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Towards an Integrated Model for Locating Transportation Hubs Depending on Urban Indicators

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Abstract Transportation hubs are major urban nodes and they play a unique role in enhancing cities' infrastructures. However, analyzing the process of selecting transportation hubs' Locations and relevant methodologies reveals a significant lack of including urban criteria and indicators in planning and application. The adopted factors and criteria of selection are limited to requirements of mobility and transportation, without having a clear description/measuring indicators of significant urban criteria. This paper aims to integrate urban criteria in selecting the best places for transportation hubs. First, this is accomplished by identifying such comprehensive criteria for location selection. In identifying criteria, the research methodology relied on various layers, include: inferring relationships between transportation development and modern urban trends, analysis of different approaches developed in planning transportation hubs, spotting differences in literature in transportation and urbanism disciplines concerning selecting points of transportation hubs, and finally, through analysis of global trials in the Location selection process and inferring common points. Six groups of comprehensive criteria were developed; under these groups fall some main and sub-criteria. Measurement indicators were found for each criterion and reference points for each indicator on a 1-5 Likert Scale. Then, Results were presented to 36 academic experts in transportation and urban planning, to ensure the quality, of each group of criteria separately. In general, the results were largely positive. 26.3% of the experts agree that criteria are excellent, 52.6% say they are very good, and 21.1% think they are good. Meanwhile, 100% agree that criteria are applicable to any city, and 93% find the measurement indicators sufficient. Finally, using Saati's hierarchical analysis, the relative weights of the proposed criteria were found depending on expert views via a series of paired comparisons. In conclusion, the results introduced by this model can be used for assessing each transportation hub nominated location. Thus, the research gap in the practical methodology adopted was filled. This would help planners spot all factors influencing location determination and assess their total urban impacts. Hence, sound decisions can be made, considering the urban surroundings, current and future development, and achieving maximum desired benefit from transportation hubs at all levels, supporting layout decisions.

Keywords Transportation Hubs, Locating, Quality Urban Indicators, Sustainable Mobility, Analytical Hierarchal Process

1. Introduction

The word "hub" is defined, according to Cambridge Dictionary, as the central point in general and the most active part. There are various terms used in theoretical studies to refer to transportation hubs [1]. Transportation hubs. are the most commonly used ones, particularly in references and urban guidelines. A transportation hub is a location where various transportation means meet to reinforce mutual connections and provide first and last access to different destinations via transportation facilities [2]. There, passengers are exchanged among cars/ different transportation means such as railroads, buses, trucks, ships, metro lines, trams or planes, boats, and pedestrians. They also contain various transportation services (car parking, tickets and information centres) and may also be integrated with stores, services, and recreational places [3,4].

Their importance is acquired as they handle different types of networks, designed separately by different authorities; being the bottleneck of the city as they are locations of high rate [4].

Literature definitions of transportation hubs went beyond stations combining more than one means of transportation to surrounding places. This is since they play a critical role in the transportation system; whether an origin, destination, or transportation point for an unlimited number of daily trips and places for seamless connection among means, where various services are available for passengers and work, shopping, and recreation zones can be found in one place.

2. The Research Gap Sought to Be Covered by the Paper

Many recently published pieces of research, and a group of development projects/guidelines,were studied to identify the latest research achievements on the research topic; and to answer the following initial research questions:

Are location efficiency assessment criteria limited to Mobility criteria only?

How far do we depend on urban factors in planning and selecting the locations of transportation hubs?

- Urban criteria mentioned in previous research, through which the efficiency of transportation hubs is raised, were limited to general aims without addressing measurement indicators.
- The research is concerned with the planning phase, contrary to previous ones, the targeted execution and redevelopment. The previous research overlooked the initial phases and the degree of engaging the urban dimension therein, focusing only on Hub's redevelopment of the center as a sustainably designed one.
- The basis of this research is to support a mutual review of the transportation plan by evaluating its proposed locations to reach a judgment where the urban dimension prevails (through reaching several goals and assessing the same with indicators).
- The research assumes that a better location can be selected from the beginning for the transportation hub if urban indicators intervene in the location selection phase, which is much better than discovering urban inappropriateness after establishing the hub and redeveloping the hub in terms of urban appropriateness with the place.
- The previous studies assumed that locations selected by urban experts are taken for granted and cannot be changed, contrary to this research (avoiding the lack of integration between the transportation hub and the urban environment from the beginning.

It was inferred and made clear in the research gap that there is no transparent model that adopts urban efficiency indicators for the urban transportation hub location to enable the urban designer/planner to assess the success of the location nominated by the transportation planner.

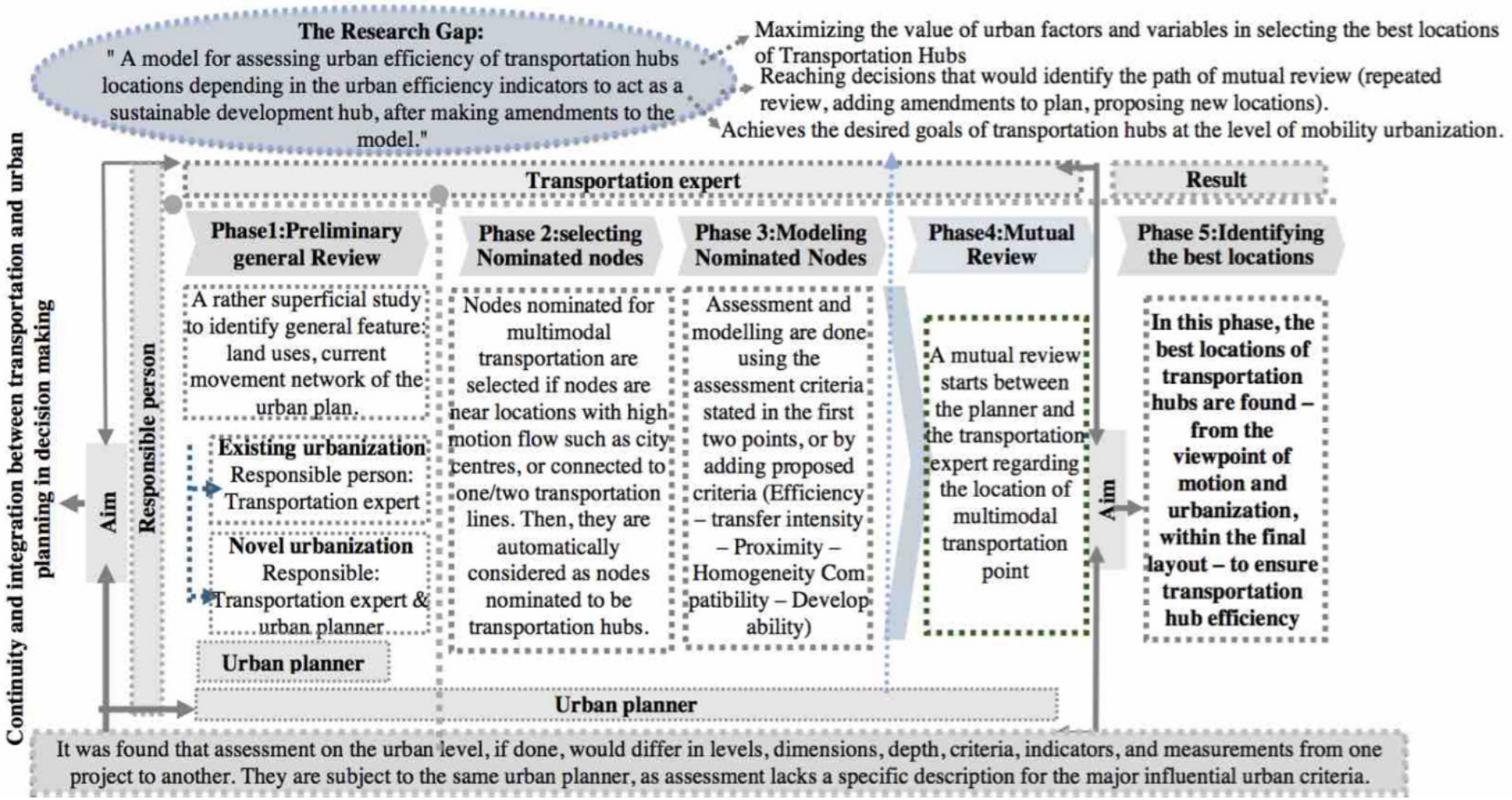
3. Analysis of Sequence Followed in Planning Transportation Hubs

Figure 1 summarizes the role of the transportation plan and the current urban plan in setting the transportation hub and the criteria taken into account in location selection. The figure shows the following sequence under the global orientation for integrating transportation and urban planning.

4. The Target Role of the Transportation Planner and the Urban Planner in Location Selection

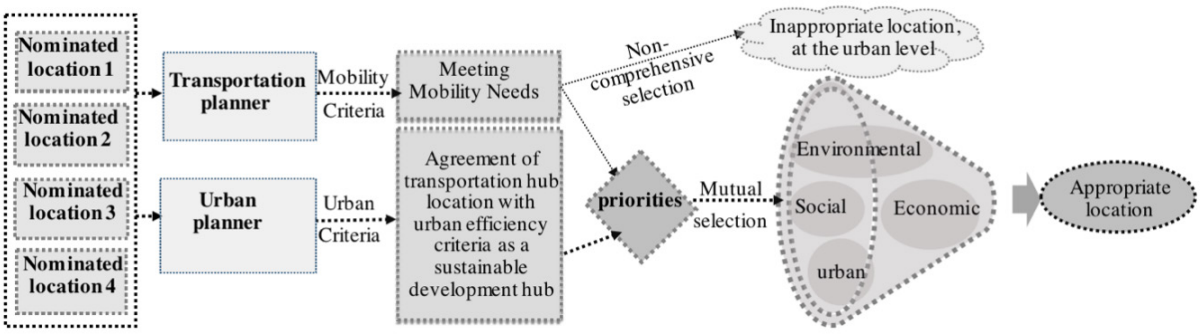
The aim of achieving parallelism between the role of the urban planner and that of the transportation planner is materialized through hub selection. This is done through the success of "mutual review" that would not be achieved without a model with clear urban criteria for selecting the best location from the urban viewpoint.

Here, we had to clarify that this research aims to find out efficiency criteria from the urban viewpoint only, not the absolute best. Figure 2 shows the target role of the urban planner and its relevant integration with that of the transport planner.



Source: authors from previous studies [5,6,7,8,9], interviews with urban transportation experts

Figure 1. shows an inferred summary of the sequence adopted in setting transportation hubs under the global orientation for integrating transportation planning and urban planning, the research gap, and the influence of its processing and development on the model.



Source: The authors

Figure 2. The target role of the transportation planner and the urban planner in the research

5. The Methodology Adopted for Finding Criteria and Indicators

Several mutually interacting layers/groups of aspects were adopted for identifying efficient "urban criteria" for selecting locations of transportation hubs and deriving indicators as follows:

- **The first layer:** Results of overlapping between modern urban trends and the development of urban transportation, in addition to the aims of planning transportation hubs approved by urban literature – which must be achieved in planning the transportation hub layout.
- **The second layer:** Analysis of transportation hubs' keys of success for the three inferred levels regarding its development in the urban environment (as a transportation node, as a public place, as a stimulus for urban development), in addition to factors influencing new trends in transportation hubs.
- **The third layer:** Inferring points in common among theoretical literature, whether for transportation or urbanization, in the aims and criteria of selection hubs locations.
- **The fourth layer**: Inferring points of agreement and difference among global trials and practices regarding the aims and criteria of selection transportation hubs locations.
- **The fifth layer:** is the Analysis of sustainable location requirements, as stated in global assessment systems.

5.1. The First Layer: Results of Overlapping between Modern Urban Trends and the Development of Urban Transportation

This is done via introducing a relationships network that shows the time sequence of integration of urbanization with the development of urban travel to the relationships that link such transformations with new urban trends/orientations to identify the major influence areas of the current urban principles and the influence of each principle on travel transformations, as well as synchronizing such transformations and common influence areas with the development of city views/forms shown in Figure 3.

This analysis resulted in several principles concerned with urban Mobility, included in the methodologies of new urban trends, which differ in terms of goals in nature. Principles diverging from our research focus were excluded (Urban transportation).

5.2. The Second Layer: Urban Success Keys of the Transportation Hub

There are various approaches to planning and design of the transportation hub. Also, there are various levels of criteria influencing its success.

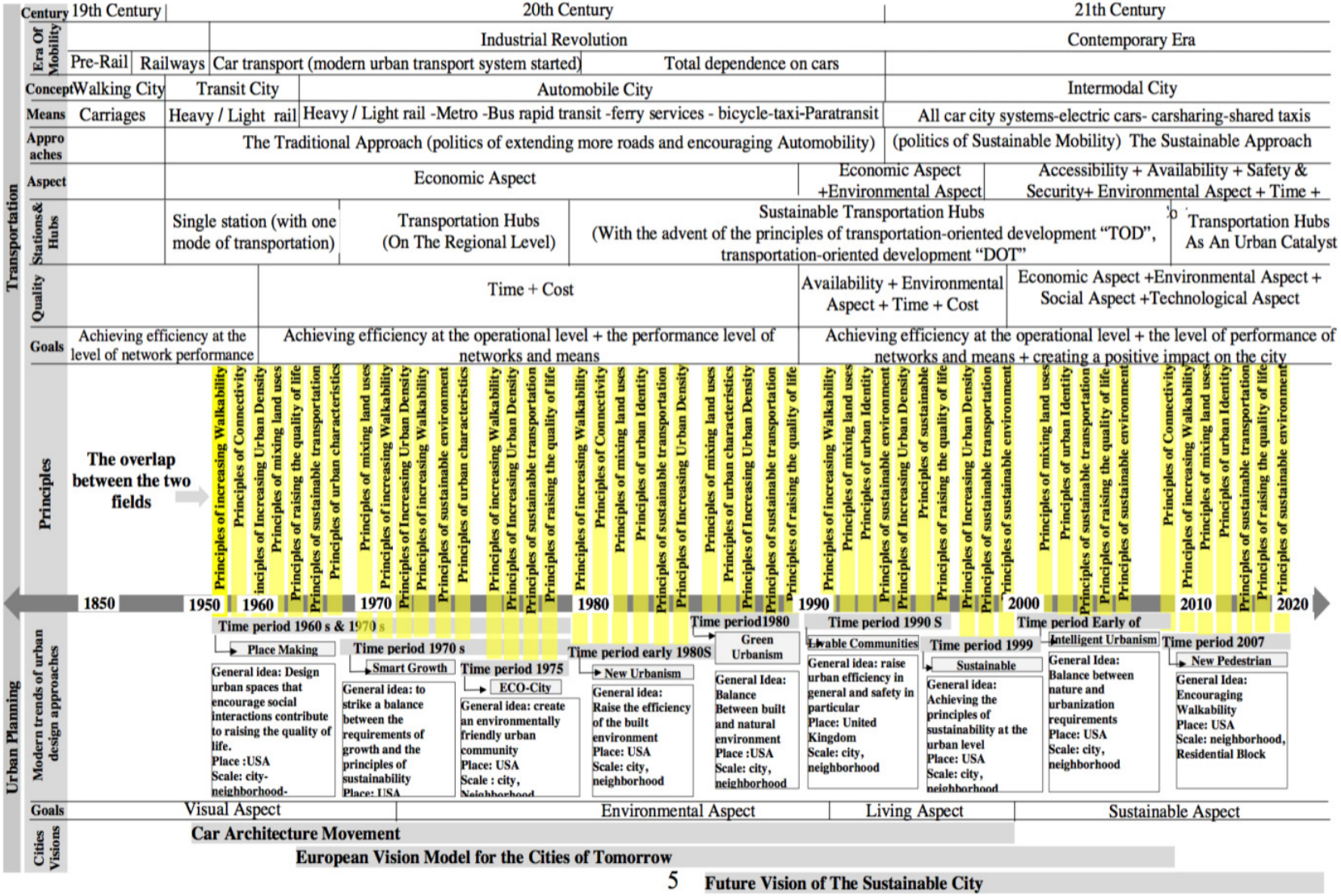
This section aims to analyse and collect the overall criteria discussed by literature needed for TH success, whether a transportation node or a place for gathering. In addition, other criteria influencing its success as an urban node positively impacting the urban surrounding will be deduced, as shown in Figure 4.

5.3. The Third Layer: Inferring Points of Agreement among Theoretical Literature in Terms of Selected Locations of Transportation Hubs

The aim is to answer questions related to the major aims to be achieved by the location of the hub and the criteria adopted by previous studies in selecting and assessing the efficiency of such locations. This point is covered through two aspects:

Transportation: Through reviewing/collecting criteria and variables introduced by theoretical literature in terms of selecting the location in transportation.

Urbanization: Through reviewing/ collecting recommendations of urban literature, guidelines, and development plans. aims and criteria of selecting hub locations; it is worth mentioning that literature specializing in urbanization that addressed this point directly is Limited and only stated aims without introducing clear indicators for measuring such criteria [20].



source authors from [10,11,12,13,14]

Figure 3. Interrelationships between urban transport transformations and modern urban trends

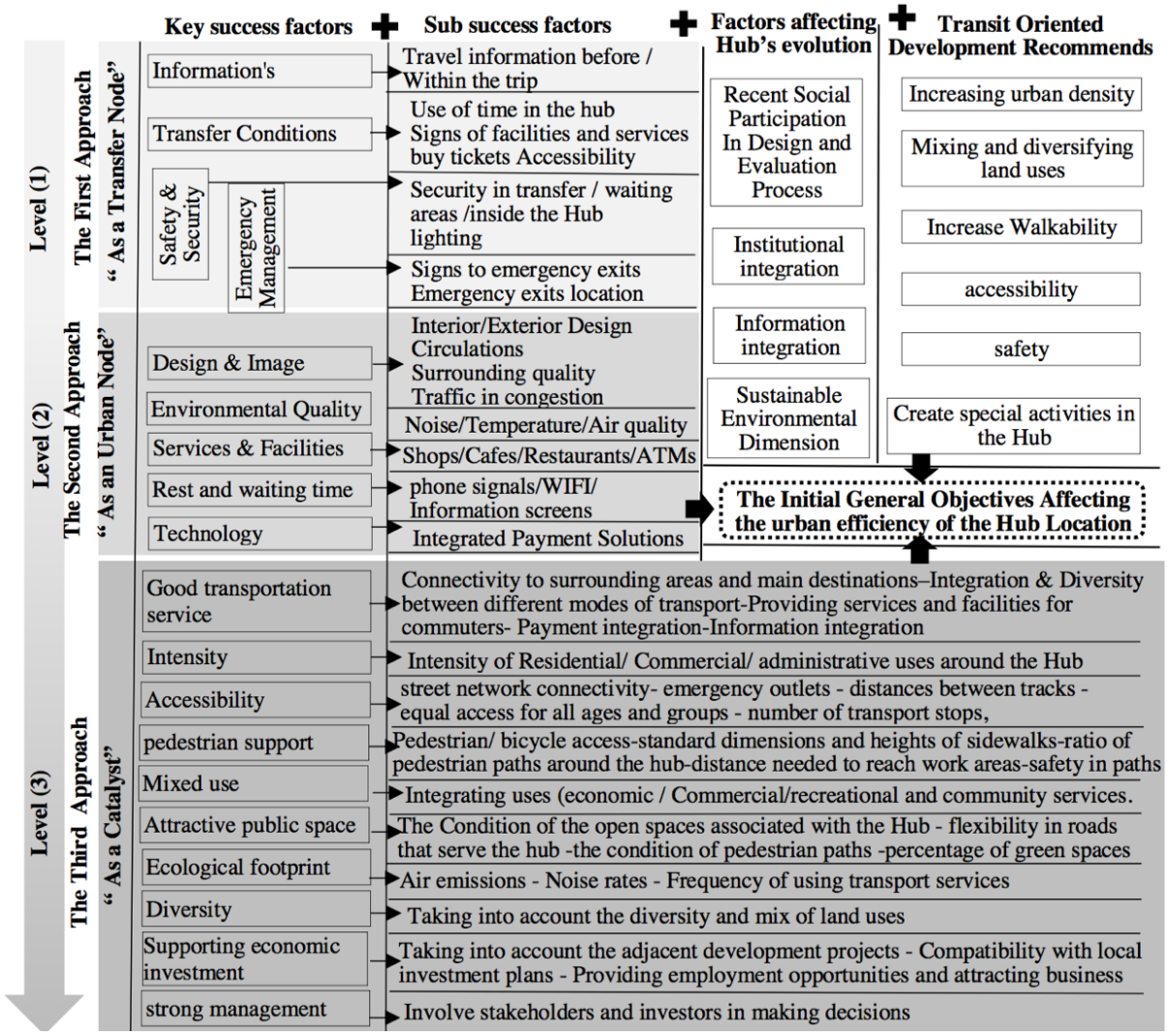


Figure 4. Success factors of the three-level interchange transport center, Authors from [16,17,18,19].

5.4. The Fourth Layer: Points of Agreement in Agreement and Difference among Practices

Analysis of practical plan recently adopted by cities for selecting locations of transportation hubs, in order to infer the aims and criteria recommended by projects – along with analysing the strategy of location assessment and selection.

5.4.1. Projects/Plans Selection Criteria

First, we have to demonstrate how limited the available plans which show the phase (location selection). Under the limitedness of such plans, a number of criteria were set for selection, including Novelty of plans, Variation of tools and techniques adopted for selecting locations, and Balanced participation of urban experts and transportation experts in planning hubs. And finally, Reports need to be issued by research centres in developed countries excelling in sustainable transportation; the study included the following cities: (New Ark, Ohio; Broward, Florida; Pinellas, Florida; Auckland, California).

5.4.2. Results and Lessons Learnt from Trials

Experience shows that not only literature but also current practices lack urban criteria. Even if such criteria exist, they would be general, not meant to specify a certain location for a transportation hub.

- There are no unanimous urban constants among trials. Constants reached (points of agreement among trials) are related to urban transportation criteria.
- Priorities of the criteria differ from one trial to another. Despite previously stating that this is a con, in terms of priorities, such difference is logical and is determined by project experts and local development experts.

Table 1. Transportation Hubs Location Selection Criteria Used in transport and urbanization disciplines

		Criteria	Indicators	sources
Transport literature	Phase1:Selection of nominated nodes	Accessibility and connectivity	Near locations of high motion flow	[5,7,21,22,23,24].
			Connected to two or more lines	
		Travel Density	The density of transportation activities in a specific network	
		Proximity	Proximity to multimodal transportation facilities/ commercial areas/ entertainment areas/ residential areas of high- density	
	Phase 2: Assessment of nominated nodes to reach a final location	Efficiency	Average weighted travel time per demand as a criterion for assessing the total efficiency of the transportation hubs network.	
		Homogeneity	Percentage of infrequent coverage of the service zone in the study network.	
		Compatibility	% of vacant land owned by the government	
		Development potentials	The potential of expanding hubs to adapt to future needs.	
		Predicted ridership		
		Transportation services	Modes of transportation in the urban area.	
		Trip generation	Location appropriateness for land uses generating trips/ activities	
Urbanization literature	**Criteria**			
	Easily accessed Areas		Proximity to two or more main traffic paths	[20,25]
	Population density		Population density across the total path length, and places of other modes stations.	
	Distances between stations		Transportation hubs are distributed over specified distances based on the type of station and city scale.	
	Proximity to main facilities/destinations		Ease/ difficulty of access to high way facilities and important destinations from the location of a certain station	
	Social effects criterion		Safety and security – the compatibility of comprehensive domestic plans – urban design integration potentials – potentials of visual sequence/integration, as well as in rim social/economic benefits.	
	Environmental impacts		Noise, air quality, water quality criteria, traffic jam reduction.	
	Possible sources of funding		Land development projects in the hub location will attract lenders and developers.	

Source: authors

Table 2. A summary of criteria recommended by the four trials / current practices

project	Specialties of project experts	nominated nodes	Assessment				Final Nodes	Ref
			criteria		technique	Accuracy		
NewAk,	Transport/economy/ civil engineering/ urban design and planning.	**3**	The availability of land/ building, Proximity to services, Proximity to existing modes of transport, The number of main destinations, Ease of access:, Expansion potentials.		Personal experience	weak	**1**	[26]
Broward, Florida	Transportation experts+ stakeholders (investors, officials, local development)	**103**	Minimum criteria	Two or more traffic roads half a mile away.	Personal experience			[27]
				Railway stations.				
				Park n' Ride stations.				
			Expanded criteria	Market assessment Recommendations of travel areas qualified, identified in the comprehensive plan of city land uses.				
				Intersection of two bus paths. Readiness of project sponsors. The possibility of benefiting from funding partnerships and execution partners in the nominated locations.				
Pinellas,	Technical Coordinating-Planners Advisory-Mobility Management Advisory)		Density (population+ labor + poverty and minority).		Appropriateness analyses through thermal maps		**6**	[28]
			Design (road density+ block size + building recessions+ density of intersections+ link to node ratio).					
			Variation (a mix of land uses + labor + value of building to land + age of structure).					
Auckland	transportation engineering planning team, School of transportation planning, California University		Reduced driving (two variables: percentage of families in each block with less vehicles than the family members and percentage of residents without vehicles in each block).		Appropriateness analyses through thermal maps	١	**77**	[24]
			Deprived residents (this includes measurements of two related groups (low accessibility. - the percentage of residents in the block from KG to 12, residents + 65 years old).					
			Resistance(priority to areas with environments of low susceptibility to different natural hazards.)					
			The potential of having new services, Density of land use					
			Potential of future growth (locations expected to grow in terms of population and labor –locations given development priority by Auckland city, and what would agree with the regional plan under the California State Senate Act project).					
			Compatibility with the current investment plans.					
			Transport connectivity (high and low transport connectivity)					
			Parity					

Source: The authors

5.5. The Fifth Layer: Sustainable Location Requirements According to Global Rating Systems

Selecting sustainable locations for different development sectors is an essential sustainability requirement. Five global rating systems for assessing neighbourhoods' sustainability performance were studied. They include: (LEED 2009 for Neighbourhood Development [29], BREEAM For communities technical guidance manual [30], CASBEE for Urban Development, Technical manual 2007 edition [31], Pearl Community Rating System, April 2010) [32].

The above systems did not include selecting the locations of transportation hubs. The following is a review of the common basic specifications of such rating systems in terms of selecting sustainable locations for development in general.

- Reviving developed locations or reusing previously developed lands.
- Accessibility to public transportation.
- Proximity to services and amenities to ensure meeting labour force needs.
- Orienting development to urban areas with infrastructure to conserve existing natural areas and avoid transgressing environmental features.
- Enhancing development on land with limited wildlife value and setting a plan to protect the existing ecological features from severe damage during site preparation and building works.

It is noticed that most specifications enhance environmental protection, reducing pollution and fuel usage, goals with a positive economic return, though seemingly environmental as a whole.

6. The Proposed Urban Criteria Influencing Selecting the Locations of Transportation Hubs

based on results reached in the above parts, and according to the research assumption that shows that selecting a hub location must depend on the more comprehensive urban view – as the research suggests that an urban expert must look at (communities, urban context, and features of the nominated plot) upon selecting hub location, contrary to the view of transportation experts which depend on the number of flows – a number of criteria and indicators were set to measure achieving location efficiency. Six major dimensions were reached, on which the urban assessment of nominated locations depends:

- Physical
- Functional
- Socio-Cultural
- Environmental dimensions
- Economic Dimensions
- Policies & Laws

Each major criterion can be divided into some sub-criteria. Each of these criteria consists of a number of indicators and variables, as shown in Table 3.

6.1. Physical Criteria

These are the urban criteria that ensure the success of the nominated location by its integration with the surrounding built environment (land use features, urban texture) and features of the plot in terms of availability and development potential.

6.2. Functional Criteria

These are the criteria that ensure the functional success of the hub, directly connected to the travel goal. Thus, they express movement features (justice in hubs distribution across the city, accessibility based on infrastructure, accessibility based on proximity to flows, collective automatic penetration, and visibility of the nominated location).

6.3. Social Criteria

These express integration among decision-makers and served communities in selecting the location that most responds to the community's needs. This is done via targeting prioritized communities with the most economical/social challenges, the location that best takes the largest number of flows, the location most achieving parity in providing transportation services, the location that best fits foreseen urban growth, and the location most compatible with the travel culture/ behavior of surrounding communities to ensure depending on more than one mode of transportation.

6.4. Environmental Criteria

These ensure achieving compatibility between spatial hub needs and the natural environment through meeting the demands of transport systems while maintaining environmentally protected areas, giving priority to the selection of locations resisting natural hazards, and reducing trespassing areas with sensitive uses to reduce the effect of noise on surrounding use.

6.5. Economic Criteria

These ensure the effectiveness of the hub in terms of cost and return, ensure supporting the economy and enhancing common development opportunities between the private and the public sectors, encourage investments in the hub, ensure the success of attached activities, as well as ensure plausibility of development costs (the possibility of new activities, current commercial productivity in the area, potential logistics costs, land value, site preparation cost, and allowing for potential expansion).

Table 3. Criteria groups: major criteria, sub-criteria, and the proposed measurement indicators, source: Authors

Dim	Main criteria	Sub-criteria	Proposed Measure		Range of References					References
					1	2	3	4	5	
Physical Features Criteria	Land Uses Characteristics C01	Mixed Uses P01	Simpson's variation index		0.00	0.1-4	.41:.60	61:.99	1.00	[33]
		Density P02	Density of uses		High		Moderate		Low	
		Graded Density P03	Clark's Graded Index		Linear Curve		Med Slope		High Slope	[34]
	Urban Pattern C02	Compactness Ratio P04	Floor area ratio (FAR) within 800 around the nominated location.		>. 5		.5		<. 5	[35]
	Parcel Availability C03	Parcel Property P05	Is the nominated location owned by the government of private property?		Private		Mixed	governmental		Authors
		Current Usage P06	Is the nominated location vacant or currently occupied by use?		Yes				No	Authors
	Parcel Usability C04	Parcel Area P07	space available for the number of Travelers to be served	> 30000/day	>65500 m^2				<65500 m^2	[36,37]
				30000:120000/day	>112750m^2				<112750m^2	
				<120000	>175000m^2				<175000m^2	
		Urban Hazards P08	Hazardous waste		yes				no	[38]
			High voltage lines within/ in 25 m around the nominated hub.		yes				no	[39,40]
		Soil P09	Location free from soil problems that would hinder development.		collapsible soil	extrusive soils	clay soil		Rocky soil	[41]
Functional Criteria	Independency C05	Hubs distribution E01	Distance from the nearest hub.		> 6.4 Km< 8				6.4:8 Km	[42]
	Infrastructure Based Accessibility C06	Site's Geo-Connection E02	Percentage of area within 400m separated by a geographic barrier to the total domain of impact.		<40%	25%:40%	10%:25%		>5%	[43]

Table 3. Continued

	Infrastructure Based Accessibility C06	Non-Motorized Permeability E03	Percentage of pedestrian networks coverage with 400 m around the nominated hub.	>90%of streets With sidewalk		90%of streets Bad side walks		90% good sidewalk	[29,30,31,44,45,]
			Provision of pedestrian crosses within 800 m around the nominated hub.	None		150m > between crossings		>120m between crossings	
			Percentage of bicycle path networks coverage.	None		< 8km bad condition		< 8km good condition	
			Average vehicle speed within 400 m from the nominated location.	< 50km /hr.		30:50 km /hr.		> 30km /hr.	[46]
			Average length of urban blocks to surrounding streets within 400 m around the nominated location.	375m		250m		125m	[32]
		Private - Motorized Permeability E04	At least two main traffic paths.	> 2		2		<2	[47]
			400 m around the nominated location free from closed ends roads.	<1				none	
			The level of services in main roads adjacent to the nominated location.	>11	12:15	16:21	22:31	32:4	[48]
			Connectivity Index.	>1.4		1.4:1.6		<1.6	[49]
			Street network density	< 10 center line mi/mi2	≥10 & < 20	≥20&<30 centre line mi/mi^2	≥30&< 40	>40 center line miles/mi^2	
			Direct Road Index	<1.5		≥1.5		1	[32]
			Density of crossroads within 800 m around the nominated hub.	<200	≥250 &<300	≥300&<350	≥350& <400	≥ 400	[50]
	Facility Based Accessibility C07	Proximity E05	Average number of weighted flow attractors/generators near the nominated location (within 400 m). $C_p = \sum_{k \in K} wk.n_k^a / \sum_{k \in K} wk$ (1)	k=Location no K=Nominated Locations wk =Total Flows no that reach nominated location(Trips) n^a_k = Generators count within 400 m aroung nominated location.					[5]
				Low Value				High Value	

Table 3. Continued

	Mass Transit Permeability C08	Variety of connectivity opportunitiesE06	No of modes (train station/ ferry station / Metro station/Bus stations) within 800 m from nominated location.	> 2 modes		2 Modes		< 2 Modes	[51,52]
		Frequency E07	The number of buses stopping at the bus stop on a daily basis within 800 m.	≥4 Buses/hr.		4:10 Buses/hr.		10:30 Buses/hr.	
		Transportation Planning E08	Number of transportation lines connected to and intersecting at the location**.**	>2 (Local)		2(Local+ express)		<2 (Local + express)	[5]
	Clarity C09	Visibility E09	Viewshed analysis (Digital elevation model)	Low Value				High Value	[53]
			Proximity to traffic volume	Low				high	
Social Criteria	Priority Communities C10	Income Level S01	Percentage of leased houses to the total houses in the area.(Measuring tenure mix) The equitability index. (Owner occupation Social renting. Private renting). $EH = \frac{-\sum_{i}^{s}=1 piInpi}{InS}$ (2)	i = the tenure category S = the total number of tenure categories Pi = the proportion of the tenure category i relative to the total number of tenure categories					[54]
				0				1	
			The Ratio of public housing projects to private dwellings. The index of dissimilarity $D = \frac{1}{2}\sum_{i=1}^{N}(\frac{gi}{G} - \frac{Pi}{p})$ (3)	gi = local government housing of the ith area G =total local government housing of the large geographic entity for which the index of dissimilarity is being calculated. pi = the private dwellings of the Ith area P =total private dwellings of the large geographic entity for which the index of dissimilarity is being calculated					[55,56]
				<70				≤ 70	
			Percentage of low-income families.	High value		moderate value		Low value	[24]
		Physical condition S02	Percentage of inhabitants suffering from physical disabilities.	Low value		moderate value		High value	
		Inhabitant Density S03	The average number of individuals per area, within 800 around the nominated location.	>100 Person/ Acres		100 : 150 Persons/ Acres		< 100 Persons/ Acres	[57]

Table 3. Continued

Social Criteria	Priority Communities C10	Overcrowding Average S04	The number of persons per room.	>1.5 Person/ Room		1.5 : 3 Persons/ Room		< 3 Persons/ Room	
	Low automobility C11	Travel Behavior S05	The percentage of families having vehicles less than the number of individuals, within 800 around the nominated location.	High value		moderate value		Low value	[24]
			The percentage of families without vehicles, within 800 around the nominated location.	Low value		moderate value		High value	
		Age S06	The percentage of families with less than 18 years old/students, within 800 around the nominated location.	Low value		moderate value		High value	
			The percentage of elderly citizens (+65), within 800 around the nominated location.	Low value		moderate value		High value	
	Social Acceptance C12	Displacement S07	Locations nominated which require relocating some families if selected	Requires		moderate value		Does not require	Authors
		Expropriation S08	Nominated locations which require expropriation upon selection.	Requires		moderate value		Does not require	Authors
		Awareness & Culture S09	Percentage of people who= think multimodal transportation is urgent in many aspects.	High value		moderate value		Low value	Authors
			Percentage of smart phone users.	None	<90%Smart Phones		<90%Smart Phones +internet		[57]
		Participation S10	Providing methods of community consulting in location selection.	Not Available				Available	[31]
			Impact of community consulting on location selection	Strongly Disagree	Disagree	Neither	Approves	Strongly Agree	
	Safety & Security C13	Human Hazards S11	Crime percentage in areas surrounding and leading to the nominated location within 800 m, in the last five years.	High value		moderate value		Low value	[51]
			Accident rate in areas surrounding and leading to the nominated location within 800 m, in the last five years.	High value		Moderate value		Low value	

Table 3. Continued

Social Criteria	Safety & Security C13	Risk ManagementS12	Distance from nominated location to evacuation roads/points within the city.	<1000	500& ≥1000	250&≥500		≥250	[31]
	Population growth rate C14	Demographical Changes S13	Average annual change in population size in a specific period. GR = 100 ln (P2 /P1)/(t2 -t1)	P1& P2=the population at times t1 and t2, and the time interval (t2-t1) is expressed in years.					[58]
				High Value				Low Value	
Environmental Criteria	Natural Resources Protection C15	Land cover V01	Percentage cultivated cover of the nominated location.	<50%				not cultivation	[59]
		Protected Areas V02	Exclusion of locations within protected areas.	Within 50 m precinct				Out of 50 m precinct	
	Resilience C16	Location free from natural hazards V03	Percentage area susceptible to floods sanctuary(in a specific time domain) to the total location area.	within floods sanctuary			Away from floods sanctuary		[60]
			Percentage area susceptible to earthquakes (in a specific time domain) to the total location area.	within the earthquake belt			Away from earthquake belt		
	C17 Sensitive Land-Uses	Relationship to sensitive useV04	Is there any sensitive uses adjacent to the nominated location(schools, hospitals)	yes				No	[61]
Economic Criteria	Potential of new activities C18	Expenditure on public Transport E01	Transport costs percentage of the average income	High value		Moderate value		Low value	[24]
		Development Mix E02	the ratio of Employment to Population + Employment.	> 0. 5		0. 5		< 0. 5	[62]
		Community Variety E03	Variety of potential travelers of the hub (inhabitants within 800m), culturally and professionally and in terms of age	Low value		Moderate value		High value	[24]
	Current commercial productivity C19	Competitiveness E04	Density of commercial activities (medium – small) within 800 m.	Low Value		Moderate value		High value	[63]
			Proximity of location to large markets, within 800 m and outside.	High value		Moderate value		Low Value	
	Logistic expenditure C20	Ease/difficulty of transporting products E05	Distance to distribution warehouses in Km.	High value				Low Value	[53]
			Distance to distribution centers in Km.	High value				Low Value	

Table 3. Continued

	Land Value C21	Land Value E06	Average land price in the area (per sqm2).	High value				Low Value	[63]
	Site setup cost C22	Parcel Topography E07	Percentage of inclination (ramps) in the nominated parcel.	<40%	26%: 41%	15%:25%	15 %	>15%	[29,53]
		Proximity to existing Infrastructure E8	Infrastructure (electricity, water, internet, sanitation) available within 200 m, in a condition that would serve the entire hub	Not available		Available In Bad condition		Available in Good condition	Authors
	Expansibility C23	Flexibility E09	Percentage of vacant land connected to the nominated hub CD=Flexibility criterion $CD = \sum_{k \in K} w_k \cdot (A_k^e / A_k^p) / \sum_{k \in K} w_k$ (4)	w=total passenger flows expected. Ak= additional land available to expand the center (km2) Apk=current candidate site(km2)					[5,7]
				Low Value				High value	
Regulatory Criteria	Integration with the/comprehensive plan C24	Policies & locations of urban development L01	City locations expected to grow in terms of population and jobs.	un compatible				compatible	Authors
			Locations included in city development plans for redevelopment priority, in agreement with the regional plan and strategies for sustainable communities.	uncompatible				compatible	Authors
			Spatial compatibility of the nominated hub with recommendations of travel areas qualified, specified in the comprehensive plan of city land-uses.	uncompatible				compatible	Authors
	Conservation of /valuable lands C25	Urban conservation policies L02	Nominated hub Spatial compatibility with Regulations of the National Organization of Urban Harmony for addressing historic locations, valuable areas	uncompatible				compatible	Authors

6.6. Political and Legal Criteria

These express compatibility with domestic laws and comprehensive development policies in selecting a hub location. In other words, they ensure investors and governmental support in selecting the location.

7. Benchmarking Indicators

After introducing the main and sub-criteria and measurement indicators, it is also important to identify how to measure such indicators and find out benchmarks at which the result – reached by measuring the indicator- can be assessed.

The problem is how to transform the result of assessing quantitative and qualitative indicators into numerical values that can be added or compared. Among these indicators, there are quantitative and qualitative indicators with different measuring units.

Further, each indicator has one or more measuring tools, which makes the problem harder.

The last part of Table 3 presents assessment tools for measuring urban efficiency indicators used for selecting the locations of transportation hubs. This is done depending on the existing methodologies, references, case studies used in designing such tool/ indicator, laws and regulations used for tool reference and, last, points/ marks of the assessment tool (from 1 to 5).

8. Quality Assessment of the Proposed Criteria

This step is done via experts in urban planning and transportation and academic planners, Using a questionnaire to ensure the efficiency of the proposed criteria, correct defects (if any), and reformulate the same.

Questions aiming to measure how far the verbal expression of the main criteria expresses the content of relevant sub-criteria; as well as the clarity, importance, efficiency, and sufficiency of the proposed criteria for each of the six proposed main criteria groups; the questionnaire ends with a question about the overall satisfaction with the proposed criteria, and the appropriateness of such criteria for application to any given city, as well as the sufficiency of the introduced indicators for measuring criteria.

8.1. Analysis of Questionnaire Results

Questionnaire respondents were 38 academic experts in Egyptian and foreign universities and research centres. Table 4 shows the analysis of the participating experts.

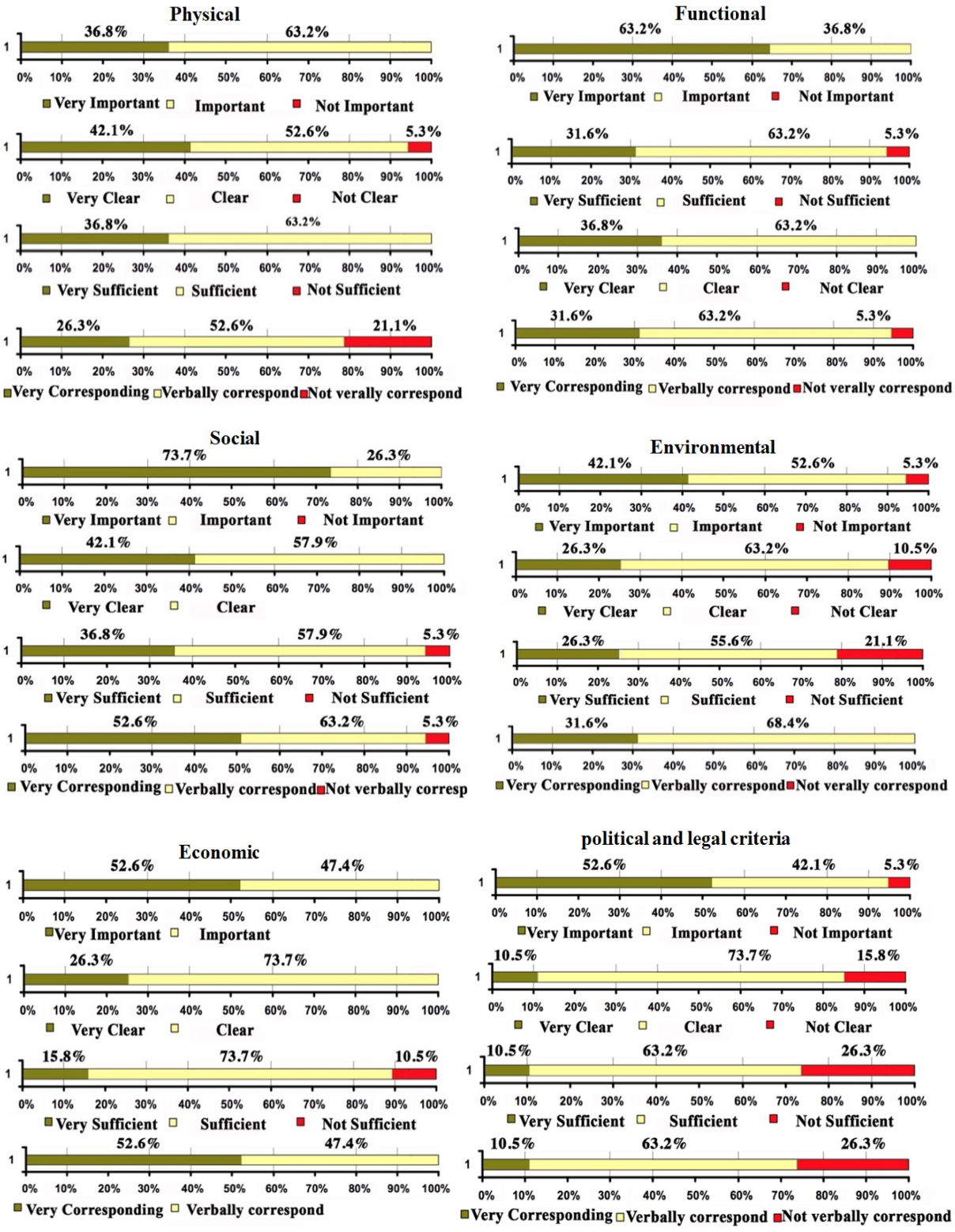
8.2. Efficiency of the Proposed Criteria

The Majority of answers stressed that the verbal nomination of the criteria ranges between "very much correctly expresses" and "correctly expresses" criteria under the same, and the proposed criteria are Either "Very Clear" or "clear" they Majority of answers also range between that the proposed criteria "Very Stuffiest", "sufficient" and "Very Important and "important." Figure 5 shows detailed results of expert answers regarding the efficiency of the proposed criteria.

The experts, who thought the criteria were insufficient, proposed the noise criterion to complete the environmental criteria. This proposal was taken into account, and the criterion was added. The experts, who thought the criteria were insufficient, proposed the “Compatibility with transportation plans and policies” criterion to complete political and legal criteria. This proposal was taken into account, and the criterion was added.

Table 4. Analysis of the samples of participating experts in the Criteria Quality Questionnaire, source: Authors

Degree		Age		Experience		Specialty		Affiliation		Nationality		Sex	
PhD	10	30-40	2	15-25	20	Urban management	6	Universities	20	Egyptian	34	Male	20
Assistant Professor	12	40-50	20	25-30	8	Urban planning	10						
						Traffic&transportation	6						
Professor	16	+50	16	+35	10	Site planning	6	Research centres	16	Non Egyptian	4	Female	18
						Urban planning	18						
						Sustainable environmental planning	4						



Source: Authors

Figure 5. Part A, B, C, D, E and F, Expert answers regarding the efficiency of the proposed criteria

8.3. Result of the Overall Assessment of the Proposed Criteria

The majority of experts stated that the proposed criteria are very good. Figure 6 in Appendix II shows the detailed results of expert answers regarding the overall assessment of the proposed criteria.

8.4. Appropriateness of Criteria for Application to Any Given City

The majority of experts stated that the proposed criteria are applicable to any given city. Figure 7 in Appendix II shows the detailed results of expert answers regarding this part.

8.5. Sufficiency of the Introduced Indicators for Measuring Criteria

The majority of experts stated that the proposed indicators are sufficient for measuring criteria. Figure 8 in Appendix II shows the detailed results of expert answers regarding this part.

9. Transportation Hub Urban Locating (THUL) Model/Tool Development

After finding the major and sub-criteria that impact TH location selection, it should be known that assessment alone – via measuring individual criteria – may not be taken, using the proposed criteria for measuring or by addressing each criterion individually. Rather, such criteria must interact with other criteria.

The measurement method alone is not sufficient, but the mutual relationship with other criteria, weight and order among criteria, and the view of decision partners – particularly urban professionals. Each is interested in a single group of criteria, which they find more influential than others in making the optimum decision regarding the transportation hub location. Therefore, we need an appropriate method for building a model for addressing this complex system in terms of factors and the hierarchical order of variables.

Transportation Hub Urban Locating (THUL) Model development is a process that depends mainly on the six aspects inferred in the previous sections, in addition to a multi-criteria decision- making (MCDM) process, which is quite useful in reaching decisions and selections that cannot be directly determined [64].

It consists of different strategies used on a large scale in the previous decades. It can be applied in different fields and disciplines. It can be included in decision finding and structuring and the design of multi-criteria cases. Here, the analytical hierarchy process (AHP) was adopted as the most common tool used in making multi-criteria decisions and the most appropriate for application herein.

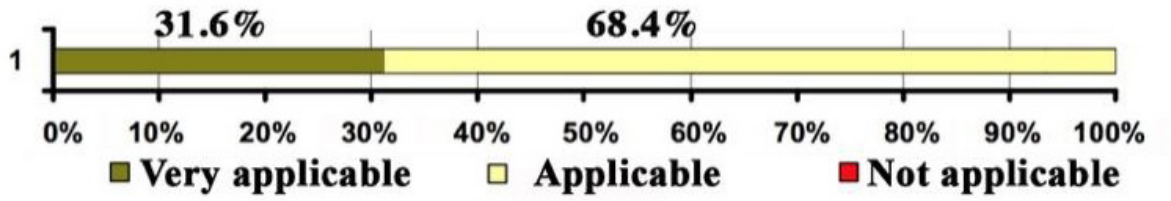


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Figure 6. Results of the overall assessment of the proposed criteria

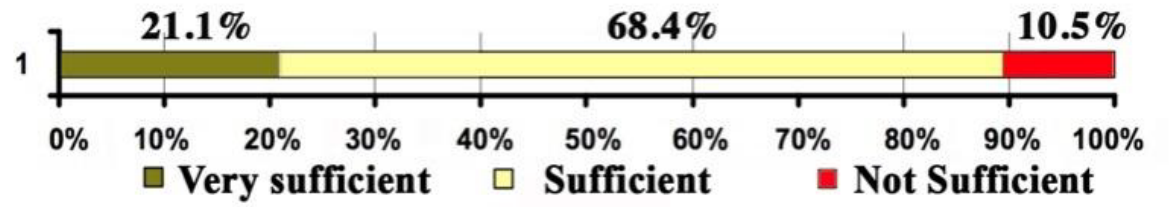

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Figure 7. Results of the appropriateness of criteria for application to any given city

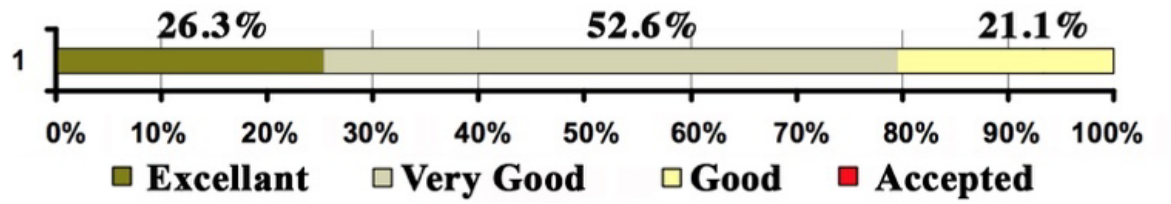

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Figure 8. Experts answers regarding the sufficiency of the introduced indicators for measuring criteria

9.1. Model

After determining the final group of hub location selection criteria and indicators, a THUL assessment model can be developed. Figure 9 shows the main phases of developing the proposed THUL tool. The figure presents each tool, relevant steps, and anticipated results. The assessment methodology comprises four main steps,

- **The first step:** The hierarchical structure of the decision problem.
- **The second step:** Finding the relative weights of the criteria.
  - Expert questionnaire of pair comparisons.
  - Computing questionnaire results.
- **The third step:** Benchmarks and indicators measurement toolbox.
- **The fourth step:** Results of the assessment model.

9.1.1. The First Step: The Hierarchical Structure of the Decision Problem

The first step of the model is to build a hierarchical structure for the decision problem [65]., as shown in Figure 10. The first level represents the aim to be achieved "Selecting the best TH location in urban terms." The second level represents the six urban efficiency dimensions influencing location selection which, in turn, include 27 main criteria. The third level presents the sub-criteria forming the main criteria. Finally, the fourth level presents decision alternatives.

9.1.2. The Second Step: Finding the Relative Weights of Criteria

This step aims to find the relative weight of each node (criterion) compared to other criteria using AHP.

It should be clear here that the proposed measuring model and weights of criteria used therein can be applied to any given city because the priorities and weights of criteria were drawn from a wide group of experts in different disciplines. The exception here is regions/ cities "of special nature." This is because priorities and weights of criteria will differ completely. For example, if a city has a history of natural disasters (earthquakes, high sea level, etc.), as well as other hazards which largely impact location selection; this would dictate adopting the proposed criteria due to agreement on their applicability – but another group expert needs to be formed. It should be noted that experts here will be selected according to the region assessed, and relative weights will be set to match the nature of the city being studied.

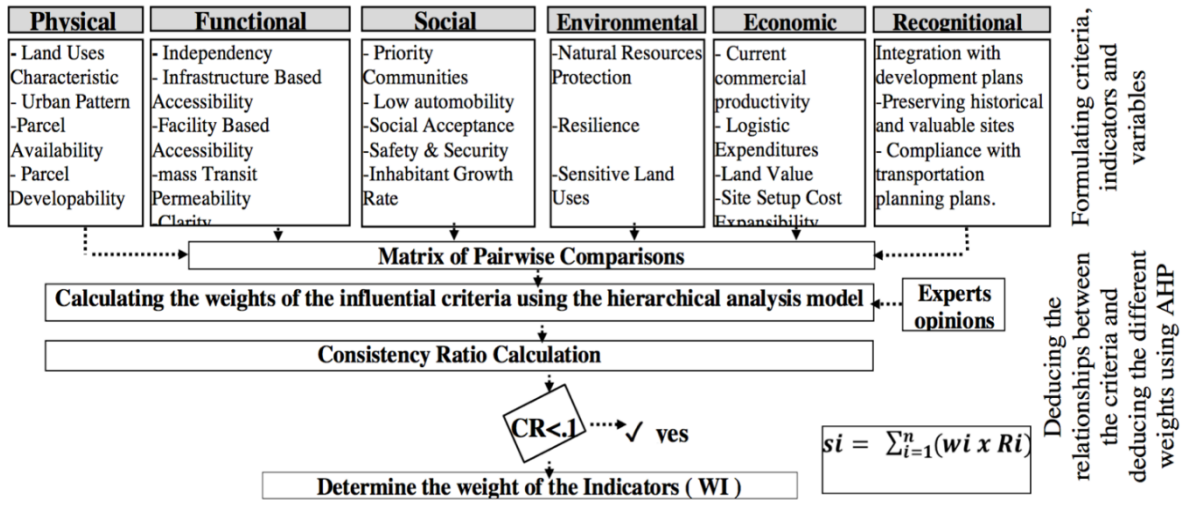

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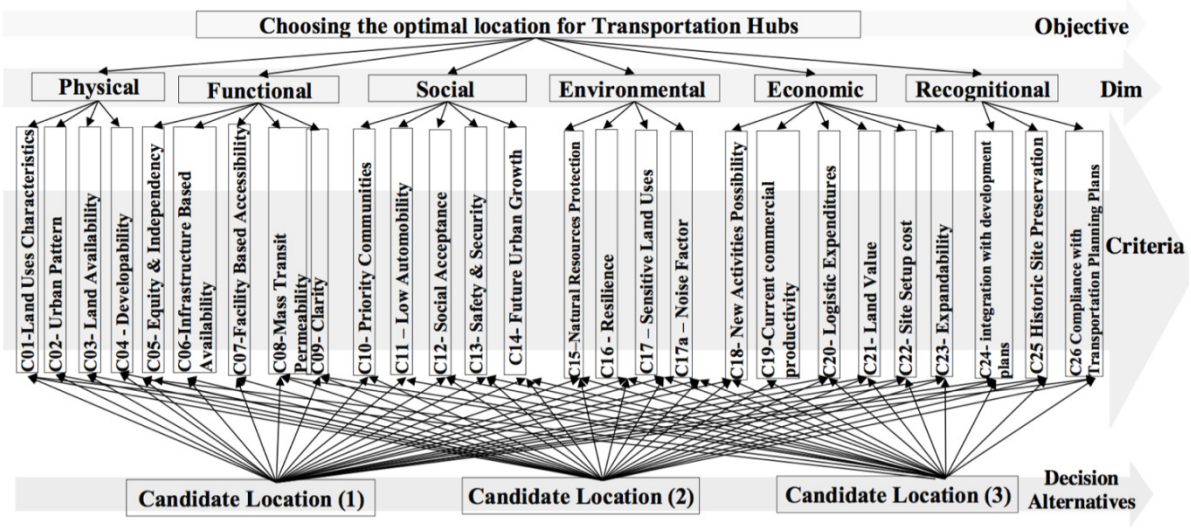
Figure 9. shows main phases of developing the proposed THUL tool



Source: Authors

Figure 10. Hierarchical structure for the decision problem

Table 5. Analysis of the samples of participating experts in Ahp Analysis Questionnaire, source: Authors

Degree		Age		Experience		Specialty		Affiliation		Nationality		Sex	
PhD	10	30-40	2	15-25	20	Urban management	6	Universities	20	Egyptian	34	Male	20
Assistant Professor	12	40-50	20	25-30	8	Urban planning	10						
						Traffic &transportation	6						
Professor	16	+50	16	+35	10	Site planning	6	Research centres	16	Non Egyptian	4	Female	18
						Urban planning	18						
						Sustainable environmental planning	4						

Expert Questionnaire

Two types of questionnaires were introduced; they consist of several questions for comparing decision item pairs used to study preferences for forming the design decision basis [66]. Experts are required to assess the importance of two items relative to each other through the Fundamental Scale of [Saaty, 66] or the Semantic Differential Questionnaire.

- **The Clusters Questionnaire:** Comparison is expressed through judging sub-dimensions relative to a third one.
- **The Nodes Questionnaire:** Judgment is based on the importance of two indicators for the same criterion.

There were 30 questionnaires completed by academic personnel in universities and research centres. Table 5 shows an analysis of the participating expert sample.

9.1.3. Computing the Relative Weights

AHP technique uses questionnaire results to identify relative weights of criteria in each level. To facilitate AHP calculations, the Super Decision Making software was used to calculate and merge relative weights of decision items and then analyze outputs.

Expert priorities were identified for each dimension, in addition to the weight of each criterion.

Further, the program measures the consistency ratio (CR), which helps determine possible errors and contradictions in judgment. The CR must be less than 0.1 to be reasonably consistent [65]. If any matrix provides a rejected CR value, the participant must be excluded. In conclusion of this step, expert priorities regarding the features of TH locations were determined. These priorities represent a number of potential criteria for decision-makers and urban planners during the selection of the optimum TH location.

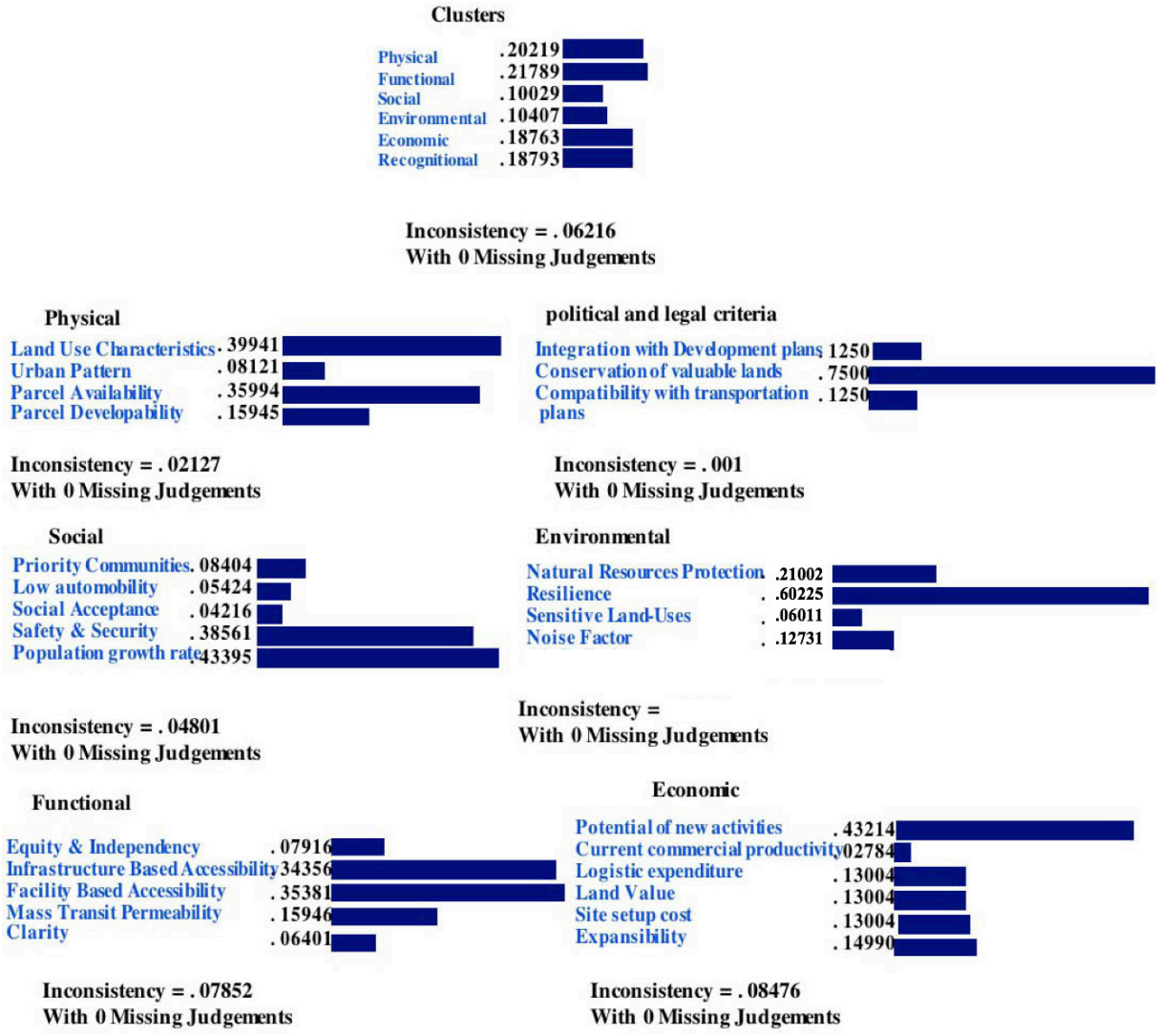


Figure 11. The priority of each dimension with respect to the main objective (Experts preferences)For (Clusters), and The priority of each normalized indicator with respect to the importance of the dimension to which it belongs (Nodes), Source: Author

9.1.4. Result of the Assessment Model

After finding the relative weight of each indicator using the AHP method, the assessment methodology for each location – nominated as a transportation hub- adopts a few steps;

1. Calculating each indicator through its own measurement tool.

If more than one proposed tool exists for measuring a specific indicator, the average value of the tools must be taken. For example, if the toolbox of one indicator has four tools, the total value of such tools must be divided by four; if it has two tools, the total value must be divided by two.

2. Taking the average value of the measurement tools.
3. Multiplying the result reached for each indicator by the relative weight of each (AHP priority).
4. Calculating the total values reached.

10. Conclusion and Discussion

The results showed the ability of the model to evaluate each of the sites nominated to be a transportation hub based on the preferences of urban experts and urban planners based on a set of comprehensive dimensions affecting decision-making to ensure the completion of the mutual review process between the transport planner and the urban planner in a balanced manner in making the optimal site decision Interchange Center.

The proposed model also made it possible to explore the interrelationships between the criteria affecting decision-making, as the proposed indicators for measurement took into account the combination of stakeholder preferences represented by urban experts and transportation experts through physical, functional and environmental criteria, meeting societal needs, achieving societal acceptance through social criteria and taking into account the priorities of investors Through economic

standards and compliance with government trends through political and legal standards.

The model also takes into account that each set of criteria has a relative weight affecting the decision, where the set of functional and physical criteria came at the top of the priorities for experts, followed by the set of economic and political criteria, followed by the set of environmental criteria and social criteria. In addition, each sub-criterion has its relative weight and its arrangement within the main set of criteria, and Settlement is done by dividing the priority value for each criterion's goal (within one feature)by the grand total of all priorities, in terms of criteria goals falling under the same feature In order to ensure the accuracy of the evaluation and comparison for each proposed site.

It is recommended that the model be further developed to include reaching not only the hierarchical relationships between the sub-criteria within one major set of criteria but also the network relations between each sub-criteria within the set of major criteria with all other sub- criteria.

11. Recommendations

Good management of the stakeholders involved in decision-making:

Due to the intertwining of the parties involved in the decision-making, their priorities in deciding to choose the site differ according to the objectives and background of each party:

The research assumes that choosing a location is a joint decision where stakeholder participation reduces conflicts, leads to better planning outcomes and, most importantly, allows communities to influence the future shape of the places in which they live. It is the responsibility of the planner, in this case, to create compatibility between all these parties while achieving the overall urban efficiency of the site, and it is necessary to take into account these differences to choose the appropriate stakeholders, as well as to choose the best way for the participation and management of stakeholders. The research also recommends taking into account the diversity in the different functional areas of the participating parties; They can be summarized as follows:

Society: They are the primary stakeholders who are directly affected by the existence of the hub.

- Governmental bodies: as the executive force the expertise to implement the hub.

Investors: They are those who have an influence on the implementation of decisions or have an interest in the case.

- Non-governmental organizations.
- Continuous follow-up after the site selection process and project implementation: The research recommends issuing a quarterly report for each implemented transport exchange centre that includes the development of the activities surrounding the site and the expansion of the area in order to monitor the extent of change resulting from the presence of the hub and the success of the site selection and evaluation of its suitability.
- Introducing laws regulating the relations between the exchange transport hubs and the urban environment.

The research recommends the development of laws to regulate spatial relations between the various hubs and uses, which take into account the requirements of the building area, urban conservation policies, and the environmental impact of the presence of the hub.

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The Authors declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere.

The Authors Also confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed.

The authors declare that they did not receive support from any organization for the submitted work.

Conflict of Interest

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts.

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