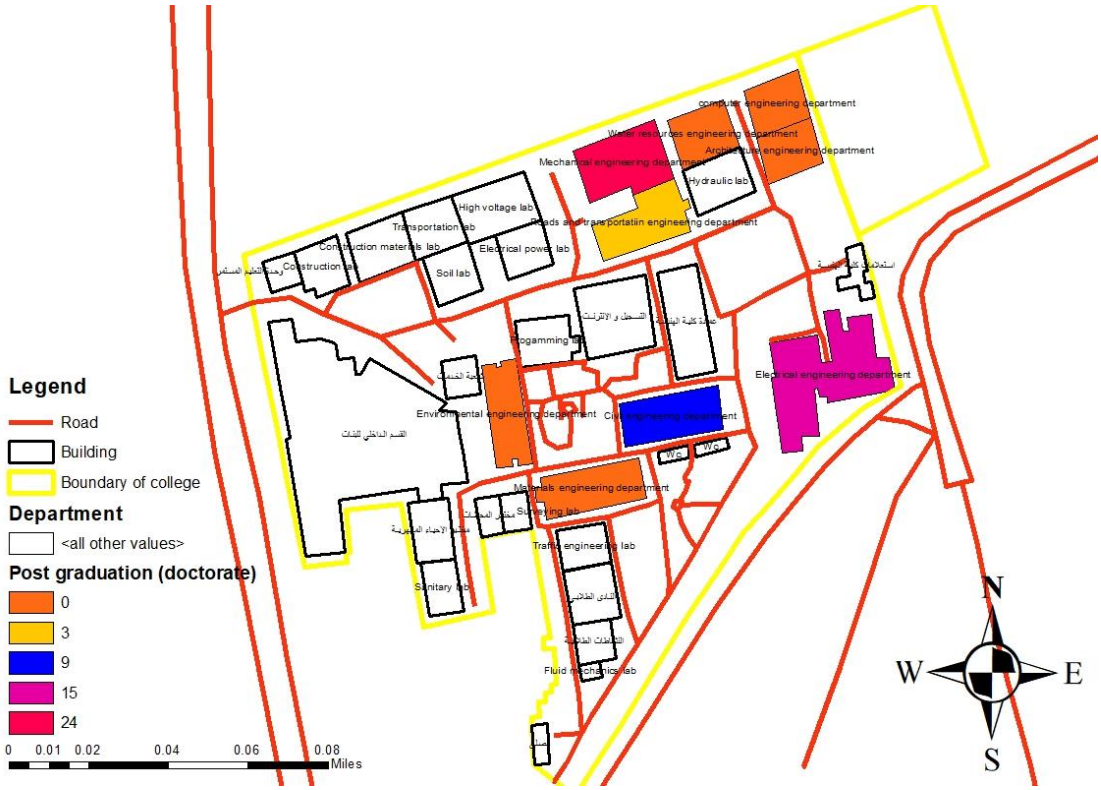

Figure 13: Spatial analysis according to the feature of Number of postgraduate students (P.h.D).

The disparity in departmental spaces can be explained by the Department of Highway and Transportation Engineering requiring large halls and specialized infrastructure due to its practical applications, which require extensive laboratories for testing materials. The Department of Environmental Engineering is relatively new compared to other university departments,

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which explains its small size. Furthermore, students are distributed among the college's laboratories during their lectures.

The increasing number of faculty members in the Civil Engineering Department is due to the diverse specializations and courses offered by the department. Architectural Engineering, a newly established department in 2013, relies largely on specialized professors from other departments and a limited number of lecturers specializing in practical projects.

In terms of the number of administrative staff, the Electrical Engineering Department has a significant number of laboratories that require constant technical support and staff present in the laboratories permanently. Furthermore, complex research projects for graduate students require management and follow-up. The Department of Water Resources Engineering was also established in 2018. It is limited in terms of structure and research activities, as graduate studies began in the department in 2025, reducing the need for a large staffing requirement at this time.

The number of undergraduate and graduate students by academic level and type of study can be seen in Table 1, arranged in order from highest to lowest within each department. The increase in the number of students in certain departments, such as Electrical and Mechanical Engineering, is due to job opportunities available after graduation, which explains the students' interest

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in these departments. The decrease in the number of students in certain departments, such as Architecture and Water Resources, is due to the significant disparity in graduate student acceptance rates. The Department of Architecture accepts students with the highest grades, while the Department of Water Resources accepts students with lower grades compared to the rest of the college's departments.

Table 1: Number of students by educational stage, by type of study, and by sequence from highest to lowest in each department.

Academic Stage	Highest Department	Lowest Department
First Year	Roads and Transportation	Architecture
Second Year	Electrical	Environmental
Third Year	Mechanical	Architecture
Fourth Year	Electrical	Water Resources
Postgraduate Studies (Master's)	Electrical	Water Resources + Architecture
Postgraduate Studies (PhD)	Mechanical	Architecture (without students)

C. Spatial analysis of the road: The network analysis tool was used to perform the spatial analysis according to the feature of length and type as in the Figures 14 and Figure 15. It’s clear that the longest road in the college

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has a length of 236.7 m, which starts near the Hydraulic lab and ends near the Construction lab, and the shortest road has a length of 6.9 m, which found in front of the Environmental engineering department.

The interpretation of the road length map indicates the distribution and spacing of buildings, which does not obstruct the movement of students and faculty members between the college's departments and centers, especially in harsh climatic conditions. The proximity of some departments to the college's deanship office also indicates attempts to compensate for the lack of space by providing easy access.

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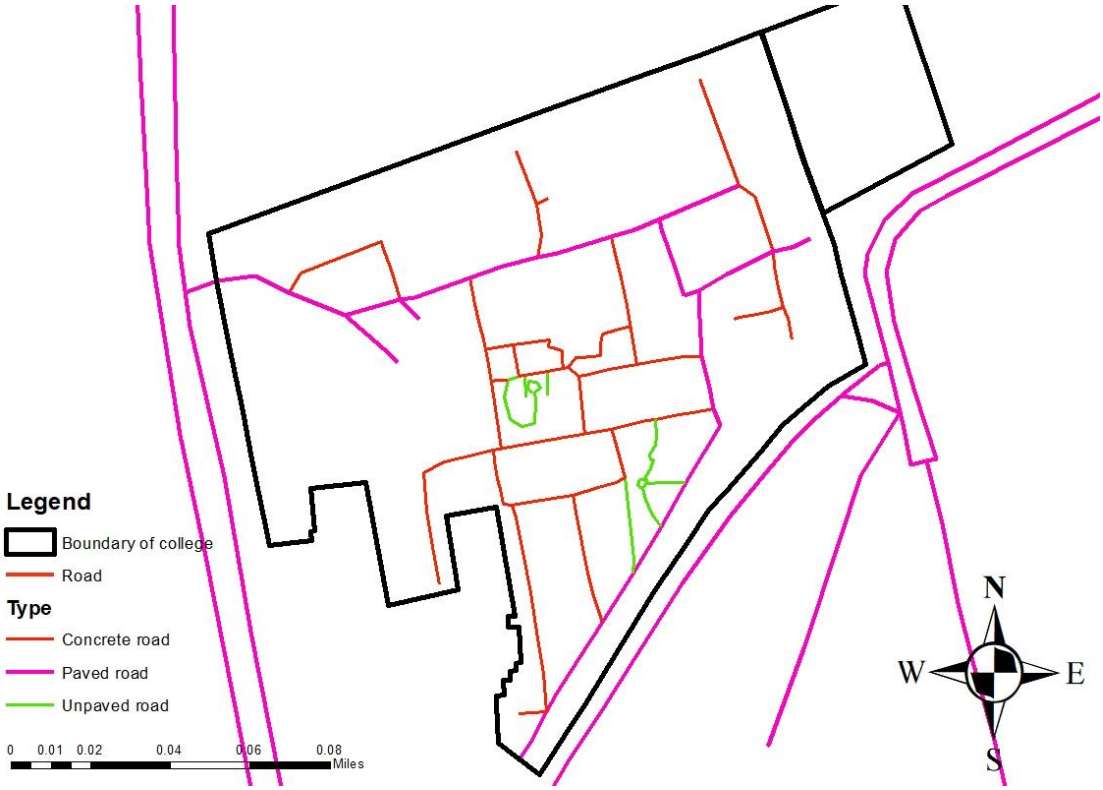

Figure 14: Spatial analysis according to the feature of road type.

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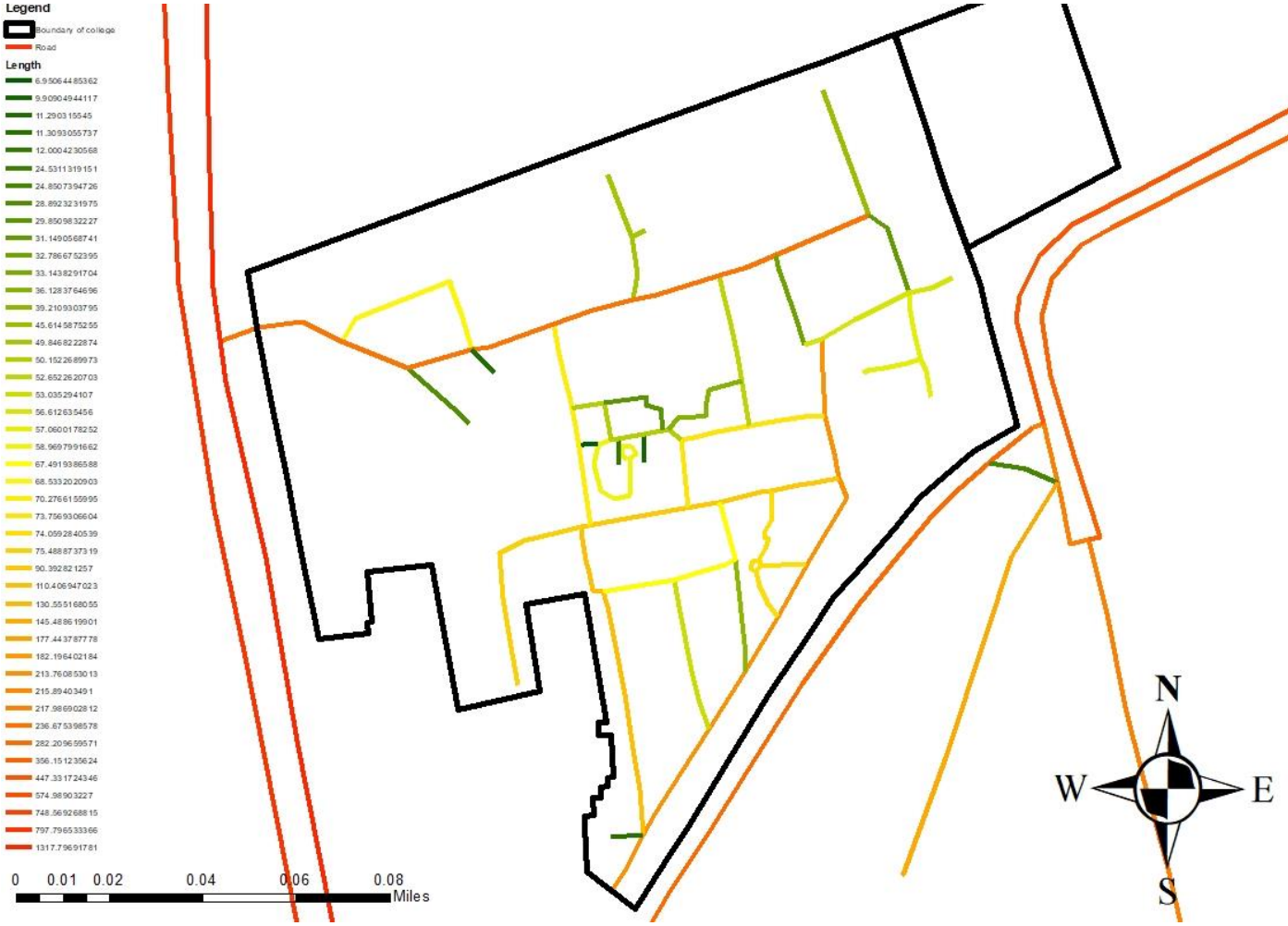

Figure 15: Spatial analysis according to the feature of length.

Conclusions:

1. The College of Engineering covers an area of 42,202.3 square meters, with a perimeter of 1,046.39 square meters. The largest departmental

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areas were in the Department of Highways and Transportation Engineering, followed by the Department of Mechanical Engineering. The smallest area was in the Department of Environmental Engineering, indicating the need to expand the Civil Engineering Department relative to the number of students.

2. The longest road in the college is 236.7 meters long, starting from the Hydraulics Laboratory and ending at the Construction Laboratory. The shortest road in the college is 6.9 meters long and is located near the Department of Environmental Engineering. A spatial analysis of the college's road network revealed good integration and connectivity between the roads, facilitating access to all departments and college facilities.
3. The largest number of lecturers is in the Department of Civil Engineering, while the smallest is in the Department of Architecture. The largest number of staff is in the Department of Electrical Engineering, followed by the Department of Mechanical Engineering, and ending with the Department of Water Resources Engineering. This requires future re-studies to regulate the number of staff and faculty in each department to match the department's resources, including students and laboratories, particularly in the Department of Water Resources Engineering and the Department of Architecture.

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4. The smallest number of students in the first year was in the Department of Architecture, with the largest number in the Department of Highways and Transportation Engineering. The largest number of students in the second year was in the Department of Electrical Engineering, followed by the Department of Civil Engineering, and the smallest number in the Department of Environmental Engineering. In the third year, the Department of Mechanical Engineering had the largest number, with the smallest number in the Department of Architecture. The fourth year saw the largest number of students in the Department of Electrical Engineering, followed by the Department of Civil Engineering, and the smallest number in the Department of Water Resources Engineering. This distribution is consistent compared to the analyses of teaching staff, as it aligns with the resources of the Departments of Highways and Architecture.
5. The largest number of graduate students (Master's) was in the Department of Electrical Engineering, with the smallest numbers in the Department of Water Resources Engineering and the Department of Architecture. The largest number of PhD students was in the Department of Mechanical Engineering, followed by the Department of Electrical Engineering. This indicates the expansion of the future

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admissions plan after the graduate studies database is linked to international networks with universities around the world, allowing for the exchange of expertise and collaboration with prestigious international universities.

Recommendations

1- To improve the functional performance of the units and departments of the College of Engineering at Al-Mustansiriya University and their spatial distribution, the research recommends the following:

2- Expanding spaces: By expanding some laboratories with high operational density, which attract students from both inside and outside the college, such as the Construction Materials Laboratory, which requires an expansion of 400 m2, based on the number of students arriving in 2025.

3- Balancing staffing: Re-evaluating the distribution of staff to match the work requirements of each unit within the college, especially its administrative units within the departments, particularly the Department of Water Resources Engineering and Architectural Engineering, which require an administrative staff of at least two employees in each department. There is also a need to increase technical support for science laboratories and provide them with

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new specialized engineers, with at least two engineers per laboratory.

4- Merging some functionally similar units, such as the Continuing Education Unit with the Student Activities Unit, to reduce administrative duplication and optimize the use of existing spaces and staff.

5- Automating administrative procedures within college departments: There is an urgent need to automate some administrative procedures related to graduates and morning and evening students in the college's offices and registration department. This reduces the need for a large staff and maximizes their use within departments. This also helps direct resources toward the academic and research aspects that enhance the college.

6- Developing and managing infrastructure using smart systems: Improving the work environment in cramped laboratories and equipping them with modern, smaller equipment to make them more efficient and attractive for research. Furthermore, monitoring the spatial distribution of college facilities and improving their future planning is important through periodic management of these facilities in GIS systems.

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7- Redistribution of resources and space: Expanding the Environmental Engineering Department to attract broader research and laboratory activities in the future. Also, strengthening the infrastructure of the Water Resources Engineering Department, especially the administrative staff and specialized professors, to increase its capacity to attract students and researchers.
8- Supporting smart infrastructure between departments: This is achieved by connecting vital college departments and centers with shaded green pedestrian paths, and creating a smart application that helps students research and navigate within the college centers, identifying the locations of laboratories and research centers they need and relevant to their specializations.
9- Creating modern graduate programs: After reviewing the reasons for the decline in the number of graduate students in some departments, incentives are being created to encourage enrollment by providing international and visiting professors and signing temporary contracts with them. Furthermore, graduate study paths that are aligned with sustainability and interdisciplinary, such as linking artificial intelligence with sustainable energy and smart transportation, are being created.

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10- Supporting international cooperation: By seeking international academic accreditation for some international programs, which increases graduates' international employment opportunities. Memoranda of understanding are also being established with world-class universities in the strongest local fields (civil engineering, electricity) for student exchange and joint research.

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