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Professional practice

Environmental assessment of road alignments based on multicriteria scoping: a case study of Cairo–Ain Sukhna freeway

Khaled A Abbas

This research develops a multicriteria scoping framework by which alternative road alignments can be assessed, using the Cairo–Ain Sukhna freeway in Egypt as an example. Four alternative alignments were assessed using 60 comparative criteria covering technical, accessibility, economic and financial matters, development, safety and security, severance, social considerations, as well as natural and man-made environmental aspects. Baseline information was collected from maps, site visits and consultants' reports. A comparative analysis ranks the alternative alignments based on their potential impacts. Weightings, giving higher weights to environmental aspects, are applied to the rankings, and the best alternative is identified. The multicriteria scoping framework proved a sufficient tool for assessing alternative road alignments and for selecting the most environmentally preferable one.

Keywords: environmental assessment; road alignments; Egypt; mulitcriteria scoping

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IT IS IMPORTANT for the economic and social development of societies to guarantee the efficient, effective and safe movement of people and goods through space and time dimensions. Transport mobility and accessibility are necessities for promoting sustainable growth. However, there are several deleterious outcomes resulting from the construction and operation of transport systems, namely congestion, increase in vehicle operating costs, energy consumption, and other environmental effects including traffic accidents.

It is widely acknowledged that transport systems have harmful impacts on the local, regional, national and global environments. These range from local air and noise pollution to harming the global life-support systems, consumption of non-renewable resources, endangering living conditions, deteriorating human health and causing safety problems. This entails planning, evaluation, design, construction, operation and maintenance of transportation infrastructure taking into consideration expected environmental issues.

This paper relates to developing a multicriteria scoping framework through which alternative road alignments can be assessed. The research demonstrates applicability of this process as a basis for selection of an environmentally preferable alignment for the Cairo–Ain Sukhna freeway in Egypt. This is based on comparing and assessing four alternative alignments using 60 comparative criteria, which are selected to cover technical, accessibility, economic and financial, development, safety and security, severance and social considerations as well as natural and man-made environmental aspects.

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The research relies on available baseline information collected from maps, site visits and consultants' reports. A comparative analysis is used to rank the alternative alignments based on their potential impacts. This is followed by points weighting giving higher weights to environmental aspects. Such weightings are applied to the rankings and the best alternative is identified based mainly on its high scoring with regard to environmental friendliness as well as to other considered aspects.

Alternative alignments for the freeway

Several studies are required for road projects. The first is the assessment of alternative alignments. This is to judge the environmental feasibility of alternative alignments with reference to their effects on components of the physical, biological, ecological, cultural, social, and man-made environments. Such a study is based on conventional alignment analysis procedure as well as on an environmental impact assessment (EIA), and a final selection is made of a preferred corridor.

The second study required for road projects is that concerned with examining geometric and structural standards. An EIA would judge the environmental feasibility of such standards. Finally, a fully-fledged EIA ought to be carried out to assess the environmental feasibility of the various phases involved in transport infrastructure projects. These include pre-construction (mobilisation), construction, operation and maintenance phases. The main environmental effects, and their relative intensities, that could be considered for such phases are shown in Table 1.

Recently reviewed research shows that multicriteria analysis can be used to evaluate route alignments, (Sadek *et al*, 1999; Li *et al*, 1999) and to compare road improvement projects (Frohwein *et al*, 1999). It has also been used in combination with cost–benefit analysis to come up with an overall assessment of the impacts of transport initiatives over different geographical regions and time periods (Tsamboulas and Mikroudis, 2000). This paper suggests a multicriteria scoping framework by which an environmental assessment of alternative alignments for roads can be conducted. The approach, depicted in Figure 1, consists of six main steps. These are applied to assessing alternative alignments of the Cairo–Ain Sukhna freeway. The steps are:

Step 1: Deciding on alternative alignments Ain Sukhna is an existing resort on the Red Sea towards the east of Cairo, the capital of Egypt. It is characterised by a number of existing and planned tourist and industrial developments. The Egyptian Ministry of Transport stipulated that the existing Cairo–Ain Sukhna road could not be assimilated into a freeway and that a completely new alignment should be established.

In this context, the Ministry of Transport via the General Authority for Roads, Bridges and Land Transport, sought proposals in 1998 in open competition from qualified bidders for a new freeway (approximately 115 km). The Cairo–Ain Sukhna freeway was selected in accordance with the current policy of the Government of Egypt to promote build, own, operate and transfer (BOOT) road projects.

The importance of this road lies in the following:

- The new Cairo City, currently under development, is located on the Cairo ring road and is very accessible to the starting point of the intended Cairo–Ain Sukhna freeway. This city is meant to act as a main pole for attracting population and relieving pressure from the capital.
- A new city named Al-Amal City is also planned for development at the Cairo end of the intended freeway, about 30 km from the Cairo ring road.
- The Suez new industrial area is currently developing at the other end of the intended freeway towards Ain Sukhna. This is meant to act as an exporting pole for Egyptian products.

Four major alternative alignments were considered for the new Cairo–Ain Sukhna freeway (see Figure 2). All considered options start from the same point from the Cairo end. Three of these run to the north of the existing road and the fourth runs to the south. Each ends at a different point in relation to the new Suez industrial area.

Table 1. Potential intensity of environmental effects due to road projects

Main phases	Environmental effects						
	Air pollution	Sound pollution	Water pollution	Solid waste	Vibration	Visual intrusion	Traffic accidents
Mobilisation	High	High	Low	Low	High	None	Low
Construction	High	Very high	High	High	Very high	None	Low
Operation	Very high	High	High	Very high	High	High	High
Maintenance	High	Very high	High	High	Very high	High	High

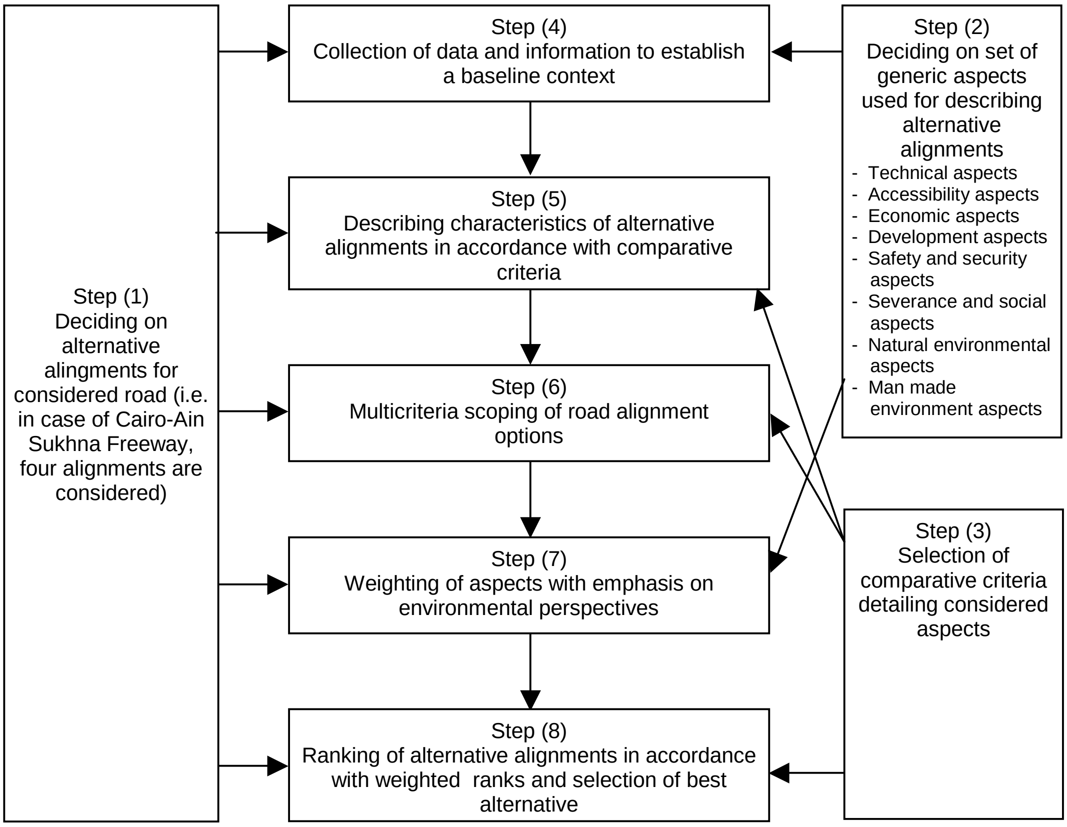

Figure 1. Multicriteria scoping framework for assessing alternative road alignments

Step 2: Deciding on a set of generic aspects Eight generic aspects were selected as constituting the main ingredients for ensuring the sustainability of the considered alignments. These included technical, accessibility, economic and financial, development, safety and security, severance and social, as well as natural and man-made environmental aspects. These were used to describe the alternative alignments. It is worth noting that the biological aspect was not included because of a lack of relevant baseline data.

Step 3: Selection of comparative criteria More than 60 comparative *criteria* were selected in an effort to detail the eight considered aspects describing alternative alignments (see Table 2).

Step 4: Collection of data to establish a baseline Data and information that were considered necessary for comprehensively assessing the possible impacts of alternative alignments were collected by means of site visits accompanied by thorough inspection of maps. Baseline information included:

- start and end points of considered alignments
- topographical information
- drainage and geology
- committed and planned development
- major utilities
- land use and availability.

Figure 3 shows details of existing natural and man-made environments in the vicinity of the considered alternative alignments.

Step 5: Describing characteristics of alignments This step aimed to describe characteristics of alternative alignments. This involved examining all data and information collected to provide baseline data. Alternative alignments were judged in accordance with the 60 comparative criteria (see Table 2). Cells of the table were completed to reflect the judgement of alternatives in relation to each other.

Step 6: Multicriteria scoping of options For each of the considered criteria, comparative scoping was conducted to rank the alternative alignments horizontally based on their specific potential impacts (see Table 2). Rank 1 represents the best alternative in relative terms, while rank 4 represents the worst. This was followed by vertical scoping of all criteria representing a specific aspect. Overall judgements of alternative alignments with respect to each of the eight generic aspects were decided based on the accumulation of individual ranks given to the criteria describing that aspect.

Step 7: Weighting emphasising the environment The eight aspects were given different weighting points. It has to be noted that environmental and social aspects were intentionally given higher weights to bias them in relation to the other aspects, which are mainly economically related (see Table 3). Economically related aspects are assessed using cost–benefit analysis, which attaches monetary values to perceived costs and benefits. Cost–benefit analysis is limited when it comes to attaching monetary values to social and environmental aspects. In this

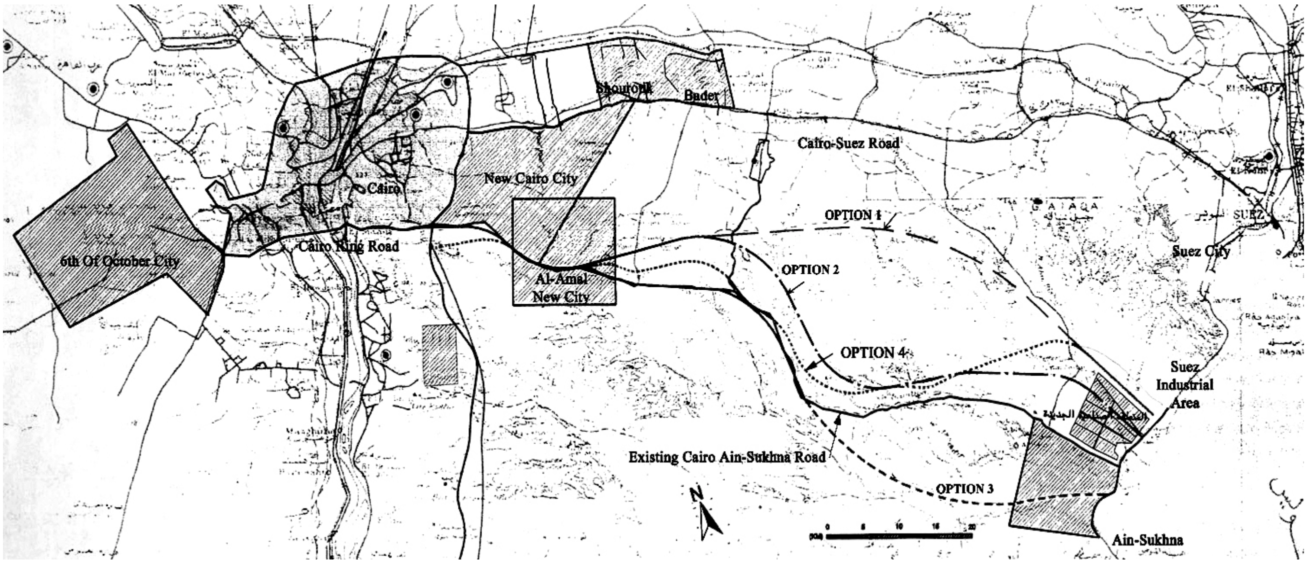

Figure 2. Four alternative alignments considered for Cairo Ain-Sukhna Freeway
Source: Adapted from UGHD (1999)

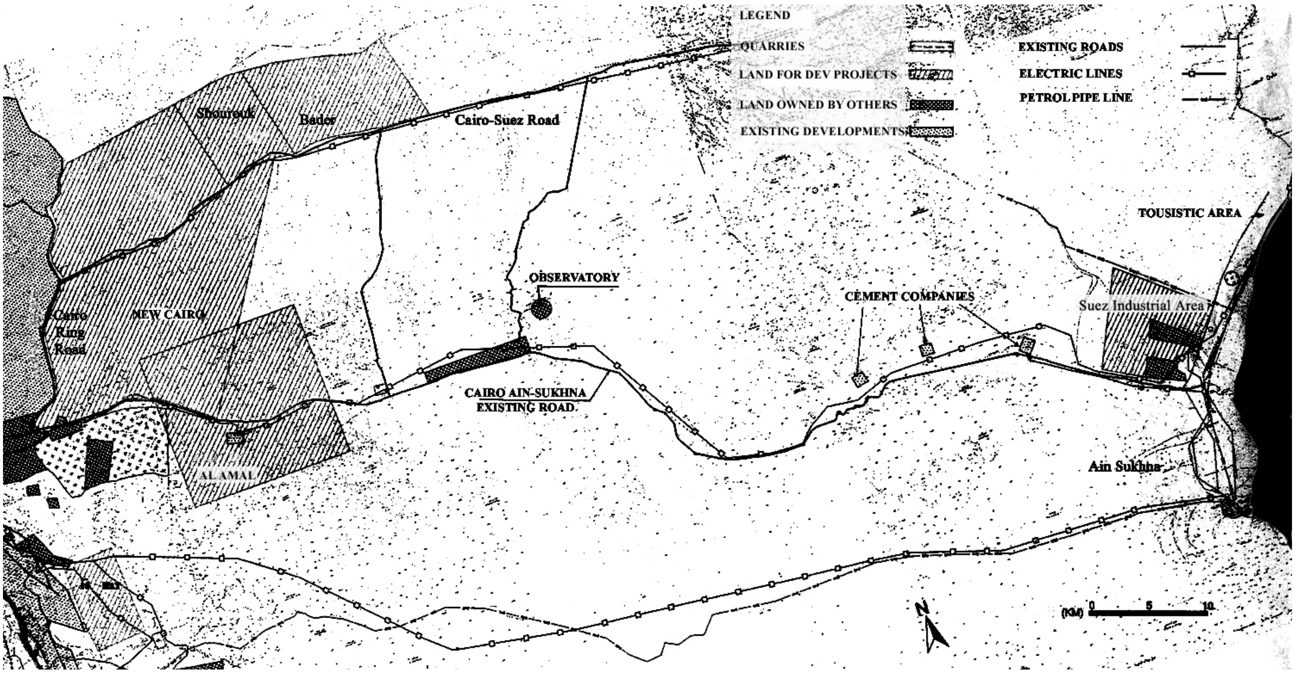

Figure 3. Natural and man made environments in vicinity of Cairo Ain-Sukhna freeway alternative alignments
Source: Adapted from UGHD (1999)

context, the proposed multicriteria scoping approach is meant to act as a support to cost–benefit analysis. Still, with the benefit of hindsight, it might have been better to elicit such weightings from experts and decision-makers involved in this project using a Delphi approach.

Step 8: Ranking in accordance with weighted ranks
Weightings were applied to the rankings given. Based on weighted ranks, a new rank order for the considered alignments was obtained. The best alternative, in terms of the chosen weights, could then be identified. This would be the alternative that scored high in most of the aspects and particularly the environmentally related ones. It can be seen from Table 3 that alternative 4 achieved the highest weighted score of 82.5. This can be considered, from an environmental perspective, as the best alignment in relative terms.

It is obvious that two of the three alignments to the north of the existing road scored higher than the alignment considered to the south of it. It is also clear that the alignment that swept far to the north into desolate territory, where it is difficult and costly to provide infrastructure, had no advantage over routes closer to the existing road. The sweep to the north increased the overall length of the road, thus increasing construction and user costs. Drainage provision is also expected to increase as the alignment moved further north.

The available land in the new Suez industrial area

Table 2. Multicriteria scoping of alternative alignments for Cairo–Ain-Sukhna freeway

	Alternative alignments			
Comparative criteria	**Alternative (1) mostly far north of existing road ending towards edge of new Suez industrial zone**	**Alternative (2) north of existing road and penetrating new Suez industrial zone**	**Alternative (3) south of existing road**	**Alternative (4) in proximity to existing road, ending towards edge of new Suez industrial zone**
(1) Technical aspects				
Total length	Longer (3)	Long (2)	Longest (4)	Shortest 115 Km (1)
Route directness based on map visual inspection	Mostly direct (1)	Number of directional changes (3)	Mostly direct (2)	Number of directional changes (4)
Terrain of road	Relatively difficult (hilly sections) (3)	Mostly flat (1)	Relatively difficult (hilly sections) (3)	Mostly flat (1)
Availability of construction materials (sand, gravel, limestone, etc)	Available in far quarries (3)	Available in nearby quarries (1)	Available in far quarries (3)	Available in nearby quarries (1)
Rail road crossings	None	None	None	None
Crossing points for main existing roads	Almost none (1)	Few (3)	Almost none (1)	Few (3)
Crossing points for secondary roads	Almost none (1)	Almost none (1)	Almost none (1)	Almost none (1)
Drainage provision	Lot of construction works due to a no. of wadi formations (3)	Relatively less construction works (2)	Lot of construction works due to a no. of wadi formations (3)	Least construction works in relative terms (1)
Relocation of existing utilities	Far from existing road, hence minimum utilities relocation (1)	Near existing road, hence high potential for relocation of existing utilities (3)	Far from existing road, hence minimum utilities relocation (1)	Near existing road, hence high potential for relocation of existing utilities (3)
Overall ranking of technical criteria	**2**	**2**	**4**	**1**
(2) Accessibility aspects				
Start point (connection)	Connection to New Cairo (ring road) (1)	Connection to New Cairo (ring road) (1)	Connection to New Cairo (ring road) (1)	Connection to New Cairo (ring road) (1)
End point (connection)	North boundary of new Suez development zone (2)	Penetrates new Suez development zone (1)	South of new Suez development zone (4)	North boundary of new Suez development zone (2)
Linkage to existing road network in the area (Cairo side)	Connecting to ring road (1)	Connecting to ring road (1)	Connecting to ring road (1)	Connecting to ring road (1)
Linkage to existing road network in the area (Ain Sukhna side)	Connecting to Suez–Ain Sukhna coastal road (1)	Connecting to Suez–Ain Sukhna coastal road (1)	Connecting to Suez–Ain Sukhna coastal road (1)	Connecting to Suez–Ain Sukhna coastal road (1)
Linkage to existing road network in the area (existing Cairo–Ain Sukhna road)	Long connections to existing Cairo–Sukhna road (3)	Shorter connections to existing Cairo–Sukhna road (1)	Long connections to existing Cairo–Sukhna road (3)	Shorter connections to existing Cairo–Sukhna road (1)
Accessibility to existing developments along existing Cairo –Ain Sukhna road	Relatively low (3)	High (1)	Relatively low (3)	High (1)
Overall ranking of accessibility criteria	**3**	**1**	**4**	**2**
(3) Economic/financial aspects				
Expropriation costs	Low as far from developments on existing road (1)	Some potential to pass through existing developments (3)	Low as far from developments on existing road (1)	Some potential to pass through existing developments (3)
Construction costs	Hilly terrain & long (3)	Relatively flat & shorter (2)	Hilly terrain & long (3)	Relatively flat and shorter (1)
Drainage costs	Very high (3)	High (1)	Very high (3)	High (1)
Maintenance costs based on distance/terrain	(3)	(2)	(3)	(1)
Environmental costs during operation (traffic emissions & noise)	Based on distance & terrain (3)	Based on distance & terrain (2)	Based on distance & terrain (3)	Based on distance & terrain (1)
Users' financial costs	(3)	(2)	(3)	(1)
Kilometre based tolling, vehicle operation costs (VOC) & travel time costs (TTC)				
Users' economic operation costs based on distance and terrain (VOC & TTC)	Increase in VOC and time costs (3)	Relative savings in VOC and time costs (2)	Increase in VOC and time costs (3)	Relative savings in VOC and time costs (1)
Overall ranking of economic/financial criteria	**3**	**2**	**3**	**1**
(4) Development aspects				
Agriculture development potential	Low possibility	Low possibility	Low possibility	Low possibility
Industrial development potential	Potential (3)	High potential (2)	Potential (3)	Highest potential (1)

(*continued*)

Table 2 (*continued*)

Comparative criteria	**Alternative (1) mostly far north of existing road ending towards edge of new Suez industrial zone**	**Alternative (2) north of existing road and penetrating new Suez industrial zone**	**Alternative (3) south of existing road**	**Alternative (4) in proximity to existing road, ending towards edge of new Suez industrial zone**
Housing development towards start of road	High potential (1)	High potential (1)	High potential (1)	High potential (1)
Housing development towards end of road	High potential (1)	Potential (3)	Potential (3)	High potential (1)
Housing development along route	Low potential (3)	Potential (1)	Low potential (3)	Potential (1)
Tourism development at start & along road	Low potential	Low potential	Low potential	Low potential
Tourism development towards end of road	High potential (1)	Low potential (4)	High potential (1)	High potential (1)
Commercial/recreational development towards start of road	High potential (1)	High potential (1)	High potential (1)	High potential (1)
Commercial/recreational development towards end of road	Potential (1)	Low potential (4)	Potential (1)	Potential (1)
Commercial/recreational development along road	Low potential	Low potential	Low potential	Low potential
Mining development at start & end of road	Low potential	Low potential	Low potential	Low potential
Mining development along road	Potential (1)	Potential (1)	Potential (1)	Potential (1)
Overall ranking of development criteria	**2**	**4**	**3**	**1**
(5) Safety and security aspects				
Traffic safety based on directness & desolation	(1)	(3)	(1)	(3)
Security	North desolate territory (4)	Vicinity of existing Cairo–Sukhna road (1)	South desolate territory (3)	Vicinity of existing Cairo–Sukhna road (1)
Flash flood	susceptible to flooding (3)	minimum susceptibility to flooding (1)	wadi plain & more susceptible to flooding (4)	less susceptible to flooding (2)
Overall ranking of safety & security criteria	**3**	**1**	**3**	**2**
(6) Severance & social aspects				
Destruction/removal of man-made culture	Limited	Limited	Limited	Limited
Passing through/adjacent to cemeteries (near Cairo side)	Yes (4)	Yes (4)	Yes (4)	Yes (4)
Human resettlement	Minimum if any (1)	Minimum if any (1)	Minimum if any (1)	Minimum if any (1)
Split of communities	Split of Al Amal City	Split of Al Amal City	Split of Al Amal City	Split of Al Amal City
Employment opportunities	Yes (1)	Yes (1)	Yes (1)	Yes (1)
Overall ranking of severance & social criteria	**1**	**1**	**1**	**1**
(7) Natural environment aspects				
Passage through wadis	Passing many catchment areas (3)	Passing about 70 catchment areas (1)	Passing many wide catchment areas (4)	Passing about 70 catchment areas (1)
Sections build on unused land	mostly (1)	most (3)	mostly (1)	most (3)
Sections build on existing road tracks	NA	some link roads (1)	NA	some link roads (1)
Land take	Minimum (1)	Minimum (3)	Minimum (1)	Passage through owned land (3)
Fuel energy consumption (based on distance & terrain)	High travelled kilometres per journey (3)	More travelled kilometres per journey (2)	High travelled kilometres per journey (3)	115 travelled kilometres per journey (1)
Exhaust emissions during operation (air quality)	Longest road & more travelled kilometres (3)	Longer travelled kilometres per journey (2)	Longest road and more travelled kilometres (3)	Travelled kilometres per journey 115 km (1)
Exhaust impact during operation	Desolate area and ends north of Suez industrial area (2)	Vicinity of existing road ending inside Suez industrial zone (4)	Desolate area and ends north of Suez industrial area (1)	Vicinity of existing road ending north of industrial zone (3)
Noise emissions during operation	Longest road & more travelled kilometres (3)	Longer road & travelled kilometres per journey (2)	Longest road and more travelled kilometres (3)	Travelled kilometres per journey 115 km (1)
Noise impact during operation	Desolate area and ends north of Suez industrial area (2)	Vicinity of existing road & ends inside Suez industrial zone (4)	Desolate area and ends north of Suez industrial area (1)	Vicinity of existing road ending north of industrial zone (3)
Visual intrusion for travellers on proposed & existing Cairo–Ain Sukhna roads	Minimum (1)	Maximum due to penetration of Suez industrial zone (4)	Minimum (1)	Maximum (3)

(*continued*)

Table 2 (*continued*)

Comparative criteria	**Alternative (1) mostly far north of existing road ending towards edge of new Suez industrial zone**	**Alternative (2) north of existing road and penetrating new Suez industrial zone**	**Alternative (3) south of existing road**	**Alternative (4) in proximity to existing road, ending towards edge of new Suez industrial zone**
Visual intrusion for man made settlements	Minimum (1)	Maximum due to penetration of Suez industrial zone (4)	Minimum (1)	Maximum (3)
Water quality of wadis	Affected by construction of crossing structures (3)	Affected by construction of crossing structures (1)	Affected by construction of crossing structures (3)	Affected by construction of crossing structures (1)
Soil contamination due to traffic emissions, spillage and erosion	Minimum (3)	Minimum (2)	Minimum (3)	Minimum (1)
Overall ranking of criteria related to natural environment	**3**	**4**	**1**	**1**
(8) Man-made environmental aspects				
Passing adjacent to military sites	Far (1)	Yes (3)	Far (1)	Yes (3)
Passing through/adjacent to industrial areas	No (1)	Yes (adjacent to three cement companies) (3)	No (1)	Yes (adjacent to three cement companies (3)
Passing through/adjacent to residential developments	Yes Al Amal City	Yes Al Amal City	Yes Al Amal City	Yes Al Amal City
Passing through /adjacent to quarries	No (1)	Yes (through) (4)	No (1)	Yes (adjacent) (3)
Passing adjacent to garbage areas	No (1)	Yes (3)	No (1)	Yes (3)
Passing adjacent/over pipelines	No (Far) (1)	No (far) (1)	Yes (near) (4)	No (far) (1)
Passing under existing high voltage electrical transmission lines	No (1)	Yes (3)	No (1)	Yes (3)
Overall ranking of criteria related to man-made environment	**1**	**4**	**2**	**3**

also influenced approach alignments to Ain Sukhna. Southern approaches to the region could not penetrate industrial areas under development and had the additional burden of being located in a wadi plain that is susceptible to flooding. Northern alignments seemed more favourable generally in terms of providing better opportunity to acquire suitable land for more development projects close to existing development proposals.

Conclusions

This paper was mainly concerned with adapting the EIA process into a multicriteria scoping framework by which an environmental assessment of alternative alignments for roads can be conducted. The adapted approach consists of eight steps. These were applied to assess alternative alignments of the Cairo–Ain Sukhna freeway in Egypt. This freeway is meant to act as an alternative parallel to the existing Cairo–Ain Sukhna road connecting the capital Cairo, the new city of Cairo, and the planned Al Amal city to the new Suez industrial zone located at Ain Sukhna on the Red Sea.

The approach started by deciding on four major alternative alignments for the freeway. This was followed by deciding on a set of generic aspects to be used for describing these alignments. These included technical, accessibility, economic and financial, development, safety and security, severance and social, as well as natural and man-made environmental aspects. In the third step more than 60 comparative criteria were selected in an effort to detail the eight aspects describing alternative alignments. This was followed by collection of data and information that were considered necessary for comprehensively assessing the possible impacts of the considered alternative alignments.

The fifth step was concerned with examining and

Table 3. Relative weightings for generic aspects characterising alternative alignments

Generic aspects	**Relative weightings**	**Alternative (1)**	**Alternative (2)**	**Alternative (3)**	**Alternative (4)**
Technical aspects	10	2	2	4	1
Accessibility aspects	10	3	1	4	2
Economic & financial aspects	10	3	2	3	1
Development aspects	10	2	4	3	1
Safety and security aspects	10	3	1	3	2
Severance & social aspects	15	1	1	1	1
Natural environment aspects	15	3	4	1	1
Man-made environment aspects	15	1	4	2	3
Final score (weighted rankings)	100	**67.5**	**60**	**61.25**	**82.5**

Note: Rank 1 = 1, Rank 2 = 0.75, Rank 3 = 0.5, Rank 4 = 0.25

scrutinising all collected data and information and presenting, in a tabular format, the judgement of alternatives in relation to each other. This was followed by a multicriteria scoping of road alignment options, where for each of the considered criteria, comparative scoping was conducted to rank the alternative alignments based on their specific potential impacts. Overall ranks for each aspect were then produced based on the accumulation of individual ranks given to the criteria for that aspect.

In step seven, weighting of aspects, with emphasis on environmental perspectives, was conducted. This was followed by applying the weightings to the overall ranks and obtaining a weighted score for each alternative alignment. Based on this approach, it was concluded that alternative alignment 4 achieved the highest weighted score of. 86.25. This can thus be considered as the best environmental alignment for the freeway.

Finally, it can be concluded that the multicriteria scoping framework, suggested in this research, proved a sufficient tool for assessment of alternative road alignments as well as a basis for making decisions pertaining to selecting the most environmentally preferable alignment.

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