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ARTICLES

Evaluation of the Labour Cities Locations Using a GIS-based on Multi-criteria in Kuwait

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Abstract

Objectives: Labour cities is a term used to describe residential areas purposely constructed to host a large group of workers of a particular company or employed in a certain sector. In Kuwait, six labour cities are proposed by the government to house the disproportionately large number of expatriate workers in the country. This research evaluates the locations of these proposed labour cities. **Method:** This study describes a framework based on GIS and MCDA that uses multiple population and spatial criteria to assign suitability scores to each of the proposed locations. The criteria weights were derived from interviews with official stakeholders and geospatial data. Separately, Raster data was used to validate the findings of the primary GIS/MCDA model of the study. **Results:** It is found that the most suitable site is South Sabah Al Ahmed with a suitability score of 68%. This was confirmed by raster suitability analysis. **Conclusion:** The findings show that the capacity of the new labour cities is not high enough to significantly drive down population density, traffic congestion and pressure on infrastructure systems in Kuwait, but there are benefits for population in existing districts.

Keywords: Analytical hierarchy process, GIS, Kuwait, Labour cities, Multi criteria decision analysis.

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Introduction

History of labour cities

Cities constitute the dominant settlement type developed by human for a variety purposes (Harris & Ullman, 1945). Reasons for establishing cities include regional control, proximity to sites of historical settlements, proximity to farmlands and agricultural production, access to trade and resources. In turn, the respective types of cities that emerged over centuries include political, religious, commercial and industrial cities. The emergence and subsequent development of cities around the world is a wide and fascinating topic that continues to attract significant research interest globally. In particular, the influence that industrialisation had on the development of cities during the 19th and early 20th century is an extensively studied topic in the broader field of population research (Straus & Zamfira, 2017). At the time, industrial enterprises were growing at unprecedented rates. The majority of cities that evolved to accommodate the industrial workers, especially within Europe and North America, were seemingly under deplorable conditions due to pollution and high population density.

Still, the head industrialists of the time were devising new ways of tapping into the rather unexploited human potential within these cities. To achieve this, the notion of company cities was established. Company industrial cities, sometimes referred to as labour cities, significantly differed from other cities in many aspects. Essentially, industrial cities were conceptually engineered, exclusively owned and operated by large corporations that produce industrial goods (Richman, 2018). The purpose of these cities was to offer the working-class residents access to basic amenities like standardised housing, healthcare and education, as well as urban life conveniences like grocery shops, hairdressers and clothing stores (Nix, 2018). A major factor that differentiated labour cities was that they were located outside and typically spatially disconnected from the realities of other industrialised urban areas that were heavily polluted and overpopulated.

The idea behind the establishment of such company owned and run cities was originally materialised as a mean of reducing the negative consequences associated with industrialisation such as pollution and overcrowding. Also, it served the role of maintaining continuous production within the factories of the parent company. Bata is a good example of companies that heavily invested in company cities as a means of fostering their production. In the 1930s, for instance, the company had succeeded in building several company towns around the world under a structure epitomised by a centralised vertical system of control that regulated the entire production cycle right from the processing of the raw materials to the selling of the finished products (Straus & Zamfira, 2017). Some of the most notable company towns in the late 19th and early 20th century at the peak of industrialisation include Pullman of Illinois, Hershey of Pennsylvania, Steinway Village of New York, Roebling of New Jersey and Scotia of California (Nix, 2018).

Characteristics of Labour Cities

As indicated earlier, a major attribute associated with company cities was that the majority of them were spatially and functionally isolated from their neighbours. Naturally, the citizens either worked in the factories of the parent company or in some smaller businesses within the towns that provided goods and services to the workforce. To some greater extent, in order to reside within these cities, one was required to have at least one family member working within the boundaries of the city itself. To ensure adequate social interactions, the company looked after the construction and operation of social amenities, like churches that were built to host local congregations, parks and cultural events (Richman, 2018).

Interestingly, some towns that were in existence before the creation of a major factory evolved to display similar characteristics to company cities. This occurred naturally, when the majority of the citizens of a particular town or neighbourhood ended up being employed or conducting business with a single entity (Richman, 2018). As such, these neighbourhoods developed distinct economies

that acted as a differentiating factor from the rest of the towns in the area. It can be argued that most of the modern cities evolved from company cities. With time company cities in most cases become more open to the public, as they started attracting other settlements nearby, as well as connected with their environment via public transportation and other service infrastructure.

While there is certainly merit in the notion of a centralised purpose-built city that improves the efficiency of industrial production and the social wellbeing of workers, there were certainly major risks with company cities. In the instance that the parent company encounters hardship or the industry loses its significance, the economic effect linked to the city can be extremely devastating and may reverberate over multiple generations. This was the case with the decline of the anthracite mining industry, as a result of its over-dependence on steam locomotives in generating demand (Straus & Zamfira, 2017). In such cases, and with no other source of employment, the local community quickly experience a reduction in population, as people begin moving away in search of better opportunities.

Labour Cities in GCC

The Gulf Cooperation Council (GCC) is an international council consisting of the member states of Kuwait, the United Arab Emirates, Qatar, Bahrain, Oman, and Saudi Arabia since 1981 (Hvidt, 2012). Over the last few decades, the economies of the GCC countries have undergone massive transformation due to wealth accumulated from the sale of petroleum products. The transformation process has been striking; even though these countries were poor and dependent on regional trade a few years ago before the discovery of oil, today they have futuristic skylines, rapid economic growth, and strong development plans. With the rapid increase in economic activity in the region, the labour demand in these countries has also increased, as these countries had low population which hampered any plans for major developments (Hamza, 2015). As a result, the numbers of foreign laborers in GCC countries have tremendously increased over the past few decades. However, GCC countries have been often accused of

providing poor accommodation and essential services to foreign workers. Besides the criticism, there were lawsuits from neutral observers like human rights associations. Therefore, after long deliberations, GCC countries decided to build labour cities, which they believe will be vital to providing affordable accommodation to foreign employees (Kothaneth, 2019).

To begin with, labour cities could help employers comply with international laws and regulations. Over the past few years, there has been a lot of concern about the living conditions of the employees in GCC countries. Employees have been living in poor conditions and without proper medication and other essential services. The introduction of the labour cities in the GCC countries will provide the workers with decent standards of living. For example, Abu Dhabi is determined to build labour cities that operate with a model that safeguards the rights of the workers for access to healthcare, personal safety and modern living conditions. The country has invested AED 20 billion in the construction of 23 labour cities in the vicinity of the local industrial hotspots. In addition to that, Abu Dhabi has introduced regulations, which require employers to provide means for commute to their workers from the working sites to the labour cities and back. The regulations also strictly forbid employers from keeping their employees in the working sites under suboptimal living conditions (Arabstoday, 2012).

Another example is the construction of several labour cities in Qatar in preparation for the World Cup which is to be hosted in 2022. The main labour city in Qatar is located outside Doha city and has a capacity of 68,640 laborers. The facility includes a 17,000 seat theatre, four cinemas, a cricket field, two police stations, medical centres, mosques, markets and commercial centres. For safety measures, security and surveillance have also been enhanced within the city (GCR, 2015).

Furthermore, the labour cities are expected to reduce the number of employer-employee conflicts. These conflicts between employees and employers have been among the major socioeconomic issues that GCC countries are facing. Frequent interactions between the two

parties outside of work are likely to trigger such conflicts, as it is not uncommon for foreign workers to reside within the workplace or at a designated area in the employer's property. With the introduction of labour cities, the employees will have minimum interactions with their employers as they will only meet each other during the day or when the work is in progress. Some employees have reported mistreatment by the companies they work for, especially during the night. Hence, relocating the workers' residence to the labour cities will help minimise risks, like physical and mental abuse or sexual assaults (Dito, 2010).

Finally, labour cities will allow the workforce to enjoy various amenities that they would otherwise not have access to. Ideally, these newly developed cities are to be equipped with facilities such as theatres, playgrounds, swimming pool and parks. Therefore, after completing their work shift or when they are on leave, workers shall be able to enjoy the facilities at the labour cities. This plays an important role in helping them stay mentally and physically fit, as well as improving the morale of the employee which ultimately increases productivity. This is expected to be advantageous to the economic growth of the GCC countries (Menayang, 2015).

Criteria of Evaluating the New Labour Cities Locations

Any decisions about the location of the labour cities or relocating industries closer to the workforce are generally made after well-defined selection criteria are examined by the planning authorities. While these criteria have changed over time and are different in each jurisdiction, typically they include accessibility to work, availability of area for development, projected capacity, network connectivity, project costs, social and environmental factors (Hatami & Ameri Siahooei, 2013).

Planning in such construction projects begins by identifying the key elements that will in the long run facilitate the overall success of the project, in this case city planning. To begin with, the accessibility of the city must be assured to enable key operations within the area. The accessibility of labour city was considered a key element in a sense that the main purpose of its existence is to improve the company's productivity

(Hatami & Ameri Siahooei, 2013). This implies that the town has to be built in close proximity to the industry in order to reduce unwarranted delays both in terms of the personnel and other necessities like raw materials. For this reason, local transport links and walkways were given priority in designing labour towns.

Additionally, decisions about the city's environment are also made based on the parent company's main business and the availability of resources. For instance, the geographical characteristics of the surroundings have been essential to consider in planning, especially in terms of the availability of water and food sources. Parent companies or state authorities that design labour cities have incentives to establish the towns in areas that have easy access to water and food (Richman, 2018). Socially, the environment of a labour city was historically deemed suitable if it was able to provide significant separation of the town from the rest of the urban neighbourhoods. The labour cities were excluded in an attempt to increase resilience in terms of the company's operations and maximise regulation and control efficiency. Seclusion of such towns was not only a means of fostering privacy, but also the capability to achieve or in some cases acquire required services.

The local area's demographic factors including the size of the population in the region have also been essential in planning these cities (Hatami & Ameri Siahooei, 2013). To fully support the workforce, the company was required to cater the necessary basics to its citizens in the most efficient and affordable fashion. Similarly, the ease of expansion to include other social amenities, such as schools and recreational centres has been a historically significant criterion at the planning stage of labour cities. Last but not least, the locations of company cities were mostly guided by the principle or rather the objective of having them free of overcrowding in both living quarters and public places and commute. As such, the chosen locations need to minimise travel time to the workstations.

Finding the optimum location for new labour cities involves multiple criteria that are typically classified into physical and human-related in the literature. The physical factors include geographical

characteristics, such as the elevation, slope, soil, water bodies and land use, whereas the human factors include accessibility, connectivity, capacity, distance to shops and other needed services. In order to evaluate the site selection, Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) have been utilised in research studies by decision makers (El-Mewafi, 2015; Lukoko & Mundia, 2016).

Using GIS and MCDA for site selection

Selecting the optimal site for labour cities is a complex process involving the balancing between various (often conflicting) factors. Geographic Information Systems (GIS) is a set of useful tools that can be used by planners and policy makers to determine and evaluate the best location for such cities. In particular, GIS combined with analytical hierarchy process (AHP) based on Multi Criteria Analysis (MCA) can be utilised as the means to determine the proper site from various locations (Al-Shalabi et al., 2006).

In relevant works, Lukoko and Mundia (2016) aimed to identify the most suitable sites for a sugar factory in Trans Mara district in Kenya utilising GIS based Multi-criteria evaluation. Nine suitability factors were used in the process, derived by the relevant literature and the opinions of specialists. AHP was then applied to elicit weights, which were assigned to each suitability factor. The authors asserted that GIS techniques are essential in locating suitable sites for land development. Moreover, they concluded that the application of GIS in the site selection process may minimise some of the negative environmental impacts, as well as reduce the construction costs. Finally, the site selection framework was able to determine a clear winning site, as they found that 2.02% of the total area was optimally suitable, whilst 82.33% was moderately suitable, 13.54% was marginally suitable, and 2.11% of land was not suitable (Lukoko & Mundia, 2016).

In a similar study, El-Mewafi (2015) developed a methodology that uses GIS and MCDA to determine the most suitable site in Al-Nasiriyah city for setting up industrial zones. AHP was used to assign weights to 12

factors, such as the terrain slope and land use. They found that 19% of the total area of Al-Nasiriyah is suitable for industrial use, whereas 81% is unsuitable. Another work that relied on GIS weighted multi-criteria evaluation to identify which industrial districts are most suitable for investment and development in Connecticut State in the USA was carried by Berude (2014). In addition to suitability studies for industrial or commercial development, GIS has also been applied for the assessment of sites related to social infrastructure. For instance, Youzi et al. (2017) aimed to determine the best location for a new hospital in Kuhdasht City. As with the works discussed earlier, they used a GIS integrated approach and AHP based on multiple criteria such as utility, performance, safety, population, density and proximity in order to identify the best location. The outcomes demonstrate the flexibility of GIS, as it could provide the fastest access for both spatial and non-spatial data.

Mokoena et al. (2017) applied similar methods to identify land for new settlements in Ekurhuleni Municipality, South Africa. They assert that the combination of such planning tools can assist planners and decision makers to identify, quantify and visualise the function of a new city. Chen (2014) supports this view; according to her findings, land use suitability assessment with the help of Multi-criteria GIS analysis is a key factor for future planning decision making.

Inspired by the success of prior work in the field of assessing and comparing site suitability with the help of GIS and AHP, this study aims to evaluate the labour city locations proposed by the Kuwait municipality and compare them using a MCDA methodology. The primary objective includes the quantitative evaluation of the proposed locations of labour cities in Kuwait according to multiple suitability criteria. The secondary objective is to model the potential positive impacts of various labour city locations in alleviating issues such as crime, traffic congestion, housing shortage and infrastructure pressure. Finally, the effects of developing labour cities in each proposed location on the local demographics will be investigated. The framework used towards these goals is GIS and MCDA. The proposed model is expected to help decision makers and planning authorities in Kuwait in establishing the proposed labour cities.

Study Area

Kuwait is a country located in the north west of the Arabian Gulf with a total population of 4,776,407. Around 70% of population consists of non-Kuwaiti expatriate workers (PACI, 2020). Non-citizens started arriving in Kuwait as a result of the oil industry boom in the 40's and 50's and had increased dramatically since. In 1955, the total population of non-citizens in Kuwait was only 6,500; in 1995 it reached 1,250,000 which is over 60% of total population.

The majority of foreign workers in Kuwait are individuals with low level of education and skills predominantly from other Arabian and south Asian countries. These workers tend to be employed in jobs that are not undesirable to locals, such as private servants, cleaners, hospitality workers and in the construction sector. There is a smaller cohort of highly skilled and educated migrant workers that end up being employed in public and private sectors in management or technical positions. The demographic characteristics of the non-citizens show most (70%) are male between 25 and 50 years old (PACI, 2020). Table 1 shows the visa types for non-Kuwaitis in 2019 (KCSB, 2020), highlighting the dominance of private sector visas compared to all other types.

Table 1

Foreign employees' distribution according to visa type in Kuwait in 2019

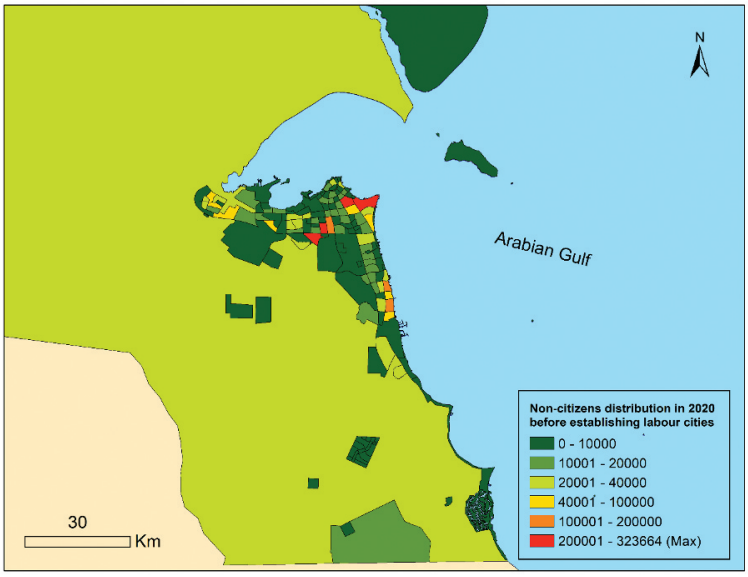
Visa types	Number of residences	%
Temporally residence	70,624	2
Working in public sector	105,970	3.2
Working in private sector	1,547,205	46.3
Indoor servants*	731,376	21.9
Joined avail (family members)	541,830	16.2
Others (such as Freelancers, studying and expenditure source)	3,608	0.1
Violating the residence law	343,749	10.3
Total	3,344,362	100%

Note. * some of the registered indoor servants work independently.

Since the early days of immigration, foreign workers in Kuwait mostly settled in commercial districts that contain high-rise buildings. By law, non-citizens are not allowed to own any kind of property in Kuwait, thus they are only able to rent houses or flats (Alshalfan, 2013). However, due to the relatively low salaries and high rents they almost always prefer sharing living spaces. There are specific districts that groups of foreign workers based on nationality are gathering in. For example, Jleeb Al-Shuyoukh is a district located in the middle of the country; the demographics show that 99% the non-citizens in the district are from south Asia (India and Bangladesh). Further examples are Hawalli and Salmiya; in these districts locals account for only 0.9-2.5% of total population, while the majority of the residents are from Arabian countries (Egypt and Syria). Figure 1 shows the districts that are mainly occupied by non-Kuwaitis as of 2020.

Figure 1

Non-Kuwaiti population distribution in Kuwait in 2020



Note. Based on data from (PACI, 2020).

The high concentration of non-citizens in certain residential and commercial districts has aggravated a variety of urban issues, such as traffic congestion, housing shortages, pressure to the infrastructure systems and a notable increase in crime rate especially in commercial areas (Alghais & Pullar, 2018), which in turn motivated the state government to consider the creation of new cities that will be able to relieve the demographic pressure. The government and the developers formally consider these as labour cities, as their primary purpose is to offer accommodation and amenities to foreign labourers in Kuwait or to any new incoming immigrants. The new cities are supposed to be developed in six different locations outside the main urban area under its latest master plan in 2008. These new cities will be developed under the Kuwait Authority for Partnership Projects (KAPP), which is a collaboration between the government and the private sector (KAPP, 2020).

In July 2019, the Minister of Public Works of Kuwait sent a memo that documented the plan and the characteristics of the proposed labour cities. The memo revealed that the construction of the first city would be launched in South Jahra at the end of 2019, will span over 101.5 hectares and will have the capacity to accommodate 20,000 residents. Upon completion, the project is anticipated to provide affordable and adequate housing mainly for the large and highly concentrated male expatriate population in Kuwait. It is the intention of the government that the project will maintain consistency with the traditions and culture of the local society, whilst at the same time offer high standards of security, leisure and recreation to its inhabitants. The residential units will be constructed with the goal of meeting a broad range of modern living standards, such as access to sunlight, adequate space per tenant and the existence of laundry, garbage collection and security systems (KAPP, 2018).

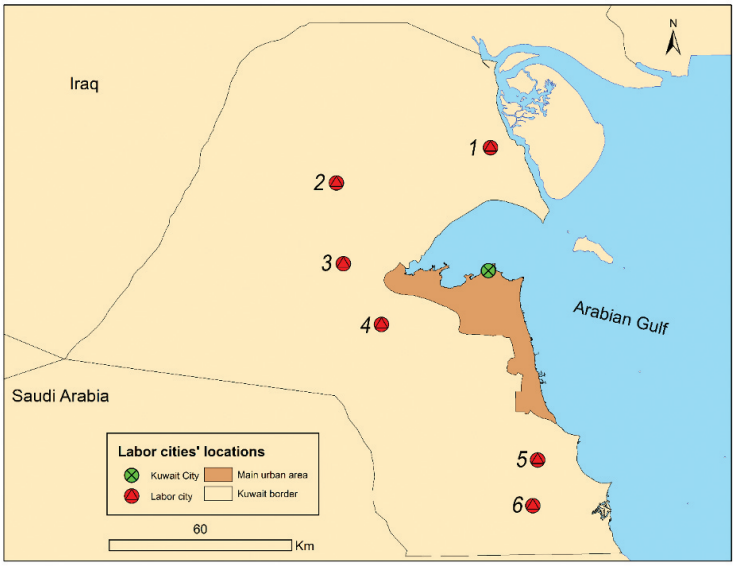
Table 2 shows the names, capacity, and area of the proposed new cities.

Table 2
List of new labour cities in Kuwait

Number	Name	Capacity (person)	Area size (Km^2)
1	Al Subiya	40,000	2.465
2	Al Matlaa	40,000	2.465
3	South Jahra	20,000	1.015
4	Kabd	40,000	2.465
5	South Sabah Al Ahmed	40,000	2.465
6	Wafra	40,000	2.465

Source. Kuwait Municipality, 2020.

Figure 2
New labour cities' locations as proposed by Kuwait Municipality



Note. Based on data from (Kuwait Municipality, 2020).

While the plan to develop these new cities is certainly ambitious, there has been little progress in the construction of the projects by

2020. The delays are caused by several factors, such as the drop of oil prices and hence the state's revenue, the low availability of services and power (electricity and water), the extensive bureaucracy in communication between government's authorities and ministries, and the restrictions due to the COVID-19 pandemic (Mohammad, 2019).

Methodology

This research combines GIS, AHP and MCDA to evaluate the proposed labour cities locations in Kuwait. Two methods were applied in order to achieve the objectives of the study. The first method was based on Vector format (point, line and polygon layers) analysis which provided the order of cities suitability ranking. The second method was based on Raster format (matrix of cells layers) which showed different levels of suitability sites.

Defining Criteria and Ranking

In order to apply the MCDA methodology, this study selected eight criteria that affect the site selection. These criteria were obtained from previous studies and via interviewing four specialists (the director of the master plan department in Kuwait Municipality, urban geographer in Kuwait University, civil engineer in Kuwait Municipality and planning engineer in Public Authority of Housing Welfare). The ranking of the importance of these criteria from 1 to 8 as well as a short description about each one is shown in Table 3.

Table 3
Criteria ranking based on the interviews

Criterion ranking	Criterion	Code	Rationale
1	Development constraints areas	DC	High distance from development constraints areas (national parks, oil fields, military camps etc) is preferred.
2	Current urban area	U	Proximity to current urban areas is preferred as most of the facilities and services are located there.

Cont. Table 3

Criteria ranking based on the interviews

Criterion ranking	Criterion	Code	Rationale
3	Future urban areas	FU	Proximity to the future urban development projects boundaries is preferred as workers will be needed during construction.
4	Major roads	Rd	Proximity to the main road networks (highways) is important for commute to workplaces.
5	Industrial areas	I	Proximity to industrial areas as the majority of laborers work there.
6	Commercial areas	C	Proximity to commercial areas as shops and services are located there.
7	Hospitals	H	Proximity to hospital.
8	Slope	S	Flat ground is easier to construct; luckily, most of Kuwait is flat.

Data preparation & Analysis

Data sources

The data used in this study was collected from three main sources. GIS ready data (Kuwait districts, Kuwait street network, land use and Digital Elevation Model-DEM raster layer) was collected from (Vision International, 2019; Kuwait Municipality, 2020). The labour cities locations, future cities and districts and development constraints areas were digitised from hard copy maps collected from the Kuwait Municipality (2020). Finally, the population distribution on districts by nationality were obtained from PACI (2020).

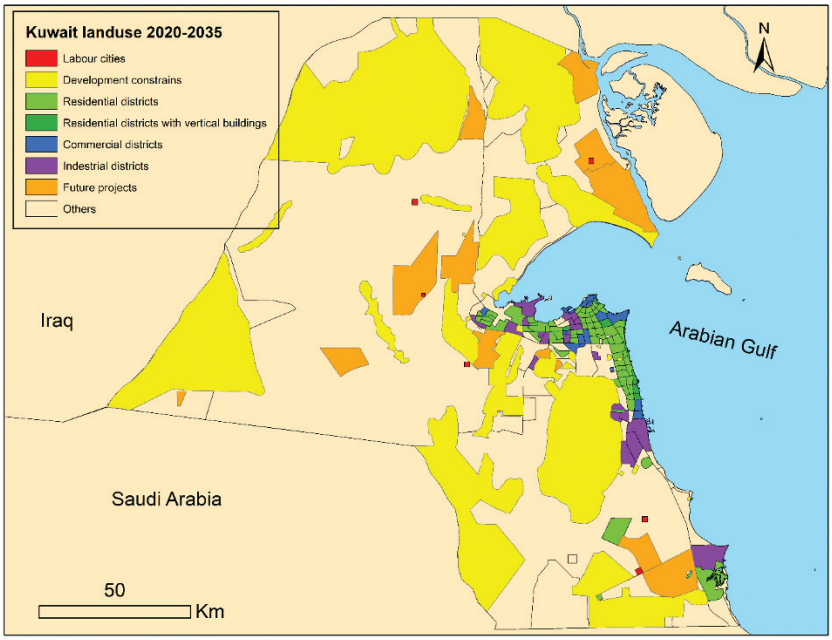
Data Preparation

Future urban areas as planned by Kuwait's new master plan were converted from hard copy map into a GIS layer. The digitised development constraints areas layer contains development constraints, such as sensitive environmental areas, oil fields, army camps, natural parks, agricultural areas and sand dunes, were merged as one feature class. The hard copy map of labour cities contains the locations and sizes; these

locations were digitised and converted into a polygon layer matching the original area sizes. The population data was added to the attribute table of Kuwait districts layer using the *Join function* in ArcGIS. Districts layers were classified into industrial, commercial, residential, residential with vertical buildings, and other uses. The outcome of the data preparation step is shown in Figure 3.

Figure 3

Data preparation outcome map



Additionally, the main urban area layer was created by merging all the mentioned classes as one feature class as shown earlier in Figure 2. After digitising the data all the layers were ready to be imported and used in the ArcGIS platform for further analysis.

Data Analysis

In this step, the data was modified and analysed with ArcGIS tools and made ready to use for AHP. In this process it was necessary to define the industrial and commercial centres: a point that shows the geographical

centre of the location for all industrial districts and another point that represents the geographical centre location for commercial districts. These two centres were acquired by using the *Median center tool*. Subsequently, the *Point distance tool* was applied to measure the distance from both centres to each labour city. Furthermore, the distances between each labour city to the nearest hospital and nearest major road were calculated using the *Euclidean distance tool*.

By using the *Generate Near Table tool,* it was possible to calculate the distance from each labour city to the nearest point of:

1. future urban areas.
2. the current urban area.
3. development constraints.

At this stage, the Vector data are ready for analysis. However, a series of tasks had to be completed for further analysis. Firstly, the Vector data had to be converted to Raster format with the help of *Feature to Raster tool*. Furthermore, the *Euclidean distance tool* was used to calculate the distance between the centre cell (main location) and its surrounding cells. This was necessary in order to provide new layers with distance zones based on strait line distance that can be used in the later stages of the suitability analysis. In addition, a new slope layer was obtained via the Slope tool via the DEM layer. Finally, the *Reclassify tool* was used to assign new values of importance to all raster layers, including the slope layer.

The movement of non-citizens from existing districts to the new labour cities was modelled in ArcPy (Python scripting language in ArcGIS) in a fashion that meets the maximum capacity to each labour city as planned by the government. This has been done randomly via selecting non-citizens from the most highly populated districts of non-citizens and relocating them to the new labour cities. The code was based on *ForLoop* as shown below:

1 - Define old districts with highest number of non-citizens with new field movement True/false (*Layer 1*).

2 - Define new labour cities with field maximum capacity (*Layer 2*).

3 - Loop in *Layer 1*, if movement True, take 50% of non-citizens and add them in a new array (*Feature to move*).

4 - Loop in *Layer 2*, while non-citizens < maximum capacity, select random feature from *Feature to move array*, take 10% from the random selected feature and add them in *Layer 2* randomly.

5 - Remining non-citizens who did not move, the next loop will return them to their old districts in *Layer 1*.

Analytical Hierarchy Process (AHP)

According to Nyerges and Jankowski (2010), AHP is a multiple criteria evaluation method that can be used to quantitatively formalise the process of site selection; in the case of the present study it is applied in selecting the location of labour cities. This approach can be used for computing weights that represent the importance of the criteria that were collected previously. The weight for each criterion was calculated based on the interviewees responses as shown in Table 4.

Table 4
Criteria weights

Criteria codes	Weights
DC	0.304
U	0.252
FU	0.145
Rd	0.117
I	0.073
C	0.063
H	0.027
S	0.019

To ensure that the criteria weights matrix is reasonably consistent, the Consistency Ratio was calculated, and it was 0.085 which is less than the standard of 0.10 (Saaty, 1987).

Suitability Analysis via MCDA

MCDA is a decision-making analysis tool that can be used for evaluating various conflicting criteria and assist in solving problems, such as site comparison and selection.

In order to evaluate labour city locations, the extent that these locations are suitable must be calculated based on the multiple criteria mentioned in Table 3. In this process, two methods were used: a Vector data suitability analysis and a Raster suitability analysis. For the Vector suitability analysis, a reference standard of minimum score must be defined, against which all other location will be assessed. Hence, a location for each criterion inside Kuwait's border was found that has the least optimal suitability: for instance, a location would score 0% in the DC criterion if it was inside a constraint local area like a national park. This process ensured that:

1. any previous research criteria and weights that are not relevant to Kuwait were not used, such as rivers, mountains, forests and others.
2. the manual estimations for the criteria are unique to Kuwait's geography and population characteristics.

Table 5 shows the worst location for each criterion and the actual distance of each labour city for that criterion.

Table 5

The criteria worst location and distance for each labour city in km

Criterion code	Worst location	Labour city 1	Labour city 2	Labour city 3	Labour city 4	Labour city 5	Labour city 6
DC	0*	8.4	2.1	6.9	1	9.1	2.6
U	122	43.9	38.9	16.3	12.4	15.2	31.9
FU	60	0	12	0	1.9	4.5	0.6
Rd	70	2.9	21.8	10.1	16.7	10.5	1
I	167	74.9	85	65.8	45.4	29.3	43.5
C	162	50.6	64.7	51	37.6	53.8	68
H	127	46.1	38.4	19.1	14.9	36.3	51
S**	15	0.77	1.8	1.4	2	2.3	2.3

Note. * Best location is 25 Km, ** in Degrees.

In addition, it was necessary to normalise the measurements for all criteria by converting the distances and slope levels to percentages. These percentages were then multiplied by the weights generated from the AHP.

The Raster suitability analysis is a cross-check step that was applied in order to compare and validate the Vector suitability analysis results. In this methodological step, the *Weighted overlay tool* was utilised for all reclassified raster layers based on the weights in Table 4. This approach produced the suitability map showing the best sites in Kuwait according to the pre-set criteria. The *Model builder tool* was used to run all the necessary processes in order to obtain the suitability map as shown in Figure 4.

Figure 4

Suitability map process derived by Model builder tool

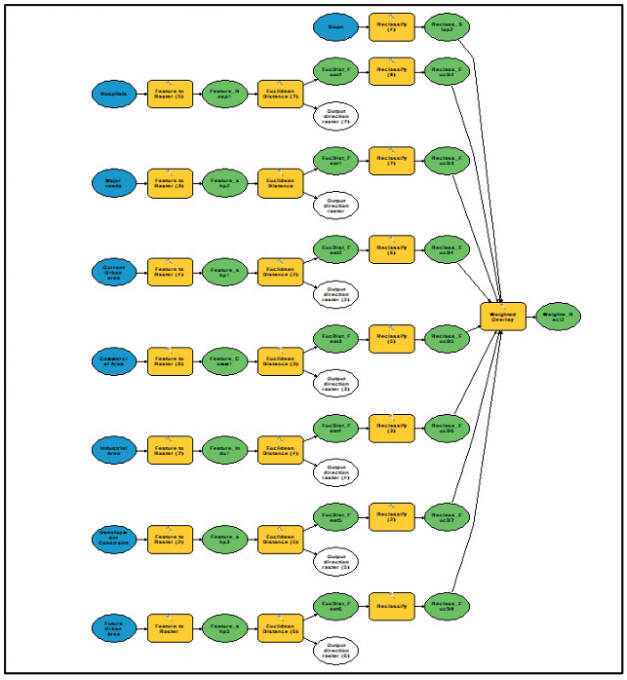
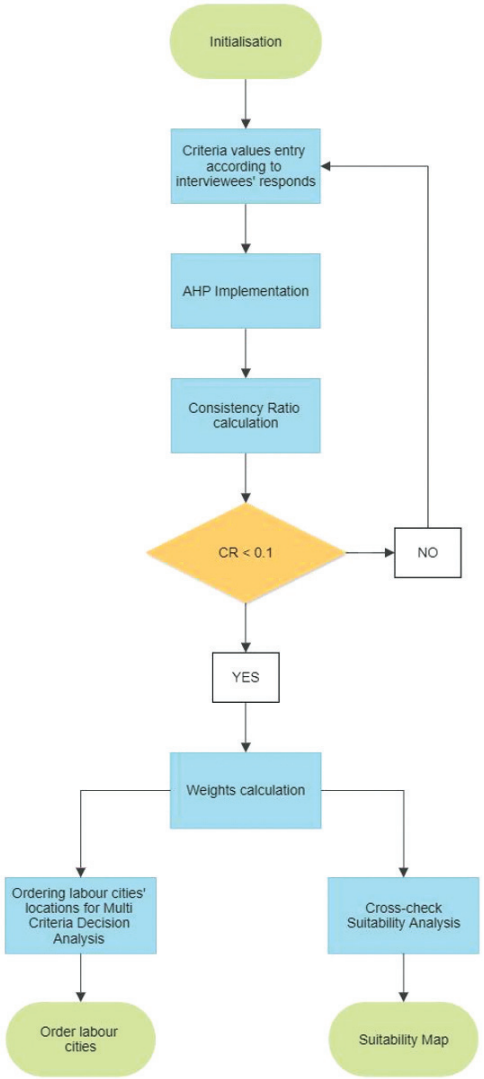


Figure 5 shows the methodology flowchart.

Figure 5

Methodology process flowchart



Results

Suitability Ranking of Labour Cities

The results show that the new labour cities are different in their suitability for their purpose. A comparison of their suitability scores for each criterion as well as overall is shown in Table 6.

Table 6

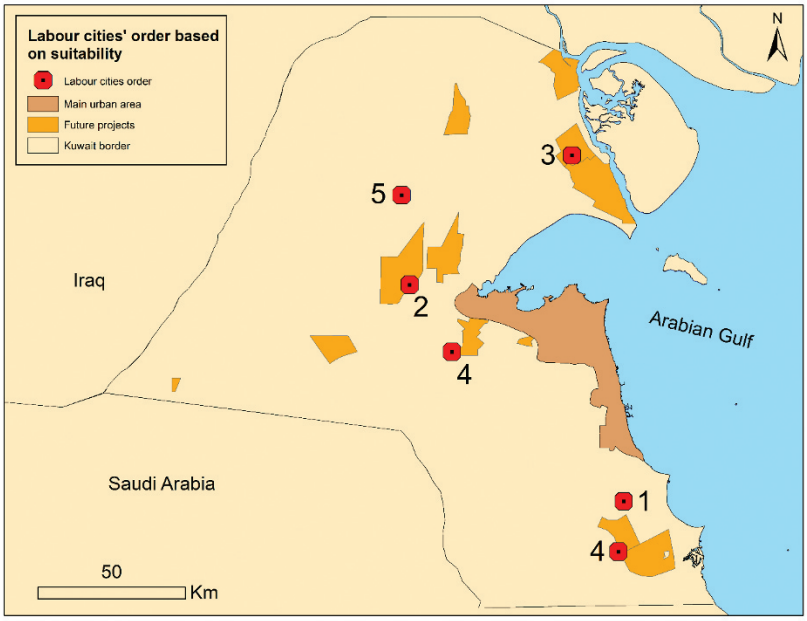
Final suitability scores for the labour cities

Labour city number	Criterion weight (%)								Total score (%)
	DC	U	FU	Rd	I	C	H	S	
1	11.6	13.4	15.8	11	3.9	3.9	1.6	1.5	63
2	2.9	14.3	12.6	7.9	3.5	3.5	1.8	1.4	48
3	9.5	18.2	15.8	9.8	4.4	3.9	2.2	1.4	65
4	1.4	18.7	15.3	8.7	5.2	4.4	2.3	1.4	57
5	12.6	18.4	14.6	9.8	5.9	3.9	1.8	1.3	68
6	3.6	15.5	15.6	11.3	5.3	3.4	1.5	1.3	57

From Table 6, it is clear that labour city 5 is the most suitable location (68%). The second and third most suitable cities are 3 and 1 with scores of 65% and 63% respectively. The least suitable location is labour city 2 (48%). The main reason behind this is its closeness to areas where the development constraints apply. The suitability score range is 20%. Figure 6 shows the map and the order of the labour cities based on their final suitability score.

Figure 6

The order of labour cities based on their suitability

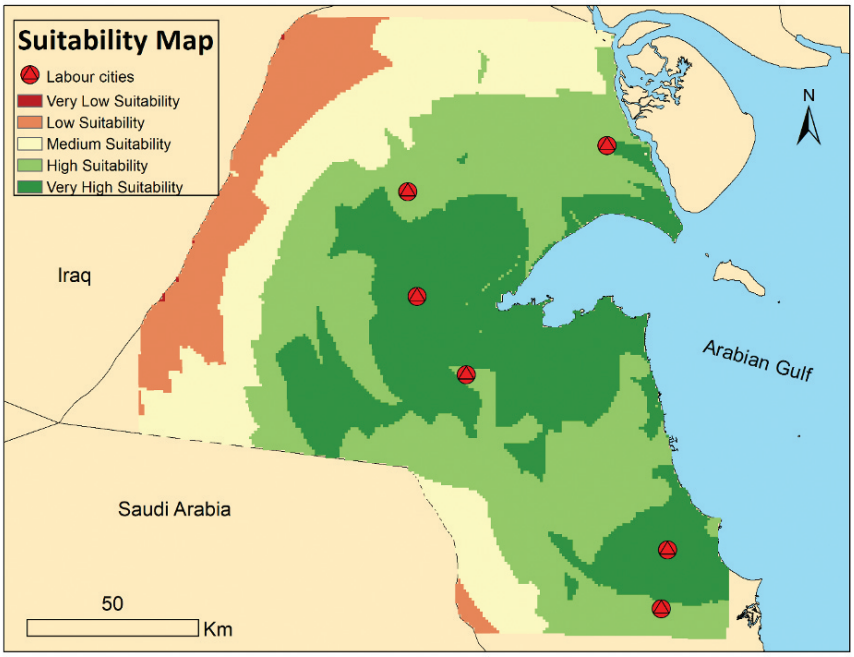


Suitability map

A suitability map was generated via the *Weighted overlay tool* in ArcGIS as mentioned in Methodology section. The map indexed locations in five levels of suitability (from very highly suitable to very unsuitable zones). It is a convenient visual medium that allows to identify the best site selection for the potential labour cities in Kuwait by inspection. The map is 100% identical with the outcome of Figure 6, except it does not show the order (ranking) of the labour cities based on their suitability. Specifically, cities 1, 3 and 5 are located in very high suitability zone; whereas, labour cities 2, 4 and 6 are located in high suitability locations. The suitability map is shown in Figure 7.

Figure 7

Suitability map derived from MCDA

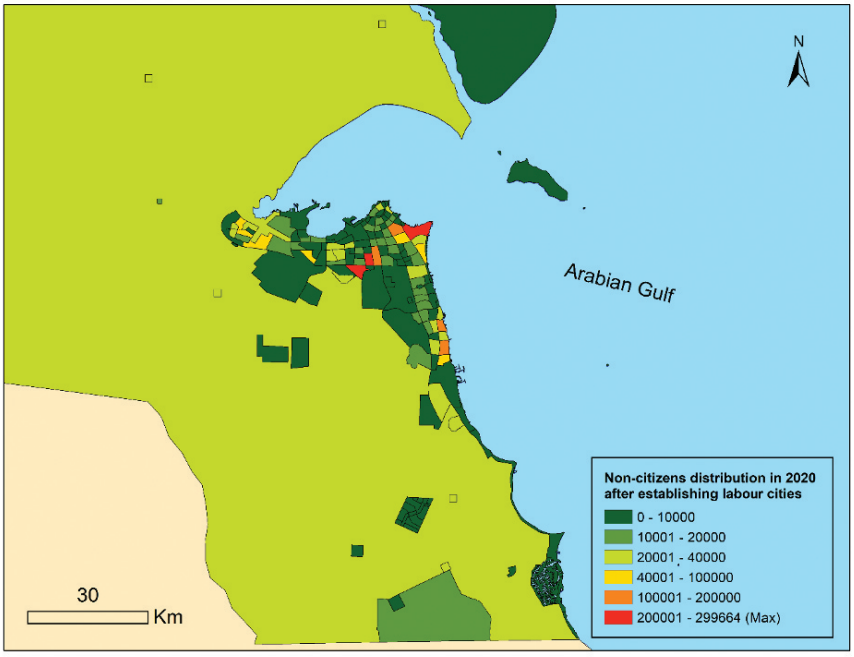


Non-citizen population distribution

As shown in Figure 8, the distribution of non-citizens is modelled to change compared to 2020 (Figure 1) after establishing the new labour cities. The most notable differences appear to be in the two districts of Abu Hulifa, in the south side of Kuwait City and Hawali, near the centre of Kuwait City.

Figure 8

Non-Kuwaiti population distribution (modelled) after establishing new labour cities



Furthermore, the population density of non-citizens (non-citizens total / district area) was found to be different to the current values after the simulations. The two districts with the most significant density changes were Abu Hulifa in south side of Kuwait City and Salmiya in East side of Kuwait City. Figures 9 and 10 show a comparison of the non-Kuwaiti population density before and after the labour cities are established.

Figure 9

Non-Kuwaiti population density in 2020 before establishing new labour cities

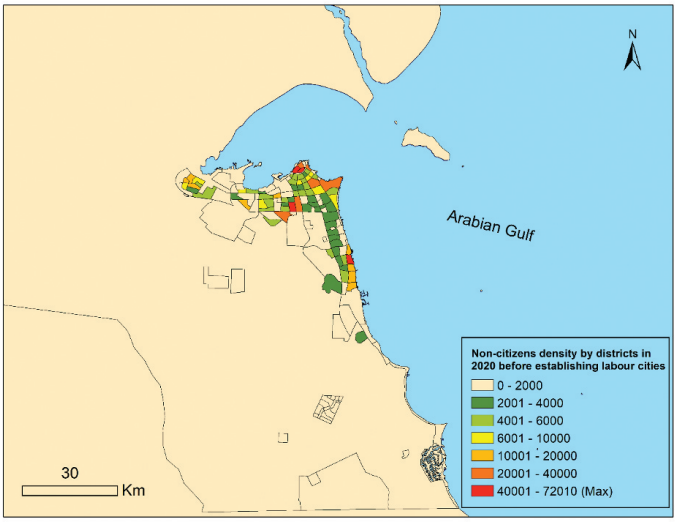
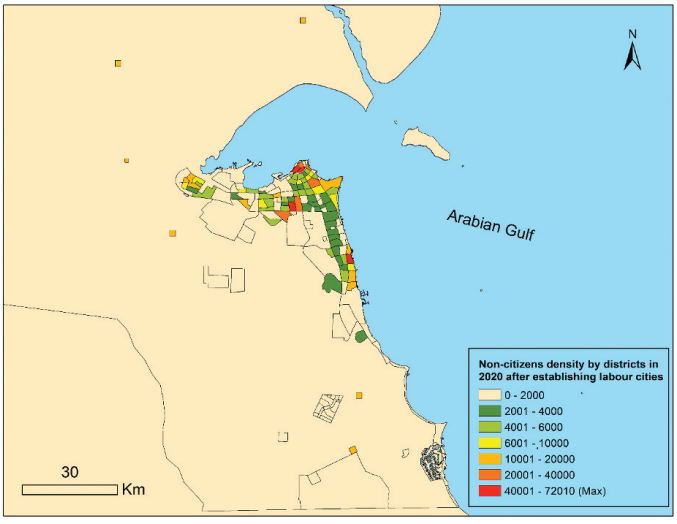


Figure 10

Non-Kuwaiti population density (modelled) after establishing new labour cities



Discussion and Conclusion

Site selection is an essential and complex process affecting urban planning, investment decisions and the wellbeing of citizens. This research study aimed to evaluate the future labour city locations as proposed by Kuwait government. Towards achieving that main objective, a broad range of spatial, demographic and regulatory data was collected and analysed with an integrated GIS and AHP model. MCDA proved to be an advantageous technique for evaluating the optimal location from a set of candidates, as it can order them based on predefined criteria. In this paper, assigning the criteria and their weights, the opinions and perspectives of certain experts and specialists were considered. In addition, the criteria were appropriately modified based on information found in other relevant studies and the authors' best knowledge about the some unique features of the case study, such as development constraints, future urban area projects, major roads, location of industrial and commercial districts, hospital and terrain slopes. After the criteria were established and the weights were determined, each location was given a score for each criterion based on the spatial data in GIS/AHP. The scores were collated and the overall suitability scores were calculated for each location.

Although some of these factors had low impact, such as the terrain slope, they were still used in the quantification process to ensure that the labour cities are built in suitable elevations. The criterion with the highest weight was related to development constraints. In Kuwait there is a set of regulations that excludes certain pieces of land from development for environmental, national security and socioeconomical reasons. These constraints greatly affect the availability of land near suburbs with many jobs and hence the suitability scores of labour cities. The other major determinant of suitability was proximity and connectivity to the main motor network, which is important for commuting and communicating between labour cities and workplaces.

In addition, and in order to ensure that the suitability ranking of labour cities is satisfactory; a suitability map was developed with the *Weighted overlay tool* based on the set of aforementioned criteria and

the Raster data. The resultant map agrees with the ranking order of labour cities derived via the main methodology.

The results of the two methods indicated that all labour cities are located in relatively suitable locations; however, there are clear winners among the sites. The least favourable location Almataa labour city scored below 50% in suitability. The most suitable location was South Sabah Al Ahmed, with a suitability score of 68%. The range of the suitability scores was between 48% to 68%.

Using the same GIS/AHP framework, it was possible to model the movement of laborers from current commercial and high rise building residential districts to new labour cities assuming they were established and able to host their maximum capacity as proposed by Kuwait municipality. It was shown that the relocation of these workers is not expected to sufficiently mitigate the main urban issues in Kuwait. Among the objectives of establishing these labour cities, according to the state government, was to solve urban problems such as traffic congestion, pressure on infrastructure and services, which does not appear to be the case based on the model's results. However, it is expected that crime rates will be lower in current urban area as the majority of labour cities occupants will be non-citizen single males which belong to the demographic with the highest participation rate in crimes (both victims and perpetrators) in Kuwait according to OSAC (2019).

The model results also indicate that the population density of non-citizens overall did not demonstrate any significant change after the new cities were established. The new labour cities are expected to accommodate approximately 220,000 workers; however, more than 1,500,000 non-citizens are assumed to be working in both public and private sectors in Kuwait by the time they are completed. The suggestion of this study is that the government increases the capacity and size of these labour cities, which will alleviate the urban issues more effectively and relieve some pressure from the high population density districts.

Finally, this research confirmed that the MCDA technique may be integrated in a framework GIS and AHP and provide a useful tool

in evaluating site selection for future urban planning projects. The results of the analysis may be used to support decision makers in their planning and implementation tasks. Future work directions include investigating additional sites, outside of the ones suggested by the government and compare their suitability as labour cities. Additionally, future work may involve the inclusion and refinement of the criteria in MCDA and the calculation of their weights, based on additional interviews and data. This methodology framework and the criteria weights may also be applied in other GCC countries' future labour cities projects.

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تقييم مواقع المدن العمالية في دولة الكويت باستخدام متعدد المعايير في نظم المعلومات الجغرافية

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ملخص

الأهداف: المدن العمالية مصطلح يطلق على مدن سكنية خاصة تأوي عدداً كبيراً من العمال الذين يعملون في القطاع الخاص. في دولة الكويت، اقترحت الحكومة إنشاء ست مدن عمالية جديدة موزعة في مواقع مختلفة في الدولة. يهدف هذا البحث إلى تقييم مواقع هذه المدن المقترحة. **المنهج:** هذه الدراسة وضعت إطار عمل مبنياً على نظم المعلومات الجغرافية (من خلال بيانات خطية وخلوية بشكل منفصل) وعملية التحليل الهرمي وفق معايير سكانية ومكانية طُبقت من خلال وضع وزن خاص لكل معيار على كل مدينة عمالية مقترحة. وقد وضعت أوزان المعايير بناءً على مقابلات مع خبراء في التخطيط والجغرافيا. **النتائج:** وجد أن مدينة جنوب صباح الأحمد العمالية تحتل أفضل موقع من المواقع المقترحة؛ إذ حصلت على نسبة 68% من حيث الأفضلية المكانية. وقد تم تأكيد ذلك من خلال الملاءمة المكانية. **الخاتمة:** إن هذه المدن العمالية الجديدة لا تعتبر كافية لاستيعاب عدد العمال الموجودين في دولة الكويت، ولن تخفف الازدحام المروري ولا الضغط على البنية التحتية كما هو مخطط له. مع ذلك فإن لهذه المدن العمالية بعض الإيجابيات التي سيستفيد منها السكان في المناطق الحضرية الحالية.

الكلمات المفتاحية: عملية التحليل الهرمي (AHP)، نظم المعلومات الجغرافية (GIS)، المدن العمالية، الكويت، التحليل بناء على معايير متعددة (MCDA).

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