University campuses' location-allocation: a case study of Egypt with insights from the Japanese context

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Abstract

Purpose – This paper aims to identify the most suitable location for a university campus in Egypt based on governorates' social needs by employing the analytic hierarchy process (AHP). The paper, then, reflects the findings retrieved from the Egyptian context on the Japanese context to reveal how different countries deal with the location-allocation decision problem for university campuses.

Design/methodology/approach – The AHP is employed to evaluate and rank Egyptian governorates based on 13 distinct criteria obtained from governmental open-source databases. These criteria measure the social needs of each governorate, guiding the decision on the location of new university campuses.

Findings – The results expose a disparity between Egypt's current campus development plan and recommendations derived from AHP analysis. The location-allocation decision for new university campuses appears to be influenced by subjective assessments, indicating a gap between planned developments and identified social needs. Additionally, contextual social and cultural differences between developing and developed countries impact the identification and fulfilment of the demand for a new university campus.

Originality/value – This paper contributes by offering decision-makers a robust location-allocation framework. It serves as a valuable tool for policy formulation in establishing new public universities in both developing and developed countries. Comparative analysis with the Japanese context enriches the understanding of how countries address the location-allocation decision problem for university campuses, emphasising the significance of context-specific considerations in such decisions.

Keywords Analytic hierarchy process, Campus planning, Urbanisation, Decision support systems, Multi-criteria decision-making, Sustainability

Paper type Research paper

1. Introduction

Universities significantly impact their surroundings, making their location allocation a critical decision (Mohammed and Ukai, 2022, 2023a; Turner, 1984; Ding and Zeng, 2015). They serve as catalysts for urban change in modern planning (Christiaanse, 2006; Muthesius, 2000). Thus, choosing a location must consider both physical and social factors to manage issues like studentification, seasonal migration, and social segregation (Moos *et al.*, 2019; Mosey, 2017; Sage *et al.*, 2011; Smith, 2008; Woldoff and Weiss, 2018). Flexibility for future development is also crucial. A poorly chosen location can lead to financial burdens and

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uncontrolled gentrification. Therefore, university campus location-allocation needs to respond not only to the interests of decision makers or planners, but also to the benefit of students as well as the surrounding communities (Mohammed *et al.*, 2022a).

To determine the most suitable university campus location, both social needs and physical characteristics must be considered. First, decision makers should assess educational demand based on social factors like population, unemployment rate, and migration for study purposes. Then, physical aspects such as land value and availability must be analysed (Mohammed and Ukai, 2023b). This paper focuses on assessing the social and demographic aspects for campus location. High population cities have more university-age students, increasing the demand for a campus. Cities with high unemployment rates need universities to improve job skills. Therefore, demographic and economic structures are crucial in assessing campus demand. The paper employs the analytic hierarchy process (AHP) to rank alternatives for a new public university in Egypt, which plans to establish 125 new universities by 2032 (Egypt Independent, 2020). It also compares the analysis results with government plans to examine demand fulfilment and reflects on the situation in Japan for insights on campus location allocation in both developing and developed countries.

2. Literature review

Reflecting on the history of university establishments, we see key factors influencing their locations. The University of Oxford, founded in 1096, was placed in Oxford for its intellectual atmosphere (University of Oxford, 2023). Harvard University, founded in 1636 to train clergy members, was located near Boston for access to resources and intellectual exchange (Harvard University, 2024). The University of Tokyo, established in 1877, aimed to provide Western-style education and was situated in Tokyo for access to government resources and academic collaboration (The University of Tokyo, 2024). ETH Zurich, founded in 1855 to promote scientific and technical education, was located in Zurich, a hub of finance and innovation (ETH Zurich, 2024). Stanford University, established in 1885, focused on research and education in California and was located in Palo Alto to support its emphasis on innovation and technology (Stanford University, 2022). These examples highlight the need for a universal framework to allocate university locations based on objective criteria.

2.1 Campus-city relationship

Large universities with high student populations raise safety concerns in urban areas. Research shows higher rates of robbery and burglary around such campuses due to their attractiveness to offenders (Cundiff, 2021). The influx of students creates opportunities for criminal activity, and studies consistently link numerous businesses near campuses to increased criminal offenses (Weisburd *et al.*, 2012). Addressing overcrowding and enhancing safety may require establishing new campuses to balance city population and student numbers. The higher the student population, the more challenging safety maintenance becomes.

Moreover, a study on studentification in the UK and China reveals frequent student mobility, resembling seasonal migration, displacing long-term residents and altering demographics (Gu and Smith, 2019). High student housing costs push some to less expensive neighbourhoods, contributing to perceptions of students as marginalised groups subject to urban policies and investor interests (Kinton, 2013; Kinton *et al.*, 2016, 2018; Nakazawa, 2017). These migration trends highlight the need for new university campuses to manage student residence, fostering a more homogeneous city environment. As, concentrated student clusters strain local services, influencing non-student residents, leading to constraints on housing availability and driving up rental rates and property values (Mohammed and Ukai, 2023c, 2024).

Additionally, the financial circumstances of students play a crucial role in the economic consequences of studentification. Research in Gdansk, Poland, highlights the limited purchasing power of students, impacting the quality of accessible services and amenities (Grabkowska and Frankowski, 2016). Unlike in China, European contexts perceive studentification as potentially disruptive to the urban landscape (Gu and Smith, 2019; He, 2014). Considering these factors, establishing new public and national universities with reasonably affordable tuition fees aims to alleviate financial burdens on students.

Furthermore, partnerships between universities and key stakeholders play a pivotal role in identifying suitable sites for new campuses, especially concerning employment prospects. Challenges faced by students regarding employment-related anxieties, particularly in lower-ranked universities, underscore the importance of selecting cities with surplus employment opportunities for new campuses (Kiraz, 2014).

Universities extend beyond their primary missions of education and research, impacting host cities profoundly. Initiatives such as "CampUS-on" and "CampUS-off" exemplify the acknowledgement of a third mission involving outreach beyond campus boundaries (Fassi, 2020). These programs highlight the contribution of youthful student populations to increased public engagement, benefiting cities across various levels. Additionally, universities can bring about profound transformations in cities, fostering creative solutions to community issues and promoting sustainability through enhanced physical and social interactions between campuses and the public (Soares *et al.*, 2020). Choosing cities with substantial young populations for new university campuses can amplify public engagement, reinforcing universities' roles as community partners.

2.2 Campus development in developing and developed countries

Japan is among the top ten countries with the highest number of universities, boasting over 800, providing a rich environment for investigating campus development and location-allocation decisions (Statista, 2021). Japan faces economic challenges due to depopulation, addressed through adaptations in its education sector (Inaba, 2020; Lefebvre, 2015; Muramatsu and Akiyama, 2011; Nguyen, 2018; Yonezawa, 2019). Conversely, Egypt aims to increase the number of universities, targeting one university per million citizens (Egypt Independent, 2020). This effort includes the Egypt-Japan University of Science and Technology (E-JUST), a collaboration between Egypt and Japan (E-JUST, 2022). The Japan International Cooperation Agency (JICA) has initiated programs to transfer Japanese educational experience to African countries, including Egypt, and established Japanese schools in several Egyptian governorates as part of the Egypt-Japan Education Partnership (EJEP) (JICA, 2010; The World Bank, 2018; Blackboard, 2022).

Comparing Egypt and Japan provides insights into university campus location-allocation in developing versus developed countries and how they address educational needs. Since the 1952 revolution, Egypt shifted from "education for the elite" to "education for all," necessitating new public universities to meet localised demand and democratise education (Emira, 2014). This policy enhanced accessibility, social mobility, and economic development (Buckner, 2013; Cupito and Langsten, 2011; Shann, 1992). In contrast, Japan's higher education system is competitive and stratified, with a focus on admission to prestigious universities, signifying status and quality education (Teichler, 1997).

In summary, Egypt's higher education demand is localised, aiming to create opportunities within governorates. Japan's demand is regionally distributed, motivated by securing places in prestigious institutions to enhance career prospects and social standing. This paper quantitatively analyses the necessity of establishing new university campuses in Egypt, considering the localised social characteristics of each governorate, and reflects on the Japanese context to compare and contrast the two types of demand for higher education.

3. Materials and methods

3.1 Study area

Egypt governorates have been selected to be ranked according to their needs for a new university campus. Egypt contains 27 different governorates that consists of several cities, towns, villages, and municipalities. Currently, Egypt also has twenty-seven different public universities, but with government plan to establish more universities in the future, allocating governorates demand may help in identifying how this demand could be fulfilled.

3.2 Selected criteria

This research aims to measure the demand for new university campuses in Egypt by analysing the social quantitative characteristics of each governorate. By doing so, it offers a tool to rank cities based on their need for a new university campus, which can be applied to other countries using available socio-economic data. The Analytic Hierarchy Process (AHP) was chosen to measure and rank demand using quantitative data, with qualitative factors considered later. The proposed workflow operates within multi-criteria decision-making (MCDM), prioritising quantitative criteria over qualitative ones. Thus, methods like AHP, TOPSIS, or ELECTRE are suitable. AHP was selected due to previous explorations of other MCDM methodologies (Miç and Antmen, 2021). If qualitative criteria were the focus, methods like Confirmatory Factor Analysis (CFA) or Structural Equation Modelling (SEM) would be more appropriate. The workflow of AHP helps decision-makers by summarising and ranking quantitative data, providing an objective overview of demand in each governorate. When finalising the solution, decision-makers might consider subjective criteria to offer a balanced solution that meets demand while achieving other objectives (Figure 1).

To assess the demand for a new university campus, several social and economic criteria were selected and evaluated by an expert using AHP (Tables 1–3). These criteria, drawn from literature and expert input, focus on public universities, which are the most common in Egypt and serve the public interest, unlike profit-driven private universities. The criteria are defined as follows:

(1) C_1 (Population): The population of a city determines the number of residents, which is crucial for measuring the demand for a new campus to reduce internal migration for study.

(2) C_2 (Percentage of illiterate people): The percentage of illiterate people reflects the need for a new university to improve awareness and ambitions among residents (United Nations Statistics Division, 2005).

(3) C_3 (Number of graduates): The number of university graduates in a city indicates the need to reduce overcrowding in existing institutions and provide graduate education opportunities.

(4) C_4 (Yearly income): Low income suggests the need for a new campus to improve job prospects and wages.

(5) C_5 (Construction cost): Low construction costs encourage the establishment of new campuses or expansion of existing ones.

(6) C_6 (Labour force): A high labour force necessitates higher education to enhance skills and job qualifications.

(7) C_7 (Unemployment rate): High unemployment highlights the need for educational facilities that prepare job seekers and offer employment opportunities.

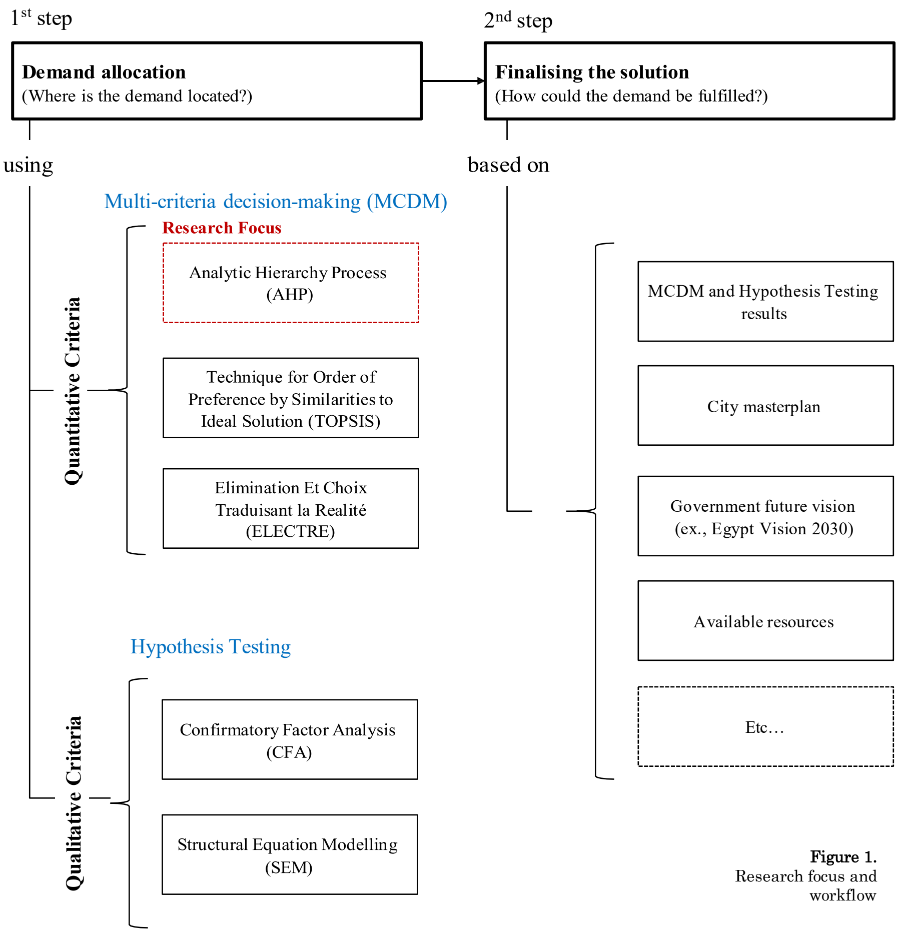


Figure 1.
Research focus and workflow

(8) C_8 (Annual household spending on education): Annual spending on education indicates how much households can spend on private education, informing the need for public universities.

(9) C_9 (Number of high school students): The number of high school students is essential for determining future university demand.

(10) C_{10} (Number of internal migrants for the purpose of study): The number of internal migrants shows the need to reduce migration by providing local higher education opportunities.

(11) C_{11} (Number of university staff): The number of university staff in a city is essential for running a new campus, indicating feasibility.

(12) C_{12} (Number of students at university age): The number of students at the age of university education reflects demand for undergraduate and graduate education.

Table 1.
Materials used for locating university campuses based on city's social needs

Criteria	Data type	Location	Processed data Data collection time	Data source	Data delivery
C_1 (Population)	Number of city's population	Governorates of Egypt	2021	The Central Agency for Public Mobilisation and Statistics in Egypt (CAPMAS)	Downloaded
C_2 (Percentage of illiterate people)	Percentage of illiterate people of city's population		2017		
C_3 (Number of graduates)	Number of graduates from city's public universities		2021		
C_4 (Yearly income)	Average yearly income per person in USD		2020		
C_5 (Construction cost)	Average construction cost in USD per operation		2020		
C_6 (Labour force)	Number of residents who work or can work at the age of 15 years old or older		2020		
C_7 (Unemployment rate)	Percentage of labour force who don't have a job		2021		
C_8 (Annual household spending on education)	Percentage of household average spending on education of its total annual spending		2020		
C_9 (High school students)	Number of students in city's high/ secondary schools		2020		
C_{10} (Number of internal migrants for the purpose of study)	Number of migrates who migrated internally from other cities for the purpose of study		2006		
C_{11} (Number of university staff)	Number of university staff who live or work at city's public universities		2021		
C_{12} (Students at university age)	Number of residents at the age from 15 to 44 years old		2017		
C_{13} (Available education opportunities)	Percentage of educational opportunities for citizens at the age from 18 to 22 years old		2013		

Criteria	Criteria explanation	Inclusion source	Related literature
C_1	Population	From literature	Gu and Smith (2019), Miç and Antmen (2021), Moos *et al.* (2019), Smith (2008)
C_2	Percentage of illiterate people	From literature	Miç and Antmen (2021), Mutula (2010), Nwaopara *et al.* (2008)
C_3	Number of graduates	From literature	Joyce *et al.* (2007), Miç and Antmen (2021), Rydon *et al.* (2008), Støren and Wiers-Jenssen (2016)
C_4	Yearly income	From literature	Anelli and Peri (2019), Miç and Antmen (2021), Pitsakis *et al.* (2015), Plu€mper and Schneider (2007), Quirke and Davies (2002), Swamidass and Vulasa (2009)
C_5	Construction cost	From literature	Alshamrani (2018), Bromilow and Pawsey (2013), Butler *et al.* (2020), Miç and Antmen (2021), Olatunde and Alao (2017)
C_6	Labour force	From literature	Kayahan Karakul (2016), Prais (1981), Simister (2011)
C_7	Unemployment rate	From literature	Cardoso and Ferreira (2010), Plu€mper and Schneider (2007), Schubert and Kroll (2016)
C_8	Annual household spending on education	From literature	Pickbourn (2015), Qian and Smyth (2010), Varughese and Bairagya (2021)
C_9	Number of high school students	From literature	Kitchen *et al.* (2018), Usak *et al.* (2009)
C_{10}	Number of internal migrants for the purpose of study	Experts' suggestion	Di Cintio and Grassi (2013), Gould (1982), Kinton (2013), Kinton *et al.* (2016, 2018)
C_{11}	Number of university staff	Experts' suggestion	Gornitzka and Larsen (2004), Pinkovetskaia (2022), Waugh (2002)
C_{12}	Number of students at university age	Experts' suggestion	Kitchen *et al.* (2018), Talmage *et al.* (2018), Usak *et al.* (2009)
C_{13}	Available education opportunities	Experts' suggestion	Curtis and Ledgerwood (2018), Talmage *et al.* (2018)

(13) C_{13} (Available education opportunities): Lower percentages of education opportunities indicate higher demand for new campuses.

Selected data have been collected for the twenty-seven governorates of Egypt from the online resources of CAPMAS, the Central Agency for Public Mobilisation and Statistics in Egypt (CAPMAS, 2022).

3.3 Analytic hierarchy process (AHP)

Analytic Hierarchy Process (AHP) is a ranking methodology used to prioritise alternatives based on attribute weights. It is a widely used multi-criteria decision-making (MCDM) technique for solving complex problems (Saaty, 1980, 1985). AHP begins by defining the main goal (e.g. locating a university campus) and identifying relevant criteria, which can be further divided into sub-criteria if necessary. Criteria are weighted using a pairwise comparison matrix based on their importance as assessed by an expert or experts. These weights are then used to rank alternatives and select the most suitable option (Akalin *et al.*, 2013; Triantaphyllou and Mann, 1995).

Saaty and Özdemir (2014) demonstrated that a single well-experienced expert is sufficient for reliable results instead of diluting his/her knowledge and experience with other participants who may not be as well versed in the field. Therefore, in this paper, the criteria

Table 3.
Collected data

Governorates		C_1 (Person)	C_2 (%)	C_3 (Person)	C_4 (USD)	C_5 (USD)	C_6 (Person)	C_7 (%)	C_8 (%)	C_9 (Student)	C_{10} (Resident)	C_{11} (Staff)	C_{12} (Student)	C_{13} (%)
A_1	Cairo	10,021,820	16.2	136,924	1991.58	1076516.48	3,085,600	13.70	19.30	183,940	40,972	30,628	4,720,227	59.90
A_2	Alexandria	5,422,608	19	34,365	3216.84	1142665.46	1,713,000	12.80	17.60	94,363	5,108	6,536	2,452,602	46.40
A_3	Port Said	778,544	14.1	7,294	1225.26	1722332.61	295,300	25.20	9.90	11,961	1,635	1,372	358,799	44.80
A_4	Suez	770,333	15.3	7,632	2096.84	602857.14	231,500	13.30	12.80	8,881	1,261	3,708	348,398	26.00
A_5	Damietta	1,578,340	20.23	6,224	1768.42	230008.47	555,000	18.90	10.40	29,292	900	1,196	690,712	20.30
A_6	Dakahlia	6,859,894	23.57	30,466	1166.32	585256.30	1,902,900	2.50	13.00	128,323	2,576	6,168	2,948,076	30.70
A_7	Sharkia	7,640,082	25.92	29,621	2136.84	495123.71	2,119,000	6.00	13.10	120,410	2,534	5,935	3,317,990	23.10
A_8	Kalyoubia	5,953,131	23.7	17,373	1305.26	434068.59	1,805,200	9.50	11.10	94,535	4,703	4,310	2,699,761	19.90
A_9	Kafr-El-Sheikh	3,600,196	28.5	13,324	1244.21	442916.38	1,101,500	2.70	10.80	54,878	861	1,520	1,546,337	16.90
A_{10}	Gharbia	5,285,660	21.4	22,507	1195.79	239695.62	1,757,200	10.20	10.00	87,252	1,189	4,651	2,313,753	23.50
A_{11}	Menoufia	4,578,910	22.5	22,245	1082.11	271609.87	1,421,900	4.20	11.50	88,413	1,363	4,289	1,978,702	18.30
A_{12}	Behera	6,632,497	32.9	12,434	1404.21	190718.27	1,993,000	3.60	9.80	74,137	2,025	1,129	2,863,823	8.90
A_{13}	Ismailia	1,400,315	21.4	N/A	1597.89	366961.03	442,600	9.60	10.20	21,148	1,911	N/A	602,707	25.90
A_{14}	Giza	9,200,884	24.9	40,443	2149.47	1009564.58	2,728,400	9.40	15.70	156,919	12,439	12,385	4,142,945	54.40
A_{15}	Beni-Suef	3,430,098	35.9	17,228	791.58	669559.81	1,059,400	3.80	9.90	41,482	2,283	2,769	1,433,121	20.80
A_{16}	Fayoum	3,897,412	34	6,192	1303.16	155964.30	1,039,200	3.60	6.90	34,956	384	2,401	1,618,657	6.80
A_{17}	Menia	6,023,203	37.2	12,910	1023.16	438021.72	1,678,300	3.30	6.60	80,471	1,828	3,196	2,527,847	10
A_{18}	Assiut	4,802,434	34.6	17,938	1109.47	953965.48	1,181,900	3.40	7.70	56,656	7,437	4,306	2,042,358	27.60
A_{19}	Sohag	5,439,346	33.6	11,737	1067.37	527229.29	1,254,600	3.00	7.00	58,000	1,066	2,189	2,258,950	14.90
A_{20}	Qena	3,463,061	29.1	12,406	1585.26	516093.53	795,000	1.60	6.80	41,799	7,870	1,771	1,480,594	17.00
A_{21}	Aswan	1,590,377	19.1	5,686	1,993.68	575356.10	448,800	5.00	7.40	17,579	3,054	1,165	702,661	18.80
A_{22}	Luxor	1,345,279	25.9	376	901.05	453303.34	378,000	6.70	8.40	16,688	111	174	605,309	17.40
A_{23}	El-Bahr El-Ahmar	387,494	12	N/A	1566.32	1044979.76	135,700	23.60	10.80	6,064	900	N/A	174,738	4.30
A_{24}	El-Wadi El-Gidid	257,752	14.7	1,111	791.58	245976.00	88,100	14.20	10.80	5,205	296	430	111,029	6.50
A_{25}	Matrouh	502,734	31.9	493	1307.37	2701307.30	106,200	4.90	10.80	4,502	354	127	195,645	4.70
A_{26}	North Sinai	489,428	22.2	1,629	2991.58	481585.18	N/A	0.00	10.80	7,895	444	340	205,925	36.60
A_{27}	South Sinai	111,870	16.6	N/A	1722.11	398875.67	40,800	33.60	10.80	28,950	432	N/A	47,370	1.80

were evaluated by the former president of Sohag University, a public university in Sohag Governorate, Egypt (Table 4).

For AHP, the decision problem must be clearly defined, and the right criteria identified. Criteria were selected from the literature and supplemented by expert input. The rationale behind each criterion and its impact on the outcome were explained earlier. This paper focuses on quantitative data from governmental sources to objectively assess governorates' needs. As shown in Figure 2, a hierarchical structure is used to define the relationship between the main goal, criteria, and alternatives. The main goal is at the top level, followed by criteria, and then alternatives (Mikhailov and Tsvetinov, 2004; Saaty, 1994).

4. Results

A pairwise matrix has been calculated to present the relative importance of each criterion. Therefore, the criteria have been evaluated first by the expert using five different levels of importance from not important at all to extremely important (Table 5). Then, using the scale of relative importance, shown in Table 6, the pairwise matrix has been calculated (Saaty, 1980). Pairwise matrix is produced by comparing the importance of each criterion in a pairwise fashion based on the evaluation of the expert. For example, population (C_1) has been evaluated by the expert as extremely important. However, the percentage of illiterate people (C_2) has been evaluated to be neutral, which means that C_1 is on the fifth level of importance. However, C_2 is on the second level. Accordingly, C_1 is four times important than C_2 and C_2 is 1/4 time important than C_1. Subsequently, as shown in Table 7, pairwise comparison has been presented as a square matrix of $A = [C_{ij}]_{n \times n}$ as in the following equation:

$$A = \begin{bmatrix} C_{11} & C_{12} & \dots & C_{1n} \\ C_{21} & C_{22} & \dots & C_{2n} \\ . & . & . & . \\ C_{n1} & C_{n2} & \dots & C_{nn} \end{bmatrix} \qquad \text{Eq. (1)}$$

where A is the pairwise comparison matrix in which entry C_{ij} describes how much the criterion C_i is important compared to C_j, while the lower part entries are computed using reciprocal operation:

$$C_{ji} = {}^{1}/{C_{ij}} \qquad \text{Eq. (2)}$$

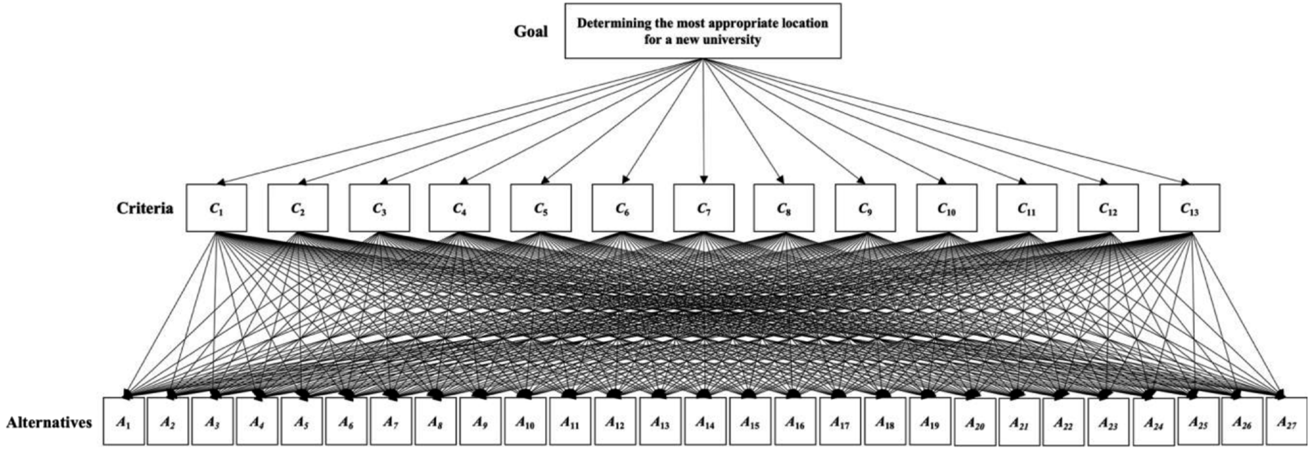
where $C_{ij} \neq 0$

In order to obtain the weights for each criterion, the pairwise matrix needed to be normalised first. Normalisation was done by dividing each element of the pairwise matrix by the sum of its column (Chen, 2016). Accordingly, normalisation was done using the following equation:

Interviewer	Interviewee	Interview date and time	Interview medium
First author	Former president of Sohag University	26th December 2022 (From 13:00 to 13:30 Greenwich Mean Time)	Online interview

Source(s): Authors' own work

Table 4.
Interview details



Source(s): Authors' own work

Criteria	Evaluation: Not important at all	Not important	Neutral	Important	Extremely important
C_1 (Population)					✓
C_2 (Percentage of illiterate people)			✓		
C_3 (Number of graduates)		✓			
C_4 (Yearly income)				✓	
C_5 (Construction cost)	✓				
C_6 (Labour force)				✓	
C_7 (Unemployment rate)				✓	
C_8 (Annual household spending on education)	✓				
C_9 (High school students)					✓
C_{10} (Number of internal migrants for the purpose of study)				✓	
C_{11} (Number of university staff)				✓	
C_{12} (Students at university age)					✓
C_{13} (Available education opportunities)				✓	

Source(s): Authors' own work

Strength of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values
Reciprocals	Values for reverse evaluation

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
C_1	1	4	6	2	8	2	2	8	1	2	2	1	2
C_2	1/4	1	2	1/2	4	1/2	1/2	4	1/4	1/2	1/2	1/4	1/2
C_3	1/6	1/2	1	1/4	2	1/4	1/4	2	1/6	1/4	1/4	1/6	1/4
C_4	1/2	2	4	1	6	1	1	6	1/2	1	1	1/2	1
C_5	1/8	1/4	1/2	1/6	1	1/6	1/6	1	1/8	1/6	1/6	1/8	1/6
C_6	1/2	2	4	1	6	1	1	6	1/2	1	1	1/2	1
C_7	1/2	2	4	1	6	1	1	6	1/2	1	1	1/2	1
C_8	1/8	1/4	1/2	1/6	1	1/6	1/6	1	1/8	1/6	1/6	1/8	1/6
C_9	1	4	6	2	8	2	2	8	1	2	2	1	2
C_{10}	1/2	2	4	1	6	1	1	6	1/2	1	1	1/2	1
C_{11}	1/2	2	4	1	6	1	1	6	1/2	1	1	1/2	1
C_{12}	1	4	6	2	8	2	2	8	1	2	2	1	2
C_{13}	1/2	2	4	1	6	1	1	6	1/2	1	1	1/2	1

$$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}} \quad \text{Eq. (3)}$$

where X_{ij} is the normalised value of C_{ij} for all $j = 1, 2, \ldots, n$.

After normalising the pairwise matrix as shown in Table 8, weights have been measured by averaging all the elements in each row of the normalised pairwise matrix by applying the following equation (Table 9):

$$W_i = \frac{\sum_{j=1}^{n} X_{ij}}{n} \quad \text{Eq. (4)}$$

where W_i is the weight of each criterion for all $i = 1, 2, \ldots, n$.

Finally, after the weights have been calculated, it is important to check their consistency by calculating the consistency ratio (*CR*), as AHP is highly dependent on the subjective judgement of experts. Therefore, to avoid any bias, it is essential to check *CR* value to verify the credibility of experts' evaluation. If *CR* value is less than or equal to 0.1, the pairwise comparison matrix is considered consistent and reliable (Chen, 2016; Yap *et al.*, 2018). In order to calculate *CR*, consistency index (*CI*) needed to be obtained first from the following equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad \text{Eq. (5)}$$

where n is the number of selected criteria.

λ_{max} is the maximum eigenvalue of the pairwise comparison matrix which is considered as an important validating parameter in AHP that is used to screen information by calculating *CR* (Saaty, 1980). To calculate λ_{max}, pairwise comparison matrix needed to be multiplied by criteria weights calculated in Eq. (4) using the following equation:

$$\begin{bmatrix} C_{11} & C_{12} & \ldots & C_{1n} \\ C_{21} & C_{22} & \ldots & C_{2n} \\ . & . & . & . \\ C_{n1} & C_{n2} & \ldots & C_{nn} \end{bmatrix} \times \begin{bmatrix} W_1 \\ W_2 \\ . \\ W_n \end{bmatrix} \quad \text{Eq. (6)}$$

Then, weighted sum value of each row was divided by the criteria weights using the following equation:

$$(C_{11}W_1 + C_{12}W_2 + \ldots + C_{1n}W_n) \div W_1 \quad \text{Eq. (7)}$$

Then, resultant values have been averaged to calculate λ_{max} (Table 10).

The consistency ratio (*CR*) was then calculated using the following formula:

$$CR = \frac{CI}{RI} \quad \text{Eq. (8)}$$

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
C_1	0.1500	0.1538	0.1304	0.1529	0.1176	0.1529	0.1529	0.1176	0.1500	0.1529	0.1529	0.1500	0.1529
C_2	0.0375	0.0385	0.0435	0.0382	0.0588	0.0382	0.0382	0.0588	0.0375	0.0382	0.0382	0.0375	0.0382
C_3	0.0250	0.0192	0.0217	0.0191	0.0294	0.0191	0.0191	0.0294	0.0250	0.0191	0.0191	0.0250	0.0191
C_4	0.0750	0.0769	0.0870	0.0764	0.0882	0.0764	0.0764	0.0882	0.0750	0.0764	0.0764	0.0750	0.0764
C_5	0.0188	0.0096	0.0109	0.0127	0.0147	0.0127	0.0127	0.0147	0.0188	0.0127	0.0127	0.0188	0.0127
C_6	0.0750	0.0769	0.0870	0.0764	0.0882	0.0764	0.0764	0.0882	0.0750	0.0764	0.0764	0.0750	0.0764
C_7	0.0750	0.0769	0.0870	0.0764	0.0882	0.0764	0.0764	0.0882	0.0750	0.0764	0.0764	0.0750	0.0764
C_8	0.0188	0.0096	0.0109	0.0127	0.0147	0.0127	0.0127	0.0147	0.0188	0.0127	0.0127	0.0188	0.0127
C_9	0.1500	0.1538	0.1304	0.1529	0.1176	0.1529	0.1529	0.1176	0.1500	0.1529	0.1529	0.1500	0.1529
C_{10}	0.0750	0.0769	0.0870	0.0764	0.0882	0.0764	0.0764	0.0882	0.0750	0.0764	0.0764	0.0750	0.0764
C_{11}	0.0750	0.0769	0.0870	0.0764	0.0882	0.0764	0.0764	0.0882	0.0750	0.0764	0.0764	0.0750	0.0764
C_{12}	0.1500	0.1538	0.1304	0.1529	0.1176	0.1529	0.1529	0.1176	0.1500	0.1529	0.1529	0.1500	0.1529
C_{13}	0.0750	0.0769	0.0870	0.0764	0.0882	0.0764	0.0764	0.0882	0.0750	0.0764	0.0764	0.0750	0.0764

Source(s): Authors' own work

Criteria	Weights	%
C_1	0.1451	14.51
C_2	0.0416	4.16
C_3	0.0223	2.23
C_4	0.0788	7.88
C_5	0.0140	1.40
C_6	0.0788	7.88
C_7	0.0788	7.88
C_8	0.0140	1.40
C_9	0.1451	14.51
C_{10}	0.0788	7.88
C_{11}	0.0788	7.88
C_{12}	0.1451	14.51
C_{13}	0.0788	7.88
Sum	1	100

Source(s): Authors' own work

where *RI* is a random consistency index that is obtained from a randomly generated pairwise comparison matrix. *RI* for $n =$ 13 is 1.56 (Table 11) (Saaty, 1980). *CI* for selected criteria was calculated as 0.0067. Accordingly, *CR* was calculated as 0.0043 which is less than 0.1 which in turn means that expert's feedback is credible. Although *CR* was expected to be less than 0.1 as there was only one expert feedback, *CR* was calculated here as a mathematical reference.

After defining the weights, alternatives' data were normalised to rank governorates according to their need for a new public university. Normalisation was done based on the potential impact of each criterion. For example, governorates with high population are expected to be in need for a new university campus. Accordingly, population data were normalised, so the governorate with the highest population would have a value of 1. On the other hand, governorates with low yearly income are expected to be in need for a new university campus. Accordingly, the governorate with the lowest yearly income would have a value of 1. Similarly, governorates' data were normalised as shown in Table 12. Then, weighted sum value for each alternative (governorate) was calculated by multiplying each criteria normalised valued by its correspondent weight and summing up all weighted values for each alternative by applying the following equation:

$$\text{Weighted sum value} = (N_{11} \times W_1) + (N_{12} \times W_2) + \ldots + (N_{1n} \times W_n) \quad \text{Eq. (9)}$$

where N_{1n} is the normalised value of C_n for A_1, and W_n is the weight of C_n.

The resultant weighted sum values of all alternatives were then ranked from the highest to the lowest with the highest value being the governorate in the most need for a new public university campus and the lowest being the governorate in the least need for a new public university campus (Table 13).

Unlike what was expected the Governorate of Cairo has been ranked in the first place as the most governorate to be in need for a new university campus. It was anticipated that governorates in Upper Egypt, which is the southern part of the country, would be in desperate need for a new university, as most of these governorates have higher percentages of illiterate people in addition to less education opportunities (Table 3). However, the first governorate to appear in the ranking was Menia Governorate in the fifth place. So, the final demand ranking was shown to be quite the opposite of what was anticipated. Cairo Governorate, which has three of the largest universities in Egypt (Ain Shams University, Helwan University, and Azhar University), in addition to Giza

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	Weighted sum value	Weighted sum value divided by criteria weights
C_1	0.15	0.17	0.13	0.16	0.11	0.16	0.16	0.11	0.15	0.16	0.16	0.15	0.16	1.91	13.13
C_2	0.04	0.04	0.04	0.04	0.06	0.04	0.04	0.06	0.04	0.04	0.04	0.04	0.04	0.54	13.06
C_3	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.29	13.02
C_4	0.07	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.08	1.03	13.09
C_5	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.18	13.02
C_6	0.07	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.08	1.03	13.09
C_7	0.07	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.08	1.03	13.09
C_8	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.18	13.02
C_9	0.15	0.17	0.13	0.16	0.11	0.16	0.16	0.11	0.15	0.16	0.16	0.15	0.16	1.91	13.13
C_{10}	0.07	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.08	1.03	13.09
C_{11}	0.07	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.08	1.03	13.09
C_{12}	0.15	0.17	0.13	0.16	0.11	0.16	0.16	0.11	0.15	0.16	0.16	0.15	0.16	1.91	13.13
C_{13}	0.07	0.08	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.08	1.03	13.09
λ_{max}															13.08

Source(s): Authors' own work

Governorate, which has Cairo University the largest public university in Egypt, have occupied the first two places in the ranking (Table 13 and Table 14). This could be explained according to criteria weights. Population (C_1), the number of high school students (C_9), and students at university age (C_{12}) were given the highest weights (14.51%) (Table 9). Which means that governorates that are high in population will be most likely at the top of the list, as higher population means a high number of high school students or students at university age. Accordingly, governorates with high population appeared at the top of the list. On the other hand, governorates with low population appeared later, even though they have no public universities at all. For example, South Sinai, El-Bahr El-Ahmar, and Ismailia have appeared in the 11th, 22nd and 24th places respectively (Table 13 and Table 14). Accordingly, residents of these governorates would migrate to the nearest governorate with a public university to study there. This could explain the high demand in Cairo and Giza governorates. Internal migration trends for study purposes may be the reason behind such high demand.

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
A_1	1.00	0.44	0.00	0.40	0.14	0.01	0.41	0.34	1.00	1.00	1.00	1.00	0.03
A_2	0.54	0.51	0.01	0.25	0.14	0.02	0.38	0.38	0.51	0.12	0.21	0.52	0.04
A_3	0.08	0.38	0.05	0.65	0.09	0.14	0.75	0.67	0.07	0.04	0.04	0.08	0.04
A_4	0.08	0.41	0.05	0.38	0.26	0.18	0.40	0.52	0.05	0.03	0.12	0.07	0.07
A_5	0.16	0.54	0.06	0.45	0.68	0.07	0.56	0.63	0.16	0.02	0.04	0.15	0.09
A_6	0.68	0.63	0.01	0.68	0.27	0.02	0.07	0.51	0.70	0.06	0.20	0.62	0.06
A_7	0.76	0.70	0.01	0.37	0.32	0.02	0.18	0.50	0.65	0.06	0.19	0.70	0.08
A_8	0.59	0.64	0.02	0.61	0.36	0.02	0.28	0.59	0.51	0.11	0.14	0.57	0.09
A_9	0.36	0.77	0.03	0.64	0.35	0.04	0.08	0.61	0.30	0.02	0.05	0.33	0.11
A_{10}	0.53	0.58	0.02	0.66	0.65	0.02	0.30	0.66	0.47	0.03	0.15	0.49	0.08
A_{11}	0.46	0.60	0.02	0.73	0.57	0.03	0.13	0.57	0.48	0.03	0.14	0.42	0.10
A_{12}	0.66	0.88	0.03	0.56	0.82	0.02	0.11	0.67	0.40	0.05	0.04	0.61	0.20
A_{13}	0.14	0.58	0.00	0.50	0.43	0.09	0.29	0.65	0.11	0.05	0.00	0.13	0.07
A_{14}	0.92	0.67	0.01	0.37	0.15	0.01	0.28	0.42	0.85	0.30	0.40	0.88	0.03
A_{15}	0.34	0.97	0.02	1.00	0.23	0.04	0.11	0.67	0.23	0.06	0.09	0.30	0.09
A_{16}	0.39	0.91	0.06	0.61	1.00	0.04	0.11	0.96	0.19	0.01	0.08	0.34	0.26
A_{17}	0.60	1.00	0.03	0.77	0.36	0.02	0.10	1.00	0.44	0.04	0.10	0.54	0.18
A_{18}	0.48	0.93	0.02	0.71	0.16	0.03	0.10	0.86	0.31	0.18	0.14	0.43	0.07
A_{19}	0.54	0.90	0.03	0.74	0.30	0.03	0.09	0.94	0.32	0.03	0.07	0.48	0.12
A_{20}	0.35	0.78	0.03	0.50	0.30	0.05	0.05	0.97	0.23	0.19	0.06	0.31	0.11
A_{21}	0.16	0.51	0.07	0.40	0.27	0.09	0.15	0.89	0.10	0.07	0.04	0.15	0.10
A_{22}	0.13	0.70	1.00	0.88	0.34	0.11	0.20	0.79	0.09	0.00	0.01	0.13	0.10
A_{23}	0.04	0.32	0.00	0.51	0.15	0.30	0.70	0.61	0.03	0.02	0.00	0.04	0.42
A_{24}	0.03	0.40	0.34	1.00	0.63	0.46	0.42	0.61	0.03	0.01	0.01	0.02	0.28
A_{25}	0.05	0.86	0.76	0.61	0.06	0.38	0.15	0.61	0.02	0.01	0.00	0.04	0.38
A_{26}	0.05	0.60	0.23	0.26	0.32	0.00	0.00	0.61	0.04	0.01	0.01	0.04	0.05
A_{27}	0.01	0.45	0.00	0.46	0.39	1.00	1.00	0.61	0.16	0.01	0.00	0.01	1.00

Governorates		Weighted sum value	Ranking
A_1	Cairo	0.68	1
A_2	Alexandria	0.34	9
A_3	Port Said	0.19	23
A_4	Suez	0.15	26
A_5	Damietta	0.21	20
A_6	Dakahlia	0.42	4
A_7	Sharkia	0.42	3
A_8	Kalyoubia	0.38	6
A_9	Kafr-El-Sheikh	0.26	16
A_{10}	Gharbia	0.36	8
A_{11}	Menoufia	0.33	12
A_{12}	Behera	0.38	7
A_{13}	Ismailia	0.17	24
A_{14}	Giza	0.53	2
A_{15}	Beni-Suef	0.29	14
A_{16}	Fayoum	0.29	15
A_{17}	Menia	0.39	5
A_{18}	Assiut	0.33	13
A_{19}	Sohag	0.33	10
A_{20}	Qena	0.25	17
A_{21}	Aswan	0.16	25
A_{22}	Luxor	0.22	19
A_{23}	El-Bahr El-Ahmar	0.19	22
A_{24}	El-Wadi El-Gidid	0.22	18
A_{25}	Matrouh	0.20	21
A_{26}	North Sinai	0.09	27
A_{27}	South Sinai	0.33	11

5. Discussion and reflections

Results indicate that ranking alternatives by social demand only partially addresses the issue. A broader perspective is necessary. For instance, large governorates with big public universities still need more institutions to meet demand. Conversely, governorates with no public universities rank lower but may still benefit from new universities to prevent internal migration to larger governorates. This approach could reduce demand in these host areas. The Egyptian government is implementing this strategy by building universities in governorates with no public universities (Table 14). Although this differs from AHP analysis conclusions, it effectively alleviates pressure on high-demand areas. Thus, while AHP helps identify the problem, it does not always provide the solution.

Furthermore, the Egyptian government uses university campuses to encourage migration from the densely populated Nile Valley to new cities. National and private universities are being established in these areas to promote urban expansion (Mohammed *et al.*, 2022b). For example, six new international universities are planned for the New Administrative Capital (Egypt Independent, 2022). Additionally, national universities are being built in rural areas to spur development (Soliman, 2022). A notable case is Sohag University, which was initially planned for El-Kawthar City but was moved to El-Kawamel City after the Ministry of Housing offered free land and infrastructure support. This decision highlights that campus locations are influenced by factors beyond demand, aiming to maximise overall benefits.

To understand how context impacts university location-allocation decisions, consider Japan, which has over 800 universities and newly established campuses to address economic

University	Foundation year	Governorate
Ain Shams University	1950	Cairo
Helwan University	1975	
Azhar University	1975	
Alexandria University	1938	Alexandria
Port Said University	2009	Port Said
Suez Canal University	1976	Suez
Damietta University	2012	Damietta
Mansoura University	1972	Dakahlia
Zagazig University	1974	Sharkia
Benha University	2005	Kalyoubia
Kafr Elsheikh University	2006	Kafr-El-Sheikh
Tanta University	1972	Gharbia
Menoufia University	1976	Menoufia
Sadat University	2013	
Damanhour University	2010	Behera
Cairo University	1908	Giza
Beni-Suef University	2005	Beni-Suef
Fayoum University	2005	Fayoum
Menia University	1976	Menia
Assiut University	1957	Assiut
Sohag University	2006	Sohag
South Valley university	1994	Qena
Aswan University	2012	Aswan
Luxor University	2019	Luxor
New Valley University	2018	El-Wadi El-Gidid
Matrouh University	2018	Matrouh
Arish University	2016	North Sinai

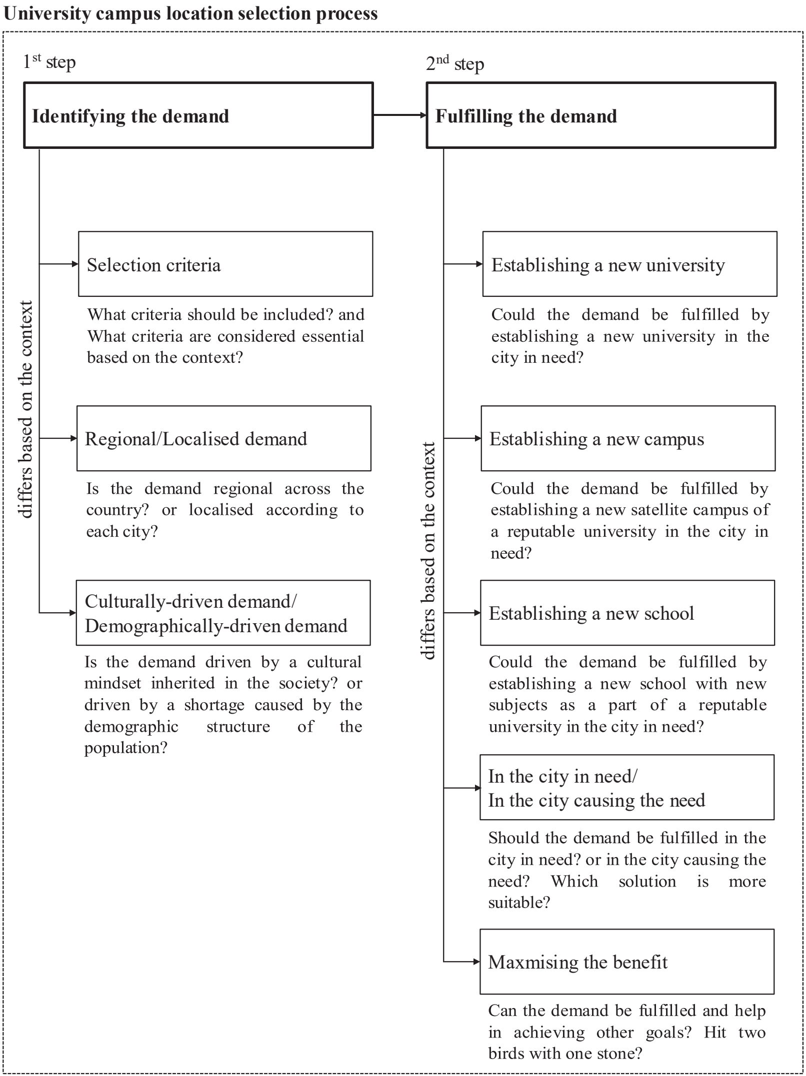
Source(s): Authors' own work

challenges (Mohammed and Ukai, 2021, 2022). Unlike Egypt, Japan does not lack universities, but cultural factors create a need for new campuses. The demand in Japan is regional, with students seeking high-ranking universities, regardless of location, due to the national entrance exam system and the cultural emphasis on academic records, known as "Gakureki Shakai" (Yamauchi, 2018). This mindset pressures Japan's top universities (Bhardwa, 2017), while lower-ranked "border-free" universities are easier to enter (Ito, 2021).

In Japan, university rankings, students' exam scores, and the capacity of top universities are crucial criteria for location decisions, unlike Egypt, which needs more universities to meet local demand. Contextual differences within countries also affect criteria weights; for instance, construction costs vary by city and are sometimes prioritised (Miç and Antmen, 2021), but may be deemed unimportant in other cases. Thus, university location criteria cannot be generalised globally and must be tailored to the specific context.

In summary, identifying and fulfilling demand are distinct steps in decision-making (Figure 3). Contextual social and cultural differences influence how demand is addressed. Criteria for allocating demand vary by context, and it is crucial to determine whether the demand is regional or localised. In Japan, where demand is regional, the government can establish satellite campuses of reputable universities to increase opportunities for students. In Egypt, where demand is localised, new local universities are established to meet city-specific needs.

The type of demand also matters: Japan's cultural emphasis on academic records ("Gakureki Shakai") requires region-wide solutions like new satellite campuses for top universities (Yamauchi, 2018). In contrast, Egypt's demographic-driven demand is met by



adding more local universities. Decision makers' perspectives also play a role. In Egypt, decision makers address demand by building universities in rural or newly established cities to promote urbanisation and migration from the Nile Valley (Mohammed *et al.*, 2022b; Mohammed and Ukai, 2023a). Additionally, universities help reduce unemployment and household education expenses, benefiting low-income families (Rydon *et al.*, 2008; Simon, 1998; Qian and Smyth, 2010; Varughese and Bairagya, 2021). Thus, decision makers' interests significantly influence how demand is fulfilled.

The main hypothesis of this paper is that governorates without public universities would top the list of those needing a new university. However, the AHP analysis revealed that governorates with the most universities ranked highest due to their large populations. Despite these results, Egypt plans to establish public universities in all governorates and new cities to encourage migration. This highlights the role of decision makers' subjective assessments and future visions in finalising solutions. Determining demand using socio-economic data remains essential, allowing decision makers to prioritise actual demand or other qualitative criteria. Thus, while AHP identifies demand based on data, fulfilling that demand involves subjective decision-making considering various qualitative factors (e.g. city masterplans, government visions, resources).

Reflecting on Egypt's government plan reveals differences from AHP suggestions. However, AHP results clarify decision makers' priorities without contradicting evaluation points. AHP allocates demand but does not provide a single best solution; fulfilling demand involves subjective decision-making (Figure 1). AHP identifies decision-making patterns rather than right or wrong answers. Without AHP, we might assume demand is in newly established cities based on government actions. The distinction between AHP results and government actions helps us understand government priorities.

In conclusion, this paper presents a mathematical methodology that offers useful recommendations for evidence-based decision making. However, contextual differences and decision makers' subjective assessments play key roles in finalising the best solution.

6. Conclusion

Choosing the best location for a new university campus depends on various context-specific criteria. Multi-criteria decision-making methodologies provide a common ground for decision-makers to identify the most suitable solution. This paper introduces a mathematical methodology to allocate campus locations based on cities' social needs, offering a valuable tool for policy formulation in establishing new public universities. However, these methodologies provide mathematical solutions that may not be optimal. Surprisingly, results indicate that Egyptian governorates with large public universities still need more. Therefore, decision-makers' interests and subjective assessments are crucial. In Egypt, new universities are often located in new cities to promote urbanisation and meet educational demands. Cultural mindsets also influence campus location choices; for instance, Japanese students favour reputable universities, creating a demand for satellite campuses of prestigious institutions. Identifying and fulfilling demand are distinct steps: AHP and other MCDM techniques help identify demand, but fulfilling it relies on government views and interests.

Future research should address this paper's limitations. To overcome data availability issues, future studies can use multi-source data from local municipalities and city wards instead of relying on open-source governmental data. Comparative analyses between different MCDM techniques in campus location decisions would provide a comprehensive view, considering social and cultural aspects. Additionally, investigating qualitative criteria through methods like Confirmatory Factor Analysis (CFA) or Structural Equation Modelling (SEM) could lead to a comprehensive framework for university campus location allocation.

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