Martinetti *et al.*
Journal of International Humanitarian Action (2024) 9:7
https://doi.org/10.1186/s41018-024-00149-6

Journal of International Humanitarian Action

RESEARCH ARTICLE

Open Access

EDUBox: finding suitable locations for offgrid mobile classrooms in the context of underserved communities

Alberto Martinetti[1*], Nina Trauernicht[1], Margot Dietrich[1] and Peter Chemweno[1]

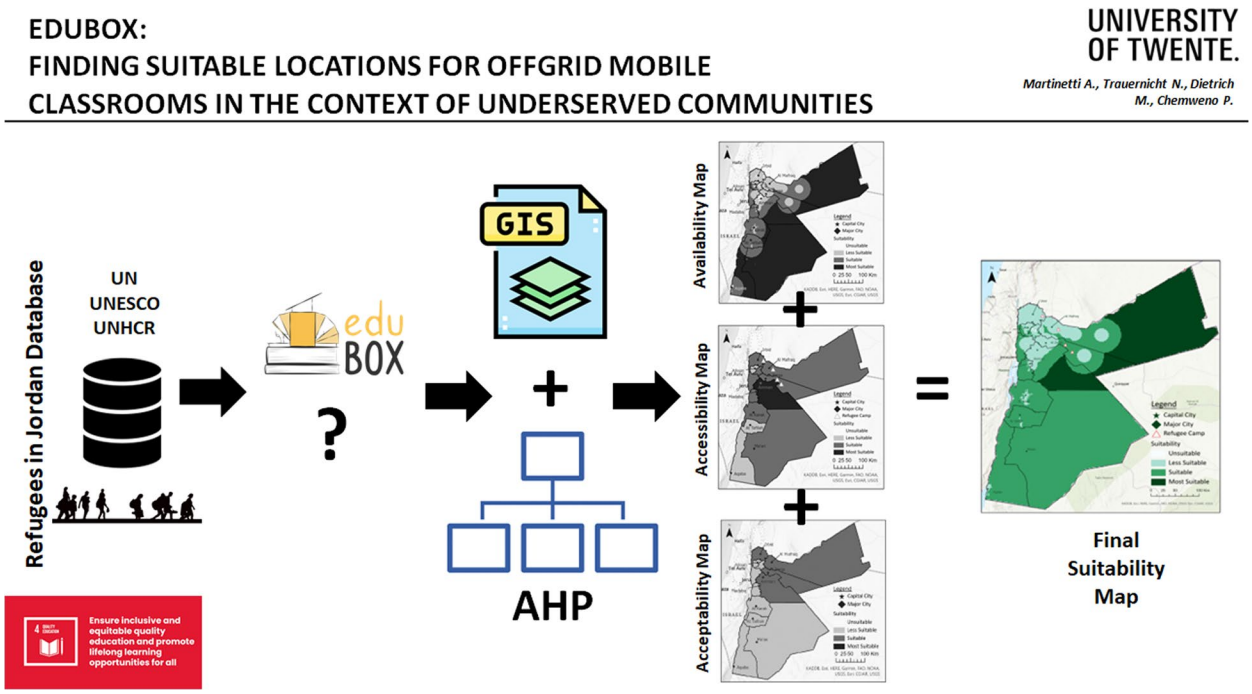
Abstract

The refugee crisis and the COVID-19 pandemic continue to negatively impact access to education, and especially disproportionately affect underserved communities. Apart from access, such communities experience additional barriers including inadequate classroom infrastructure and suitable localization of such infrastructure. This paper aims to provide an analytical framework to identify the most suitable locations for mobile classrooms for underserved communities, thereby mitigating the lack of access to equitable education for underserved communities. To construct the analytical framework, we conduct a critical literature review to conceptualize the educational needs of underserved communities. Next, we proposed parameters that may be applicable for determining locationally metrics that match the educational needs of underserved communities. On this basis, we explore tools and methods applicable for suitability analysis and developed a geo-information framework that integrates an analytical hierarchy process tool to prioritize parameters decision-makers can apply to identify optimal areas to locate classroom infrastructure. This framework was applied to a use case of determining suitable location areas for an innovative mobile classroom (EDUBox) in Jordan. Using the framework, we demonstrate its applicability by identifying appropriate locations adapted to the tertiary and vocational education needs of underserved persons including refugee communities.

Keywords EDUbox, Underserved communities, Suitability analysis, AHP, GIS, SDG 4

*Correspondence:
Alberto Martinetti
a.martinetti@utwente.nl
Full list of author information is available at the end of the article

Graphical Abstract



Introduction

The United Nations (UN) has traditionally assumed the role of developing institutions for global environmental governance, equity, justice, and important addressing needs such as access to basic needs and education. The 1992 Rio Earth Summit first framed sustainable development (SD) as reliant on economic, social, and environmental development (Baker 2015). An important concept that has become central to SD is that without one form of development, one cannot achieve the other (Baker 2015). For example, an eco-centric perspective would hold that without environmental development, social and economic development will cease as well. In 2015, the UN developed the Sustainable Development Goals (SDGs) as an update of the Millennium Development Goals (Biermann, Kanie & Kim 2017). This became a milestone in SD policy in which the integration of economic, social, and environmental goals was achieved. The SDGs are 17 interconnected goals containing 169 outcomes and means of implementation targets (McArthur & Rasmussen 2019).

The fourth SDG is focused on quality education. It aims to provide "inclusive and equitable quality education and promote lifelong learning opportunities for all" (United Nations 2015, p. 19). It specifies that equitable education should be safe, quality, and accessible (UNESCO Institute for Statistics & UNHCR 2021). Achievement of this goal would imply among other aspects that adults would access tertiary education allowing them to gain skills necessary for employment. One method through which this goal can be implemented is the expansion of learning facilities so that all may have access to learning environments (United Nations 2015). The COVID-19 pandemic has had a negative impact on the achievement of Goal 4 along with many of the other SDGs. Adult non-formal learning has decreased by 18%, whereas adult informal learning has decreased by 25% due to widespread shutdowns (Paciorek, Manca & Borgonovi, 2021). This eliminated the educational achievements of the last years. This reduction could be recuperated by 2024; however, it would rely on the uptake of intense ameliorative strategies. Furthermore, equitable access to education, including skills-based tertiary and vocational programs continues to be a challenge according to multiple education indicators. For example, women continue to have a 7% lower literacy rate than men (Economic and Social Council 2021). Further efforts are required to recuperate and improve pre-COVID levels of equitable education.

Equitable education for underserved communities

Educational needs of underserved communities

The UN's aim with SDG 4 (education) was to facilitate and enable persons to complete a basic education cycle, obtain skills and competencies required for the future, and access educational opportunities to enhance their well-being and quality of life through gainful employment and entrepreneurship activities. Achieving the targets of Goal 4 has been found to contribute positively, in an amplified way, to other SDGs, and reduce the trade-offs that accompany other SDGs (Pham-Truffert et al. 2020). Usually, not everyone can participate in the traditional education systems, and especially vulnerable and marginalized communities who due to barriers such as tuition fees, or limited classroom infrastructure, frequently fail to receive adequate education. This can worsen social issues and contribute to cycles of poverty (UNESCO 2014).

In particular, refugees face some of the largest barriers to education. For instance, when refugees are placed in camps, they often remain there for 5–10 years (Taylor & Sidhu 2012). This means their education cycle is disrupted with negative effects such as access to gainful employment. This closes an important window of opportunity for integrating the educational needs of refugees and the underserved when designing education support.

Ultimately, considering the situation the underserved are living as the basis of designing education leads to a better economic situation and improved well-being (Dryden-Peterson 2016, 2017; Taylor & Sidhu 2012). One alternative is focusing on further developing skills-based education for tertiary students. The Director-General of the United Nations Educational, Scientific and Cultural Organization (UNESCO) launched the International Centre for Technical Vocational Education and Training (UNEVOC) in 1993 aiming at bringing together Technical and Vocational Education institutions (TVET) to maximize their efforts (UNEVOC 2022). UNEVOC's goal is to contribute substantially to SDG 4 by providing quality tertiary education and contributes to Targets 4.3 and 4.5 by working towards providing "access to affordable and quality TVET for all women and men, especially those in vulnerable situations" (UNEVOC 2022, p. 4).

Furthermore, Target 4.4 is advanced by increasing the number of students with employment skills. The benefits of TVET include those at the individual, business, and societal levels (Schueler et al., 2020). At the individual level, TVET participants gain the skills needed to participate in the labour market and contribute to better social inclusion and the socioeconomic status of underserved persons. By reducing the inequalities of opportunities refugees face in their careers, TVET education may be the answer to meeting the educational needs of refugees and other underserved communities.

Framework for equitable education

A framework to organize strategies was developed by UNEVOC to provide acceptable TVET to disadvantaged students. It classifies inclusive and quality education into four categories based on Katarina Tomaševski's (2001) 4As division: availability, accessibility, acceptability, and adaptability. She argues that if all four As are achieved in their entirety, the UN's definition of equitable education, being safe, quality, and inclusive, is also realized. UNEVOC adapts this framework to fit the needs of TVET (UNEVOC 2021). In the framework, availability can be understood as the right to education provided as a governmental obligation (Tomaševski 2001).

On the other hand, accessibility is fostered at a more local level and creates an environment in which students can adequately follow a vocational education and gain the skills they require (UNEVOC 2021). Acceptability focuses on quality education while responding to the needs of society, industry, and individual needs. Acceptable education leads to decent and sustainable employment, is inclusive, and generates further education opportunities. Adaptability is defined as a continuation of accessibility and the acceptability in which curricula are customized to the needs of users. However, some factors affect the capacity of some locations to fully achieve all four categories.

According to Kučerová et al. (2020), the spatial organization of educational facilities is an important consideration but often this is not solely dependent on how such facilities are distributed, but on how the distribution integrated both vertical and horizontal links to aspects including sociocultural but political influences as well. They describe five factors that influence the spatial organization of educational facilities: physical geographic factors, historical factors, sociocultural factors, political and economic factors, and educational policy factors. The interaction of these five geospatial factors with the four categories of equitable education earlier mentioned is what makes the connection between education and location more robust (see Fig. 1).

For the categories and influencing factors to be used for suitability analysis, measurable parameters and indicators need to be defined. One approach would be to base the definition on the four categories of equitable education proposed in Tomaševski's (2001): availability, accessibility, acceptability, and adaptability. Moreover, the parameters and indicators should facilitate the determination of the most suitable location for TVET education and contribute to equitable education for underserved communities. From a literature exploration of feasible

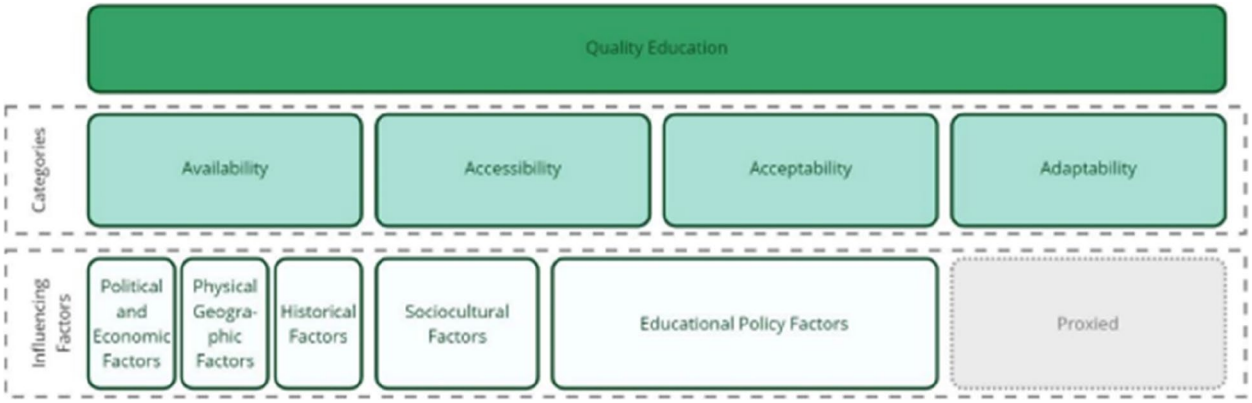


Fig. 1 Overview of quality education, its categories, and their influencing factors

parameters and indicators linked to the four categories, a list was derived and is summarized in Table 1.

Suitability challenges for education facilities in the context of refugee communities in Jordan and Lebanon

The SDGs were put in place at the same time the refugee crisis was brought to Europe's attention in 2015. By the end of 2015, 2.4 million migrants had arrived in Europe, many originating from Syria, Afghanistan, and Iraq (Spindler 2015; Stockemer et al. 2020). The rapid influx of migrants was viewed as a humanitarian crisis that required a collaborative effort of rescue and relocation from the European Union (Spindler 2015). This wave of immigration was exacerbated by a crisis of governance as members of the EU held opposing views and policies in response to the crisis (Stockemer et al. 2020). In Europe, the humanitarian crisis lasted until 2017, although it continues to impact migration policy and attitudes towards immigration (Stockemer et al. 2020).

Europe was not the only region impacted by the influx of refugees. The refugee crisis was present in Lebanon and Jordan, two of the top fifteen refugee host countries in the world, which have received many Syrian, Palestinian, and Iraqi refugees (UNESCO Institute for Statistics & UNHCR 2021). Even though these two countries have faced this crisis since 2011, they remain understudied about the impact of welcoming large numbers of refugees (Beaujouan & Rasheed 2020). This is largely due to their lack of connection to North America and the EU. From the start of the crisis, Lebanon and Jordan both held a neutral "open-door" policy. Jordan recognized itself as an asylum country and opened several refugee camps, while Lebanon only recognized Syrian migrants as displaced guests (Beaujouan & Rasheed 2020).

However, between 2014 and 2016, anti-Syrian sentiments rose in Lebanon which caused the country to close its borders to Syrian refugees. While the Jordanian government remained less hostile in this period,

Table 1 Suitability analysis framework

Category	Influencing factor	Parameter	Indicator
Availability	Political and economic factors	Policy for diverse educational facility types	% of teachers qualified for education level and type
	Physical geographic factors	Population distribution	Population density
	Historical factors	Location of educational facilities	Travel distance
Accessibility	Educational policy factors	Recognition of foreign qualifications	Extent to which qualifications are recognized
		Inclusive educational environments	Gender parity index
	Sociocultural factors	Age structure	Age-specific enrolment rate
		Demographic and migration conditions	Proportion of the refugee population
Acceptability	Educational policy factors	Responds to the labour market, societal, and individual needs	% economic sector contribution to GDP
		Provides access to jobs	Employment rate of recent graduates
		Nationally/internationally recognized qualification	Transition rate
Adaptability	Proxied by accessibility and acceptability		

opposition against Syrian refugees increased, also causing Jordan to close its borders. Lebanon and Jordan only received the opportunity to address the refugee crisis with the support of Europe after 2015 when the EU started receiving refugees themselves (Beaujouan & Rasheed 2020). Although the collaboration was unsuccessful for Lebanon, Jordan implemented more humane measures for the management of the refugee crisis even though it ended in discontent among Jordanians as socioeconomic reforms were put on hold (Beaujouan & Rasheed 2020). The refugee crisis continues to impact the quality of life in both countries.

Crises that cause mass migration have adverse effects on education. Globally, 12 countries, including Jordan and Lebanon, host 52% of the refugee population UNHCR (2021). A survey conducted with Jordan refugees found that most of the refugees living in Jordan have relatively modest educational backgrounds, with only 12% having completed post-secondary education levels (Microfinanza 2018). As such, the majority of the refugees living in Jordan do not qualify for more skilled professions, usually gained through some form of technical and vocational training. Another implication is that most refugee host countries are largely low- to middle-income, meaning that the capacity to provide an equitable education to their national citizens is already strained, thereby reducing their capabilities to accommodate refugee populations (UNESCO Institute for Statistics & UNHCR 2021). Thus, education targeting refugees is frequently managed in parallel to national education systems, with the educative responsibility taken up by humanitarian organizations. The COVID-19 pandemic added a complex layer exacerbating the challenges facing the education of refugees, with the socioeconomic conditions in the Middle East worsening, resulting in many refugees falling further into poverty (United Nations 2021). This created an urgency for new initiatives supported by the United Nations Refugee Agency (UNHCR) to accelerate access to safe and equitable education for refugees.

To facilitate access in line with the SDGs, there is a need to provide those facing barriers towards a satisfactory future with equitable education, and identifying optimal locations for implementing education infrastructure for refugees and underserved communities is critical locations. Therefore, the main research question of this paper is how to support the suitability analysis to facilitate the identification of locations considering multiple and often conflicting suitability criteria. To do that, an analytical framework for a suitability analysis to facilitate access to skills-based vocational training for refugees and underserved communities was developed. Its applicability is tested for determining suitable locations for mobile classrooms to enhance access to education in underserved communities.

As the case study, the EDUbox was chosen (Martinetti et al. 2022), which is a mobile remote learning environment to serve the needs of remote refugee communities in Jordan and Lebanon.

This need to identify suitable locations is of paramount importance in Jordan which is a country that is facing the refugee crisis, and grappling with classroom infrastructure challenges. The proposed approach is also scalable to other communities with varying or similar socioeconomic conditions and demographics. For instance, the study by Gibson (2015) seems to suggest that refugee communities in the MENA region tend to have comparative demographics; therefore, their education needs including vocational training are generalizable. This includes refugees hosted in countries such as Turkey, Iraq, or Jordan. Moreover, population-related demographics present a localization challenge, especially to contribute towards enhancing the attainment of equitable education.

The EDUBox is a unique concept, intended to provide refugees and vulnerable communities with a learning ecosystem that is adaptable to their learning wishes which are often fluid and dynamic as compared to learning in structured education settings. Several studies highlight their positive (and disruptive) impact on realizing learning outcomes by refugees and displaced communities. For instance, the study by O'Keeffe (2020) mentions the adaptability of flexible learning spaces to scaffolding education needs, often widely varying, from skills-based vocational training to online blended learning. Compared to traditional classroom settings, a flexible learning environment addresses education needs (curricula-related)—and by extension mobility, allowing quick set-up whenever new refugee camps spring up, and adaptability to displaced persons on the move to established refugee centres.

These factors are the primary motivations for considering the EDUBox as compared to traditional learning environments and supporting infrastructure, which by design are often inflexible and in our view, less adaptative to the evolving learning needs of refugees. Besides, the contextual application differs, as refugees are characterized by highly varied learning needs by the nature of their displaced which disrupts the learning trajectories.

Methodology

To determine the most suitable location for remote education systems, we developed an analytical framework which integrates two methods:

(1) A multi-criteria decision-making (MCDM) framework based on the analytic hierarchical process (AHP): the objective of the AHP is to prioritize critical parameters influencing the suitability of locating remote classrooms, with the EDUBox use case explored.
(2) The second method consists of a geographic information software (GIS)-based framework for mapping suitable locations based on quantifiable suitability indicators in Table 1, including demographic information such as the proportion of the refugee population.

The objective of combining the MCDM and GIS into a suitability analysis framework is to leverage information, here stakeholder education needs in Jordan, and prioritize important suitability parameters and indicators. As a next step, quantifiable (and prioritized indicators) derived from the AHP process were used as the basis of mapping locations using the GIS method discussed in this paper.

GIS-based suitability analysis

The GIS-based suitability analysis is an intuitive and popular tool for suitability analysis and can be used to logically visualize suitable localizations within the spatial environment, represented using mapping tools (Church 2002). Because GIS is a data-based, shareable software, it allows users to collect, process, and share large quantities of demographic data that can be used for spatial localization, for instance, locating classroom infrastructure based on population demographics as discussed in UNHCR (2022), but also useful for a much wider range of applications that go beyond suitability analysis to scenario creation and policy making (Church 2002). GIS can be used for both source- and present analysis results, which, combined with its data handling capabilities, make it a more effective process than other forms of analysis. The suitability analysis may also use parameters and indicators that define demographics of localization factors defined by stakeholders (e.g. population, or accessibility) or from literature (Kučerová et al. 2020).

MCDM method: analytic hierarchical process

The suitability analysis framework in the paper also used a multi-criteria decision method to prioritize important localization metrics or indicators that influence decisions on where to allocate remote classroom infrastructure. The decision-making here is complex with often conflicting criteria, for instance, illustrated in Table 1. Therefore, it is important to prioritize indicators to later apply in the GIS-based suitability analysis framework. Furthermore, this mitigates the limitations of overlooking important interdependencies between conflicting criteria or trade-offs, which influence overlay mapping in the GIS-based tool (Eastman 1999).

An important advantage of the MCDM approach is its combination of conflicting views of different decision-makers and stakeholders into a narrow set of prioritized decisions (Mateo 2012). This makes communicating outcomes to stakeholders more intuitive as it involves them in the decision-making process (to determine indicators they would like to consider for prioritizing and ranking localization indicators for remote classroom infrastructure) (Mateo 2012).

The analytical hierarchy process (AHP) is chosen for two reasons: first, it is intuitive for stakeholders, so the results are transparent, thereby increasing their participation in the analysis. This also ensures that local knowledge is incorporated into the assessment (Malczewski 2004; Mateo 2012). Second, it is commonly used in other suitability analyses to encourage comparability of the results. The method can also work with interdependent data with multiple parameters. Furthermore, it reduces decision-maker bias through a consistency check through stakeholder participation (Jamal 2016).

Steps of AHP

Step 1: Constructing the decision hierarchy The first step in AHP is constructing the hierarchy of the decision process, starting with defining the goal of the decision problem, and the relations between the goal to the decision criteria alternatives situated at the base of the hierarchical construction (Chen 2006). In this paper, we defined the goal as identifying suitable geographic regions for locating TVET education systems/infrastructure for underserved communities. This goal is linked to sub-goals, usually defined by criterion, for instance, demographics such as population, and distribution of TVET education systems within a spatial location. At the base of the hierarchy, decision alternatives are defined, as parameters and relevant factors influencing suitable locations of education systems/infrastructure.

Step 2: Pairwise comparison The second step is the pairwise comparison. This is where a decision-maker in the case study will be consulted for the importance rating of the criteria. This is done with a set scale in which a value between one and ten indicates how important the criteria are concerning another (Table 2).

Based on the pairwise comparison, a matrix is generated and transformed into a normalized pairwise comparison matrix. Local weights are calculated for each parameter being prioritized. The consistency ratio (CR) is checked for each comparison matrix to check bias. The ratio is calculated by dividing the consistency index (CI)

Table 2 The scale of AHP importance ratings for prioritizing location parameters adapted from Chen (2006, p. 169) and Jamal (2016, p.36)

Strength of relative importance	Definition
1	**Equal importance:** Two location parameters are equally important concerning the goal/objective of identifying an optimal location for remote education
3	**Moderate importance:** The stakeholder moderately favours the importance of one location parameter compared to a second (different parameter).
5	**Strong importance:** the stakeholder's experience strongly favours the importance of one location parameter compared to a second parameter.
7	**Very strong importance:** the stakeholder's experience very strongly favours the importance of one location parameter compared to a second parameter.
9	**Strongest importance:** the stakeholder's experience undeniably favours one location parameter compared to a second parameter.

by the random inconsistency index (RI) (Mathew 2018). Consequently, the consistency index is found by first calculating the λ max value. This is calculated by multiplying each value in the matrix by its weight, adding each row's weighted sum value, dividing each row's value by the weight, and then averaging those values. CI can then be calculated. A CR of 0.1 or below is deemed reasonably consistent and indicates good consistency in the decisions reached by the stakeholders when ranking the importance of suitability criteria against each other. The goal of this paper is to apply the AHP process for ranking the suitability parameters and not to describe in detail the AHP process. We would therefore refer the interested reader to the work of Saaty (2004) for a detailed discussion of the AHP formulation.

The outcome of the AHP is a ranking of the suitability parameters based on global weights (GW) that vary from 0 to 1. Parameters with values with larger weights are considered more important by decision-makers. Based on the ranking, critical suitability parameters were defined and considered as input for the mapping process in the GIS-based suitability analysis tool in this paper.

Data collection and analysis

GIS-based data

To conduct the spatial analysis, data was collected and then processed into geospatial information on the ArcGIS Pro software. The location suitability analysis is based on this data. This geo-referenced data from Jordan is collected through open-source maps, reports, and statistics documents. The parameter's indicators and their sources are summarized in Table 3. These are added to the administrative map layer. After being transformed into raster maps, the data is numerically coded into the four categories of suitability illustrated in Table 1. This approach is applied in many suitability analyses using the reclassification tool (e.g. Jamal (2016)).

Unsuitable locations are coded with the number 1, varying to number 4, the latter depicting the most suitable locations. For example, the indicator "number of teachers" can be coded such that geographical regions or areas with a low number of teachers, e.g. less than an average of ~ 3389 are assigned a code of 4 implying a higher need for locating education infrastructure in the locality. Conversely, unsuitable regions with a higher number of teachers, e.g. larger than the average of ~ 45,262 are coded with 1. The data is divided into these four coding categories and reflected in different colours on the geographical locality map. Dark green is most suitable, while light green/white is unsuitable. In this way, the indicators earlier derived from the literature (Table 1) were coded and mapped. Table 3 illustrates the coding for the suitability parameters.

AHP model

The AHP analysis is performed in collaboration with stakeholders with the goal of the analysis explained, namely, to "identify the most suitable location for a mobile classroom environment". The pairwise comparisons and the parameters are explained and compared on a 1 to 10 scale. An example of a comparative question asked during the pairwise comparison:

> *In terms of making education equitable, would you prioritize availability and more importantly accessibility concerning locating a mobile classroom environment in the region/area?*

In the event the "availability" parameter is prioritized as more important than "accessibility", the stakeholder is asked a follow-up question to define a quantifiable importance measure: "on a scale of one to ten, how much more important do you find availability than accessibility?". This process was performed firstly for the four categories in Table 1 (i.e. availability,

Table 3 Indicators and their data, coding, and sources

Indicator	Data, year	Coding	Data source
% of teachers qualified for education level and type	Number of teachers per governorate polygon, 2021	4: ≤ 3389 2: ≤ 22886 3: ≤ 7127 1: ≤ 45262	(Department of Statistics 2021a)
Population density	People per pixel surface area point data, 2020	4: ≤ 178.42 2: ≤ 1272.8 3: ≤ 602. 65 1: ≤ 30000	(Humanitarian Data Exchange, 2020b)
Travel distance	Euclidean distance in kilometres from point locations, 2020	1: ≤ 3.2 3: ≤ 40 2: ≤ 14.5 4: > 40	(Humanitarian Data Exchange, 2020a)
Extent to which qualifications are recognized	No data		
Gender parity index	Gender parity per governorate polygon, 2020	1: ≤ 25 3: ≤ 75 2: ≤ 50 4: ≤ 100	(Department of Statistics 2020a)
Age-specific enrolment rate	Average of age-specific enrolment rate per governorate polygon, 2020	4: ≤ 86 2: ≤ 88 3: ≤ 87 1: ≤ 91	(Department of Statistics 2020b)
Proportion of the refugee population	Number of refugees per governorate polygon, 2022	1: ≤ 6414 3: ≤ 136182 2: ≤ 18141 4: ≤ 200419	(UNHCR 2022)
Percentage of individuals with educated skills by type of skill	No data		
Employment rate of recent graduates	Unemployment rate per governorate polygon, 2021	1: ≤ 3 3: ≤ 22 2: ≤ 11 4: ≤ 37	(Department of Statistics 2021b)
Nationally/internationally recognized qualification	Average years of education completed per governorate, 2018	4: ≤ 9 3: ≤ 10 2: ≤ 11	(Department of Statistics & DHS Program, 2019)

accessibility, acceptability, and adaptability). Thereafter, the indicators grouped under each category were compared pairwise concerning the goal defined by the AHP. Afterwards, a consistency check is performed and normalized matrices are generated from which local and global weights are calculated finally, the categories and indicators are ranked according to their importance.

Suitability maps

Based on the AHP weights, the maps are overlaid. Each category's parameter is first weighed and overlaid to provide insights for the final overlay. The final overlay is completed by adding the category weights to their maps for the final analysis. This provides the final suitability locations for mobile classroom environments. These steps are completed using the weighed overlay tool in ArcGIS Pro and with the weights computed in the AHP analysis. Figure 2 shows a summary of these steps.

Results

The proposed analytical framework was applied to the suitability location challenge for a mobile classroom project, the EDUbox in Jordan. Both are explained for the reader to understand the context and interpretation of the results of the analytical framework. This helps to discern the extent to which applying the analytical framework to the EDUbox project in Jordan is successful. For the results, we first discuss the outcomes of the AHP and, afterwards, the suitability maps modelled from the GIS-based suitability analysis.

Use case: a mobile environment for TVET education for underserved communities

Locational context

The Hashemite Kingdom of Jordan is a country in the centre of the Middle East, its capital city being Amman (MLGHR 2011). It is administratively divided into governorates. These governorates are further divided into

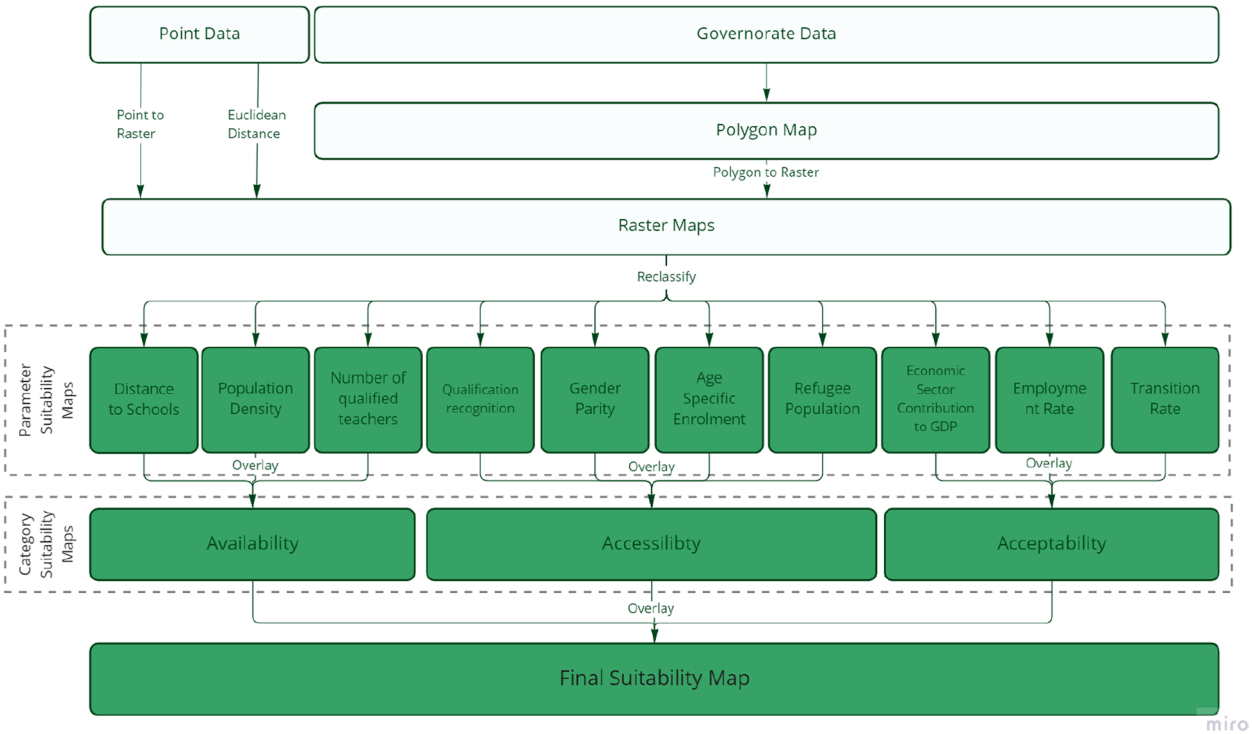


Fig. 2 The steps of the GIS suitability analysis

directorates. Jordan borders Saudi Arabia, Palestine (the West Bank), Syria, and Iraq. Soon after independence, Jordan found itself during the Arab-Israeli War. Since then, a series of conflicts have surrounded Jordan. Its central location has made it a region that has attracted asylum seekers from Palestine, Iraq, other Gulf states, and most recently, Syria (MLGHR 2011; UNHCR (2022). This has had a notable impact on Jordan's demographics. There are over three million refugees in Jordan (World Bank 2020); this makes up about 27% of the total population (WFP 2022). Syrian refugees make up roughly 40% of the refugees in Jordan. The influx of refugees has harmed Jordan's economy, specifically, the Syrian conflict changed the trend in Jordan's GDP from slowly increasing to decreasing (MPIC 2020).

The education system in Jordan has three stages: kindergarten, primary, and secondary (MLGHR 2011). Efforts have been made to improve the educational system by extending vocational education. Vocational education in Jordan is predominantly provided through the Vocational Training Corporation and it regulates and offers different levels of training. The difficulties with retention rates are greater among refugees and the right to education is only recognized for those with residency permits. This has been waived for Syrian refugees, but the numbers are lower for refugees from other countries who must abide by this law. TVET education is disjointed, and quality is not optimal, but there are opportunities for growth and development within this field of education in Jordan.

EDUbox mobile classroom project

A mobile learning environment, the EDUbox (Fig. 3), was created in a modified shipping container which can be distributed to students in remote learning environments. In its current form, the EDUbox was designed to serve the needs of TVET (Steendam 2021). The centre's structure is that of a 20-foot shipping container redesigned into a modular learning environment. Thus, it can be easily transported by ship or truck to the required location. Its energy, heating, and water needs are self-sufficient, allowing it to function in remote locations that lack services. This flexibility also means that it can function in various climates and weather conditions. The EDUbox can be redesigned to meet more specific academic needs like training for information communications technology or agriculture. For now, it remains a more universal design. The EDUbox's initial application to Jordan was to provide refugees access to education (Steendam 2021). The suitability analysis can aid in identifying where such learning environments are most relevant to deploy in Jordan.

Fig. 3 EDUbox presented to the Dutch Design Week in Eindhoven in October 2022 before the shipment to Jordan

AHP model results

For the AHP application, a stakeholder in the EDUbox project assessed the importance of the categories by answering the pairwise comparison questions. The result of this process led to the local and global weights depicted in Table 4.

Availability is deemed the most important with a weight of 71%. The stakeholder explained that education must first be made available before other aspects can be improved. Acceptability followed at 23% because education must be beneficial, while accessibility had an importance of 6% as this is prioritized once acceptable education is made available. The consistency ratio for this weighting is 0.60. For the weighting to be considered reasonably consistent, it would need to be under 0.10. This means that there is bias in the weighting.

In the weighting for availability, the location of educational facilities is given the highest weight of 69% as, according to the stakeholder, their distribution is what will ensure various populations have access to them, followed by population distribution and then the policy for diverse educational facility types. The consistency ratio equalled 0.45, and while still not under the acceptable 0.10, it is more consistent than the category weighting.

Demographic and migration conditions are weighted the highest at 37% as the EDUbox was developed with underserved communities in mind. According to the

Table 4 Local and global weights of the AHP analysis

LW	Category	LW	Parameter	GW
71%	Availability	8%	Policy for diverse educational facility types	6%
		23%	Population distribution	16%
		69%	Location of educational facilities	49%
6%	Accessibility	15%	Recognition of foreign qualifications	1%
		22%	Inclusive educational environments	1%
		26%	Age structure	2%
		37%	Demographic and migration conditions	2%
23%	Acceptability	34%	Responds to the labour market, societal, and individual needs	8%
		33%	Provides access to jobs	8%
		33%	Nationally/internationally recognized qualification	8%
*	Adaptability	Proxied by qualitative aspects of accessibility and acceptability		
Total				100%

stakeholder, if refugees do not have access to education, it does not matter what age or gender they are, they will still not have access. Age structure was second highest followed by inclusive education environments. Finally, the recognition of foreign qualifications was ranked lowest. The consistency ratio equals 1.63 which is not under 0.10.

Providing access to jobs and obtaining nationally/internationally recognized qualifications are weighted with 33% as these parameters both link to mobile futures. Responding to the labour market, societal and individual needs is weighted at 34% as student's education should be relevant to their context and interests. The consistency ratio for this category's weighting was 4.41 which is not within the 0.10 ratio.

Suitability maps results

To arrive at the GIS results, the three category's suitability maps are presented, in which also the individual parameter maps are incorporated. Afterwards, all results are summarized in the final suitability map.

Availability map

First, the results of the availability category are given by outlining the individual parameter map results contributing to the availability category. They are overlaid into a categorical suitability map based only on availability. The first indicator regarding the policy for diverse educational facility types is the percentage of teachers qualified for education level and type. There are 85,845 teachers listed, out of which 5000 only have intermediate diplomas (Department of Statistics 2021a). While the data was available at a directorate level, some directorates had missing data, so the data was used at a governorate level. In that case, the data was added to the governorate polygon layer which was then rasterized at a cell size of 1900 using natural breaks.

A high number of teachers was considered less suitable than a low number of teachers as underserved communities lack services like an adequate number of teachers or diverse education options. From this analysis, it was extracted that the most suitable governorates are Aqaba, At Tafilah, and Ajloun. This is in line with the needs of underserved communities, as the areas outside of the governorates with higher populated cities have the lowest number of teachers. The eastern area of Al Mafraq governorate shows an anomaly in the data. It indicates that there are already enough teachers, even though it is a very rural area. The data here may be slightly skewed because the analysis was conducted at the governorate level.

The second parameter of the availability category, the population density, was used for the population distribution indicator, derived from Humanitarian Data Exchange (2020b). It was classified by natural breaks, turned from a point layer to a raster layer with a cell size of 0.017, and reclassified into the suitability codes. According to the rurality dimension of underserved communities, populous areas have access to more services, like education, than less densely inhabited areas. As such, the unsuitable areas are in the areas where populous cities are located namely, Amman, Zarqa, and Irbid.

The third parameter of the availability category is the distance to educational facilities, which is determined by the institute location indicator, retrieved from Humanitarian Data Exchange (2020a). The information given is the coordinated location of various educational facilities. The point data is changed into a raster file using the Euclidean Distance tool in ArcGIS Pro. It provides the closest distance between an educational facility and any point within Jordan. This raster is then classified using the reclassification tool. The classes are divided based on literature. Lidbe et al. (2020) found that students would walk or cycle to an institute for up to 3.2 km while students would drive to the facility for up to 14.5 km. Frenette (2006) found that the distance at which students would stop taking the effort to get an education was above 40 km. The further the distance to the closest classroom, the more suitable the area would be for an EDUbox. Acknowledging this, a pattern emerges showing that areas around major cities have the smallest distance to institutes, while more rural areas have the furthest distance (i.e. above 40 km).

These areas could profit most from an EDUbox in terms of a lack of reachable educational facilities. Summarizing the findings, a suitability map for availability is constructed by overlying the maps for the number of teachers, population distribution, and educational facility location (Fig. 4A). The most suitable locations for the EDUbox in terms of availability are in areas outside of where the major cities are located, namely in the eastern parts of the governorates (i) Al Mafraq, (ii) Amman, and (iii) Ma'an.

Accessibility map

Second, the accessibility category is introduced, starting with the individual parameter maps for the accessibility category. The accessibility parameters are the basis of the categorical suitability map. For the first parameter on the recognition of qualification or graduation rates, there was no data available which could have been used as a proxy. Thus, it was not possible to develop a map and it will be excluded from the analysis. The second parameter of inclusive educational environments is represented by gender parity, retrieved from the Department of Statistics (2020a). Data on the gender parity percentages of

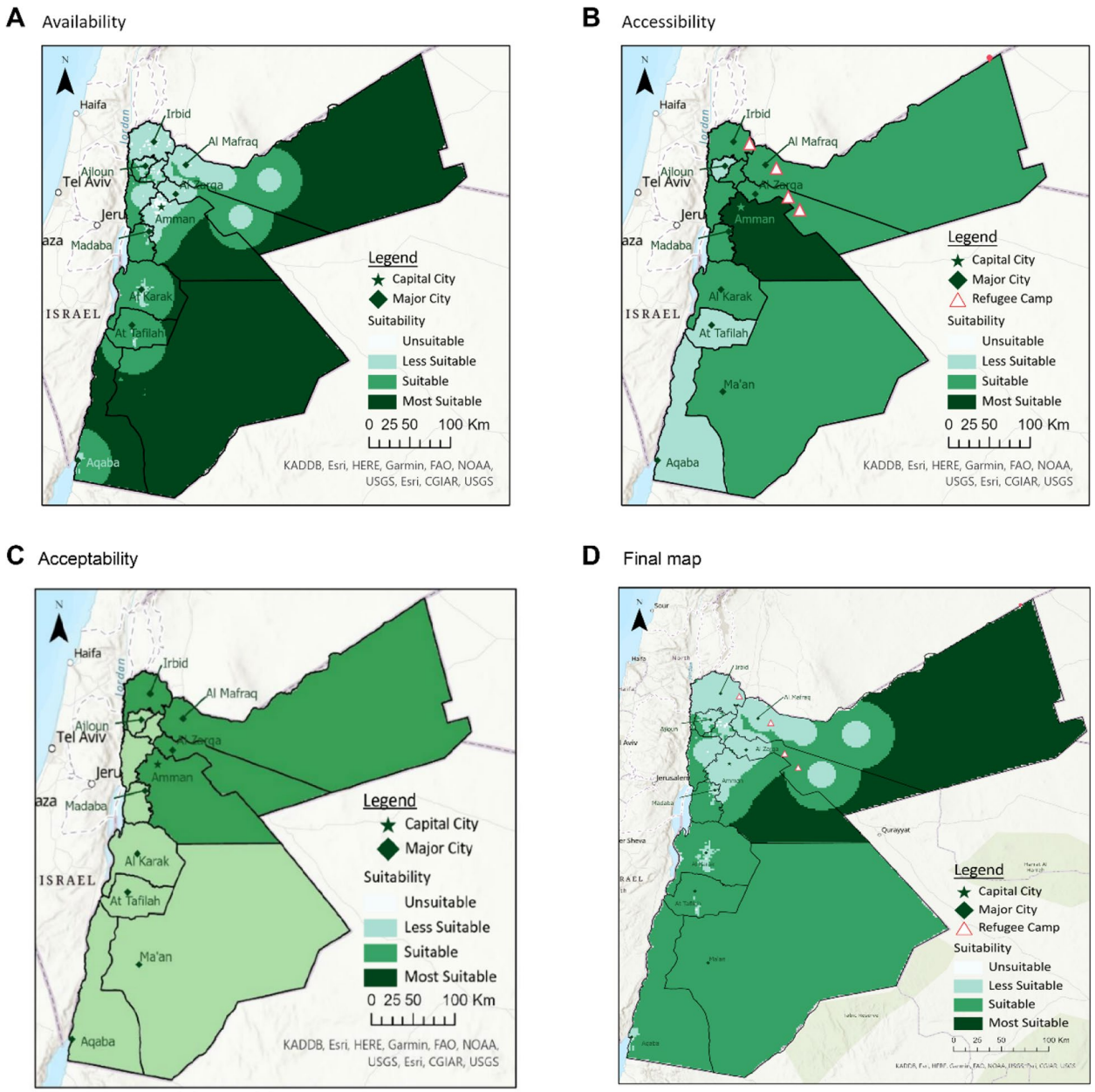


Fig. 4 The four suitability maps. **A** The availability map. **B** The Accessibility map. **C** The Acceptability map. **D** The final suitability map

industrial and agricultural vocational is averaged at the governorate level and added to governorate polygons.

The polygon layer is rasterized with a cell size of 1900. Because gender parity is a percentile indicator, the classification is divided by quartile where 70–100% (fourth quartile) is the least equal and 0–25% (first quartile) is the most equal. Areas ranking in the fourth quartile are deemed most suitable for the EDUbox as these are areas where women could benefit from increased access to education. The analysis revealed that in most governorates, there is an unequal enrolment of men and women in vocational education. The third parameter of the accessibility category is age structure, which is reflected in the age-specific enrolment rate. Data on this is available in Jordan's Department of Statistics database (Department of Statistics 2020b). The data used in the maps is the average enrolment rate of all the age groups per governorate. What is not reflected in the analysis is the fact that the enrolment rate decreases as the age group increases. Regardless, the average enrolment rate

is above 85%. Thus, after the data is added to the governorate polygons and rasterized, they are classified by natural breaks in which 85% is the lowest value and 91% is the highest.

Low enrolment rate is deemed more suitable for the location of the EDUbox. The governorates with the lowest average age-specific enrolment rate are Karak, Madaba, Balqa, and Amman. The fourth parameter, demographic and migration conditions, is indicated by the refugee population. Data is only available on the population of Syrian refugees, while refugees originating from other countries are excluded from the analysis. The information is available at a governorate level in UNHCR's data portal (UNHCR 2022). It is added to the governorate polygons and then rasterized with a cell size of 1900. The data is classified using natural breaks and the highest population was deemed most suitable for the location of the EDUbox. Syrian refugee camp locations are included (Fig. 4B, white triangles) as it shows more specifically where refugees are located. Suitable locations for the EDUbox coincide with where the refugee camps are located, namely Amman, Zarqa, Al Mafraq, and Irbid. The locations of these camps could be used as guides to place the mobile classroom. If Palestinian refugees were included in the analysis, these results could perhaps be altered.

Following this analysis, the accessibility suitability map is constructed (Fig. 4B). The weights calculated in the AHP analysis had to be redistributed because of the lack of data for the recognition of foreign qualifications. The weight of 15% was divided equally among the three other parameters. The results show that no area was ranked unsuitable; however, Amman was ranked most suitable for the EDUbox.

Acceptability map

Third, the map results contributing to the acceptability category are provided. For this, the acceptability parameter maps are overlaid into a categorical suitability map. For the first parameter on the types of skills students were acquiring in their education, there was no data available. Thus, a map was not made, and it will be excluded from the analysis. The second parameter, access to jobs, was decided to be indicated by the employment rate of recent graduates; however, the only available geo-referenced employment rate data is the country's unemployment rate in the Department of Statistics (2021b). Thus, the unemployment rate is added to the governorate-level polygons and classified using natural breaks. Governorates like Ma'an had an unemployment rate of 3% while others like Amman had one of 37%. The polygon data was rasterized and reclassified into the 1 to 4 codes.

Areas with the highest unemployment rates were considered more suitable for the EDUbox than those with low unemployment rates. It was identified that the governorates with the lowest employment rates are Irbid and Amman. The third parameter of nationally recognized qualifications is proxied by the average number of years students have completed before leaving their education. The data was taken at a governorate level from a survey made in collaboration with USAID and the Department of Statistics (Department of Statistics 2018).

It was classified by natural breaks, rasterized, and reclassified into the 1 to 4 suitability code. There were 3 years of completion: 9, 10, and 11. Areas, where 9 years of education were completed, where the average is considered most suitable for the EDUbox. From this analysis, it has been established that the governorate Al Mafraq is the most suitable for the EDUbox. Like accessibility, the weight of the missing parameter was redistributed between the available parameters. This meant that the weight was distributed from 50 to 50%. The suitable locations for the EDUbox are in the northeast of Jordan (Fig. 4C), (i) Irbid, (ii) Al Mafraq, (iii) Zarqa, and (iv) Amman.

Final suitability map

The final suitability map was constructed by overlaying the three category maps (Fig. 3) according to the weights found in the AHP analysis (Table 3). Since availability was rated most important in the AHP weighting, the more suitable locations according to availability are most visible in the final map (Fig. 4D).

The largest change from the availability map is that the southern half of Jordan has changed from most suitable to "only" suitable. Al Mafraq governorate is consistently a suitable or most suitable area in all three maps and this is reflected in the final map. This is similar to the Amman governorate. Another characteristic that is present through the category maps and the final suitability analysis is that the northwest areas in Jordan are less suitable for the EDUbox, especially Ajloun, Jarash, and Balqa. One exception to this is Irbid, wherein the availability map and the final suitability analysis Irbid is considered less suitable. However, it should be kept under consideration that according to the accessibility and acceptability maps, Irbid could be a suitable area for the EDUbox.

The accessibility and acceptability maps are also used as a proxy for the adaptability, or the needs of the students. One can retrieve from the results that Al Mafraq governorate needs to focus on making sure students finish their education and obtain qualifications, while Amman can focus on skills training for employment. According to the results, both governorates should cater their education towards refugee populations, and

Amman, especially, should develop accessibility education that meets the needs of girls and women. Similar conclusions about the accessibility needs of the southern governorates can be made. Decisions about adaptability should be made in cooperation with education experts to ensure the information from accessibility and acceptability are correctly translated into the needs of the students in those areas.

Evaluation of the analytical framework

The map results were discussed with a GIS expert from Jordan to validate them. This was done by reviewing each of the individual parameter maps, the category maps, and the final suitability maps. Questions such as, "Are the results reflective of what is to be expected in Jordan?" and "What further information would be needed?" were asked. Generally, it is confirmed that areas around the capital and other major cities have fewer needs, while areas in the south and east have more needs as they are poorer and less developed. This validates the final suitability map. However, some of these underserved areas have areas with a population of zero. Thus, populated areas in the east and south should be focussed on in further research. While the final suitability map is reflective of which areas could profit from the EDUbox, the stakeholder pointed out omissions within the parameter maps that should be discussed.

In the "availability" parameters, the map of policy for diverse educational facility types, the absolute number of teachers is indicated. The stakeholder recommends using a ratio relating the number of teachers to the population that could have better reflected which areas have a greater need for teachers. What slightly mediates this is that the "number of teachers" indicator is combined with the "population density" indicator in the availability category map. An adjustment to the parameter could be made while keeping in mind that indicators like population density are not repeated. Concerning the map indicating the distance to the educational facility, the stakeholder explains that many Jordanians do not cycle because there is a lack of cycling infrastructure. Furthermore, most transport to the institutes is through private or public transportation. The limit of 40 km is still viable, yet it should be taken into consideration that travel times are increased by traffic, so longer distances can be further prolonged. If the framework is applied to other contexts or reapplied to a specific area in Jordan, the distance boundaries should be redefined in collaboration with area experts.

In connection with the accessibility parameters, "gender parity" was discussed. The stakeholder's knowledge asserted that while labour is divided by gender norms, secondary school gender parity is very high, which is also reflected in the statistics (Department of Statistics 2021a). In agricultural and industrial tertiary education, there is little gender parity. The reasoning for this lack of parity was explained through commuting and safety. Some jobs in Jordan are less accessible to women. Although women may be studying and working in other tertiary education fields, this is not included in the national statistics. This opens a discussion about equality ideals and whether the UN's vision for gender parity should be used as a guide for all contexts. The stakeholder points out that generally, results should be related to the country in terms of social and economic factors.

Finally, the acceptability parameters were discussed. The map that the stakeholder found unexpected was the one that indicated unemployment rates. According to their knowledge, areas in the south are struggling with unemployment while Amman has the most businesses; however, this contradicts the previous statistics. The stakeholder suggested a variety of reasons why this may be. First, the statistics could be wrong. To the stakeholder's knowledge, informal or underqualified work could be included in this statistic. Another reason could be that residents travel to cities or other governorates for work. Finally, Aqaba is an important tourist area and is considered a Free Economic Zone, so the employment rates in the south could be raised because of employment opportunities there.

Generally, the stakeholder agrees that the final suitability map gives a preliminary idea of where to place the EDUbox. They emphasize that just because people may have education available or accessible to them, it may not be acceptable or equitable.

Discussion

The discussion chapter examines the strengths and weaknesses of identifying appropriate sites for vocational education systems in underserved communities. To this end, the needs of underserved communities were first identified, which served as the basis for establishing parameters for selecting sites to promote equitable education. The analytical framework for suitability analysis was developed based on GIS mapping and AHP and implemented in Jordan.

First, literature has been investigated to define the needs of underserved communities. This set a precedent that the analytical framework should be able to assess the location that would best cater to the needs of underserved communities in any context. The needs of underserved communities are outlined around the benefits education facilitates. Other than general access to services and adequate education, there is an educational need in underserved communities for TVET education to reduce the inequalities they face. This framed

the parameters used to define equitable locations for education. The parameters were defined by categories of equitable TVET education and the locational factors that influence them rather than suitability analyses. Thus, some of the parameters are influenced at a national level and are not easily operationalizable at a local level. This is especially the case for the availability category and its political and economic factors, as well as the accessibility category and its educational policy factors. Because of this, there will be little variation at a local level concerning these parameters. Despite this, a thorough collection of possible indicators for the parameters allowed for an overview of potential locally scaled assessment tools. This variation allowed for an analytical framework to be constructed. The final selection of parameters to be used in the analytical framework connects the educational needs of underserved communities to location.

The dimensions of underserved communities were used to filter the parameters found in the literature. This strengthened the relevance of the suitability analysis for decreasing the barriers underserved communities face towards obtaining equitable education. This filtering was supported by selecting indicators that can be measured at a local level. It ensured that the analytical framework would answer the research question and apply to a variety of use cases. The trade-off is that some information that can be useful to understanding the use cases context is left out such as the national education policy and financial allocation or the organizations that support education. Yet, this can be reduced in a project context by making sure these additional details are included in the case description and the discussion of results.

Second, it was decided through literature analysis that the analytical framework would use AHP as an MCDM method integrated into GIS mapping. The decision to use AHP has advantages and disadvantages. As was stated in the literature, the inclusion of stakeholders prioritizes the results, so they become more pertinent to the use case. Because of this, priority weighting can be given to the parameters without bias from the researcher, instead focusing on the relevant stakeholder's project goals. One implication of this is that the results can become easily biased towards the stakeholder. Our analysis revealed that the results of the AHP weightings are inconsistent. This implies that the final weight allocations are impacted by the interviewed stakeholder's bias. Depending on the goals of the project, this weighting can still be used, however, with the understanding that they are not statistically consistent. If a different method were used, or no weights were used at all, the results would be different. This reinforces the implication that the results provided from this analytical framework are suggestions that should be validated.

Third, to further validate the developed analytical framework and identify practical implications of its use, the insufficient local-scale geospatial data and the unreliability of the data that does exist in Jordan is an issue. This means that most of the data mapped is at a governorate scale and gives little spatially specific information for the most suitable location of a mobile classroom. Two indicators were not measured as there was no data with locational references available. In addition, the quality of the data should not be taken for granted. The Department of Statistics rarely explained the data they displayed. The collection and calculation methods were excluded from their results. Thus, little is understood about which demographic groups were considered and what is excluded from the statistics. Demographic groups were explicitly excluded from the refugee indicator as there was only information collected on the Syrian refugee population. These details have implications for how the results of the analysis can be understood as the analysis is heavily dependent on the data that is available. Still, the case selection reflects the strength of the research as an unbiased case study was examined instead of choosing a country that is known to have extensive geo-referenced statistics.

As the analytical framework showed promising results in a country with as little spatial data as Jordan, it could likely apply to any case study with as much, or more data. While the results were limited to the governorate level, they were still able to indicate which governorate could profit from a mobile classroom catered to the education of underserved communities. It is likely that if the analysis worked at a larger scale, it would also be applicable at a more local scale. The analytical framework developed in this paper can therefore be used iteratively to first give an impression of where more research into local conditions is needed. Then, using a smaller-scale fieldwork study to collect local data, the analytical framework can be used again to find a more specific location for the EDUbox or another remote education system. It is recommended that each iteration be validated with area experts because the results of the analysis should be understood as suggestions.

Conclusion

Education positively contributes towards the furthering of the UN's SDGs and starting with social goals, like education, can lead to a more sustainable and equitable future (Pham-Truffert et al. 2020). As such, this article investigates how suitable locations for TVET education systems in underserved communities can be identified. To achieve the latter, the practices that contribute to education must be better understood. Intersectional qualities like gender or race can exacerbate the barriers to services

underserved communities face. Concerning education, TVET can provide these communities access to an upwardly mobile future.

Our initial research question was: how to support the suitability analysis to facilitate the identification of locations considering multiple and often conflicting suitability criteria.

We started identifying four categories used to define equitable TVET education: availability, accessibility, acceptability, and adaptability. Parameters for each category were then used to link them to locational characteristics. For availability, these parameters are policy for diverse educational facility types, population distribution, and location of educational facilities. The parameters for accessibility are the recognition of foreign qualifications, inclusive educational environments, age structure, and demographic and migration conditions. Acceptability is measured by whether the education responds to the labour market, societal, and individual needs; provides access to jobs; and leads to nationally or internationally recognized qualifications. These parameters are integrated into a GIS analysis and the parameters are applied to the suitability analysis with AHP. Altogether, the GIS method and parameters build the analytical framework this paper developed.

The analytical framework was validated through a use case. The context of this case is the EDUbox in Jordan. The results from the research indicate that the governorates Al Mafraq and Amman could benefit the most from the implementation of the project, in addition to the southern governorates. Keeping the errors that can come from a location suitability analysis and without further verification of this analytical framework, these results should be taken as a suggestion and an indication for more concentrated research. This would limit the scope of the current research and allow for more fieldwork approaches to data collection. Notably, Al Mafraq and Amman are the two governorates with the largest number of refugee populations. Refugees and other underserved communities face inequalities that inhibit them from achieving their aspirations. Projects like the EDUbox and frameworks to increase their efficacy like the one proposed in this paper are imperative to reach fairer and just futures as stipulated by the SDGs. These projects and assessments should be developed to ensure that underserved communities are provided the services they need.

While this approach has valuable qualities, it does face limitations. First, there is a lack of previous research linking social educational indicators to TVET location. The parameters used in this study were one of the few that looked beyond physical factors and looked at historical, geophysical, societal, and economic factors. To strengthen future suitability analyses, more research regarding the links between equitable education and location could be explored. Second, the quality of available data is unsatisfactory to draw reliable conclusions. Jordan suffers from a lack of local-scale geospatial data and the reliability of the data that does exist is not guaranteed. This means that most of the data mapped is at a governorate scale and gives little spatially specific information for the most suitable location of a mobile classroom. As such, it impacts the quality of the results obtained, which should be understood as a suggestion to initiate more follow-up research at a local scale. Finally, there is error propagation that can occur when using GIS overlay tools. That is, the scales chosen introduce bias, for example, the results show that areas near large cities or heavily populated areas are less suitable. However, the other data are at the governorate level, and it cannot be assumed that the numbers are distributed in the same way.

Recommendations for future research can be divided into three groups. First, the analytical framework should be applied to other contexts and validated. This would provide information on how the framework works with other scopes and data availability. It would also test the comparability of the assessment results from this framework's application. Second, more stakeholders should be involved in the AHP analysis to check if this leads to more consistent results or a more wide-scale AHP analysis should be done with actors in education to make a universal importance weighting. Finally, the analytical framework could be developed into a standardized modelling tool that is easy for decision-makers to use. This could aid education planners and policymakers place future TVET institutes in a way that will further the achievement of Goal 4: Quality Education.

Acknowledgements
We thank the Refugees, Displaced Persons, and Forced Migration Studies Center of Yarmouk University for their insights and the anonymous reviewers for their helpful comments.

Authors' contributions
All authors read and approved the final manuscript.

Funding
Research was partially funded by Nuffic and the Ministry of Foreign Affairs in the Netherlands.

Availability of data and materials
All data generated or analysed during this study are included in this published article and its supplementary information files.

Declarations

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Department of Design, Production and Management, University of Twente, Enschede 7500AE, the Netherlands.

Received: 18 May 2023 Accepted: 25 March 2024
Published online: 25 April 2024

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