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PATH CYCLABILITY ASSESSMENT INDEX MODEL USING DECISION TREE MAKING METHOD: A CASE OF DOHA-QATAR

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Abstract: Transportation is the major contributor of ever-increasing CO_2 and Greenhouse Gas emissions in cities all around the world; while the number of vehicles is rapidly growing. Growing concern on reducing transportation hazardous emissions and securing energy sources has led to New Urbanism and Smart Growth policies declarations. The urban and transportation professionals are attempting to develop innovative techniques to change people's travel mode selection to less energy-intensive modes, particularly, cycling. The current research has developed an urban index assessment model evaluates and analyzes cyclability of path segments in association with residents' decision making in cyclable route selection, called Path Cyclability Assessment Index (PACEX). The model was developed based on decision-tree-making (DTM) method to measure the qualitative data quantifiable. The model involves ninety (90) physical and environmental cyclability variables clustered into three layers of decision-tree-making (Layer 1: Features, Layer 2: Criteria, Layer 3: Sub-criteria). Although the model is applicable in any neighborhood, this research was implemented it in Doha, Qatar where specially needs for hosting FIFA 2022. The analysis result shows the sub-criterion F1.C1.S2 Existence of Crossing mostly affects to neighborhood cyclability (24.25%), in contrast, the sub-criterion F1.C3.S7 Street Surveillance affects least (4.82%); and overall neighborhood was ranked as grade B of cyclability ranking. The model supports both personal and society needs, preferences, and priorities of cyclable environment design and development. Using this model contributes to less energy consumption, less CO_2 and GHG emissions, less street fatalities and accidents, simultaneously, promotes public health. Juxtaposing using the PACEX model aids decision makers and policy makers in sustainable urban development in prioritizing the allocation of resources for development and/or redevelopment of the area concerned.

Keywords: *Transportation, Low-emission urban development, decision tree making, path optimization, traffic congestion*

1.0 Introduction

Transportation is the major contributor of ever-increasing CO_2 and Greenhouse Gas (GHG) emissions in all the major cities in the world. IEA (2004) reports that transportation accounts for almost 70% of global energy consumption, produces almost 70% of GHG emissions, and is responsible for 23% of all energy-related CO2 emissions. Transportation (21%), after the power-generation sector (42%), is the predominant contributor in CO_2 emission reductions (in the 2°C scenario) in the world followed by industry (18%), and Building (12%) (Figure 1). The number of vehicles is anticipated to triple by the year 2050 worldwide (World Hydrogen Energy, 2010). According to EIA (2013), “the countries need to reduce the overall CO_2 emissions by at least 40% between 2005 and 2020”.

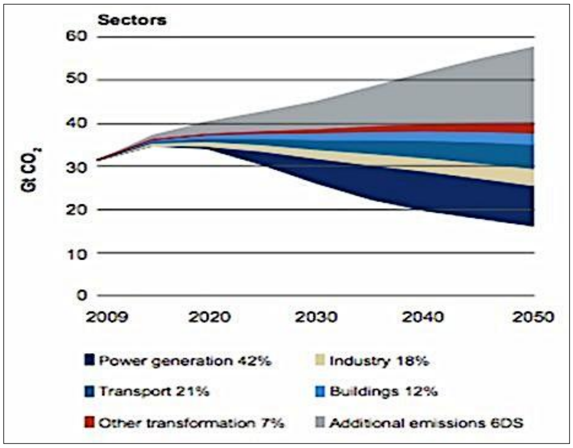

Figure 1: Global contributions to CO_2 emissions reductions in the 2°C scenario, by sector (Source: Energy Technology Perspectives, 2012)

Growing concern on transportation emissions and energy security has led to many policy declarations and innovative techniques to over the past decade (Mikalsen *et al*., 2009). Urban and transportation professionals need to change the traditional ways of urban design and planning to reduce the need for travel as much as possible; for instance, through compact and dense city designs to reduce the need for motorized-modes of travel and, simultaneously, to increase accessibility to urban facilities. They need to encourage people to change their travel behavior and to switch to less energy-intensive modes of travel—e.g., to walking and cycling. The cycling strategy contributes to less energy consumption, less CO_2 and GHG emissions, and simultaneously, fewer road fatalities and accidents in cities (american Society of Landscape Architecture, 2009). Vice President and Director Bruce Katz states Cities are good for cycling because of their inherent complexity and density (american Society of Landscape Architecture, 2009).

According to the Nationwide Personal Transportation Survey (NPTS), bicycling produces multiple potential benefits, both for the individual and their community, and there is a great potential to increase the number of trips taken by bicycle. By taking advantage of the opportunity to convert short automobile trips to bicycle trips, the City can reap enormous benefits in terms of improving the physical health of residents, reducing the negative environmental impacts of auto emissions, and lowering traffic congestion. A National Bicycle and Pedestrian Clearinghouse technical brief (1995) notes that the American public saves from 3 to 14 cents for every automobile kilometer (5 to 22 cents per mile) displaced by walking and bicycling due to reduced pollution, oil import costs and costs due to congestion, such as lost wages and lost time on the job. Bicycling and walking are environmentally clean modes of transportation, requiring no fossil fuels. Errands around town often consist of several short trips within a few blocks of each other, requiring an automobile to be turned on and off, emitting excess exhaust. Bicycle trips produce no air pollution, reduce road congestion, and often take less time, especially if convenient bike parking is provided. In fact, Traveling to destinations by bicycle instead of by car has many benefits by (Rockville City Government);

- Creating cleaner air
- Conserving energy
- Creating safer streets
- Reducing traffic noise
- Serving as a low-cost form of transportation
- Taking up less space on roadways and in parking lots
- Providing an excellent form of exercise

To address health and other policy concerns, policy makers and professionals are looking at ways to increase the use of walking and bicycling for everyday travel. While most of the focus on "active living", walking and bicycling may have a greater potential to substitute for motorized vehicle trips because of its faster speed and ability to cover greater distances. Bicycle commuting has been proved to be an activity system that is recommended at a certain intensity levels in order to lower the rate of overweight and obesity. The potentiality of bicycling as a transportation mode has been recognized nationally through objectives to raise bicycling rates and to significantly increase funding for new urban infrastructure. Several cities have also adopted aggressive policies and programs to increase bicycling. In fact planning for human powered movement is contextually sensitive, so no one solution is appropriate for all locations.

To achieve above-mentioned benefits, the current research aimed to develop an index assessment model for measuring the urban development success in providing cycling infrastructure facilities. The research planned to develop Path Cyclability Index

Assessment Tool that aids urban and transportation planners in optimizing each path's (i.e. street and junction) cyclability index score. Through understanding the Index scores of all paths within the urban area, the urban and transportation planners can make intimate and precise decision for budget management on cycle infrastructure development/redevelopment.

2.0 Urban Cyclability

The Urban Design Handbook (Gindroz and Levine, 2002) suggests that the fundamental elements of New Urbanism and Smart Growth, as defined by the CNU, are the bases for a sustainable neighborhood. New Urbanism and Smart Growth are advocating an energy-efficient and pedestrian-oriented environment that permits people to choose cycle more and drive less. New Urbanism and Smart Growth constitute a number of principles that can be applied increasingly at different scales, from micro-scale (i.e., single path) to macro-scale (i.e., entire urban area). The New Urbanism's walkability principles include sustainability, quality of life, connectivity, mixed-land uses and diversity, quality architecture, quality urban design, smart transportation, urban compactness and density.

These needs approach to a creative thinking which come up with a suitable plan for cyclable city development. To date, there are global ideas in cyclable city development. For instance, the Elevated Bike Lanes is a proposal to supplement Toronto's major transit axis. These lightweight covered lanes would allow cyclists to travel across the city unimpeded by traffic lights or adverse weather conditions. The design also makes use of solar paneling to power the street lighting, which is integrated into the supporting columns. In a still experimental phase, a titanium dioxide-coated fine mesh canopy would stretch over the entire street and extend over most of the sidewalks as well. This canopy would use a thermally-activated wicking system to prevent snow from accumulating on the street, eliminating the need for fossil fuel intensive snow removal machinery and eventually allow these thoroughfares to become restricted to emission-free vehicle usage, and particularly, provide the suitable paths for cycling.

A basic bike lane consists of a white stripe to physically separate motor vehicles and bicycles with painted bike symbols, and arrows to signify the purpose of the lane. Since bike lanes allow cyclists to have their own designated space on the road meaning that slower-moving bikes will not impede the flow of motor vehicle traffic thus debunking one of the opposition's key myths. Lanes are recommended for streets with a posted speed limit higher than 40 kl/h. They are appropriate for all types of riders – both experienced and novice. (Bike Education, 2011).

Benefits of bike lanes summarized from the NACTO design guide:

- Increased comfort, confidence, and predictability for cyclists, allowing for even novice cyclists to feel comfortable using them
- Spatial separation between bikes and cars
- Increased capacities for motor vehicles, as the bikes, in their own space, do not slow cars down
- Increased awareness of a cyclist's right to the road. (Bike Education, 2011)

There is a number of Bicycle Facility Types:

I) Off-Street Cycle Paths: Off-street cycle paths provide 2-way bicycle travel completely outside the carriageway of the road. These may be located adjacent to the road (within the ROW), or may be completely separated facilities within a park, along a waterfront, or along a linear corridor such as a power line corridor. Off-street bicycle paths can be "shared-use" (used by both pedestrians and cyclists use the same path space) or segregated (separate spaces delineated for pedestrians and cyclists). Cycle paths offer the highest degree of separation between cyclists and motor vehicles, but can result in conflicts between cyclists and pedestrians and joggers on facilities where shared use is allowed. Bicycle paths should be a minimum of 2.5 m wide if bicycle volumes are low, but are recommended to be at least 3.0-3.5 m wide if bicycle volumes are high or if the facility is to be shared with pedestrians, joggers, in-line skaters, or other users. In Qatar, cycle paths are seen as the most appropriate type of facility for recreational use, particularly for less experienced cyclists. These facilities can be installed along corniche areas, within parks, and along other linear corridors, and should link together to provide opportunities to ride long loop routes. On corridors more transportation oriented, it may be also appropriate to provide for a single cycle path on one side of the road rather than one-way cycle tracks, if there is less need for access on both sides of the road (Figure 2).

Figure 2: A shared-use off-street path, with the same space (Source: Google)

II) Separated cycle tracks: Separated cycle tracks refer to one-way separated facilities, located on each side of the road either immediately adjacent to the carriageway or just outside the carriageway. Cycle tracks differ from cycle paths in that they are one-way facilities providing for bicycle travel in the same direction as motor vehicle traffic, and are intended primarily as bicycle transportation facilities rather than recreational facilities. If located immediately adjacent to the carriageway, cycle tracks are placed outside of the outer travel or parking lane, and separated with a raised curb or other vertical barrier to keep vehicles from entering the cycle track. Cycle tracks should be a minimum 1.5 m in width, with a minimum 0.5 m raised separator between parking lane and cycle track, and a wider separator if the cycle track is located adjacent to a vehicular travel lane. Because they provide a physical separation, cycle tracks are viewed as the most appropriate transportation-oriented bicycle facility type for the urban areas of Qatar. The physical separation will have the dual benefits of it providing users with an added measure of safety, which may a shared-use off-street path, with the same space shared by both bicycles and pedestrians Cycle tracks provide for one-way travel on a separated facility outside the parking lane (Figure 3).

Figure 3: Cycle tracks provide for one-way travel on a separated facility outside the parking lane (Source: Google)

III) Striped Bicycle Lanes: Bicycle lanes refer to a striped, dedicated lane for cyclists, a minimum of 1.2 m and maximum of 2.0 m wide, along the outside (rightmost) kerb. Cycle lanes are delineated with a 100 mm wide solid line, are marked with a bicycle stencil at regular intervals (200 m), and may also be signed. In some countries bicycle lanes are marked with colored pavement for further visibility and emphasis. The color used for cycle lanes varies by country, with the most common color being red (used in cities in the Netherlands, Germany, Sweden, Denmark, Switzerland, Belgium and others), with lesser use of blue (used primarily in Denmark), yellow (used in Switzerland), and green (used in a few cities in Germany and France). One important consideration when evaluating the appropriateness of bicycle lanes is the local traffic conditions and the potential for the bicycle lane to be used illegally by motorists, either for double parking or for driving if there is traffic congestion in the vehicle lane. If there is a significant likelihood of either of those occurring, it is best to consider a separated cycle track facility where vehicles will not be able to encroach. On streets where traffic or parking problems are not an issue, bicycle lanes can serve as an inexpensive and effective means of formalizing a space on the roadway for cyclists (Figure 4).

Figure 4: A bicycle lane provides a dedicated space for cyclists (Source: Google)

IV) Shared On-Street Bikeways: On-street bicycle facilities can also include marked or signed routes that involve the bicyclist riding within the carriageway of the roadway but sharing the outside travel lane with motor vehicles. These facilities are designated only by signage or in some cases by pavement stencils that indicate shared use of the travel lane. These facilities are not preferable on high priority routes, but may be necessary if there is no room to install a cycle track or striped bike lane along a given segment, due to constraints with the width of the road. While a shared use roadway design does not include a segregated space for the bicyclist in the carriageway, the presence of signage and marking can be very important in displaying the visibility of the route, particularly if there is already heavy cycling activity. For roadway segments within the central part of Doha, there will likely be some segments of roadway where cycle tracks or even bicycle lanes are not feasible and a shared lane treatment may be necessary. (Qatar Bicycle Study Team, 2006) (Figure 5).

Figure 5: signed routes that involve the bicyclist riding within the carriageway of the roadway (Source: Google)

3.0 Methods and Materials

3.1 The Urban Cyclability Assessment Model Development

This model indicates the cyclability can be been defined as 'well-designed' cyclable urban environment and 'most-in-use' cyclable urban environment. The current study presents the 'most-in-use' concept of urban cyclability, while the other concept will be presented in future works. Urban designers and planners claim that the cyclable paths are non-motorized-oriented-designed paths. But, in reality, such paths may not been used by cyclers . In this regard, the 'most-in-use' urban cyclability assessment model aims to find out the paths which fulfilled the pedestrian needs and preferences, whether that selected path has been facilitated or not. The 'most-in-use' urban cyclability assessment model deals with 3-layered cyclability variables, and analyzed them based on Decision Tree making the cyclers' route selection.

3.2 The Variables involved in PACEX Model

Saelens *et al*. (2003) express that "traditional neighborhoods purported to be highly walkable and bikable are characterized by high population density, a good mixture of land-use, high connectivity, and adequate bike/walk design including continuous sidewalks". Babiano (2003) come up with the user needs hierarchy, which respectively from bottom to top included mobility, protection, ease, enjoyment and identity (see Figure 6). The pyramid diagram was adopted from the human's needs by Max-Neef *et al*. (1992) and Maslow (1954). In the diagram Babiano (2003) assumed that those lower in hierarchy must at least be partially "satisfied before those higher in order may become an important source of motivation". In fact, from bottom level to summit level, initial physical needs of pedestrian are being changed to mental and spiritual needs. It can be referred to the recent approach in urban design and planning which is incorporating designing urban form and individual's travel behavior. Mokhtarian and Salmon (2002) and Handy *et al*. (2005) claim that it intrinsically important to consider attitude, perception, and self-selection manner of individuals.

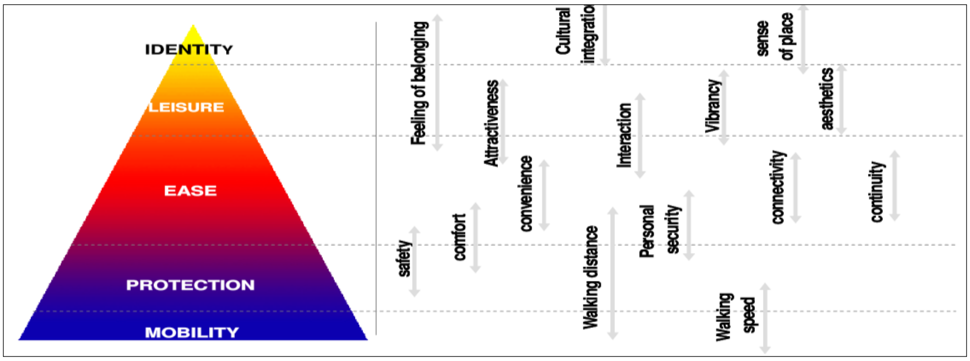

Figure 6: Urban User Needs Hierarchy (Adopted from Babiano, 2003)

3.3 The Criteria and Sub-Criteria involved in PACEX Model

To date, few cyclability sub-criteria have been empirically analyzed and measured for their influence on walking behavior. The need for detailed and comprehensive walkability sub-criteria is essential (Clifton *et al*. 2007, Painter 1996). The PACEX involves total 90 cyclability variables; clustered into 5 walkability features. Each cyclability feature includes numbers of cyclability criteria and numbers of sub-criteria.

3.4 The PACEX Decision Making Algorithm

In PACEX the facilitated paths within the neighborhood area can be identified. The analysis of path cyclability variables (including 1st Layer, 2nd Layer, and 3rd layer) will follow by using formulae 1 to formulae 3. It will indicate the priority of path cyclability needs in that under-surveyed neighborhood area.
Formula 1 and 2 are used for evaluation of respond for walkability variables, including, 1st layer (cyclability Features (F_i)), 2nd Layer (cyclability Criteria (C_j)) and 3rd Layer (cyclability Sub-criteria (S_k)). The 'Average Rate Value' of each Variable ($AvRVF_iC_jS_k$) is calculated by the following formula,

$$(AvRVF_iC_jS_k) = \frac{\sum_{r=1}^{n} RVVF_iC_jS_k \text{ (Rate Value of each variable by respondent nomber (r))}}{\text{Total number of respondent (n)}} \quad (1)$$

Where,
$R_rRVVF_iC_jS_k$, 'is the abbreviation for Rate Value of each Variable $RVVF_iC_jS_k$, by rth Respondent (Rr). It will be calculated using Formula 1-a.
$R_rRVVF_iC_jS_k$ = 'Minimum possible rate of the variable by respondent'– (rate of the variable by rth Respondent – 1 (2)

Formula 2 is used for variables involved in the 1st layer (i.e. cyclability Features).

'Actual Rate Value' of each cyclability Feature ($AcRVF_i$) =

$$(AvRVF_i) \times \sum_{i=1}^{3} a\left(AvRVF_iC_j\right) \times Max\left(AvRVF_iC_jS_1 : AvRVF_iC_jS_k\right) \quad (2)$$

Where,
F_i =Feature number 'i' which 'i' can be 1,2,3,4 or 5.
C_j, = Criteria number 'j' which 'j' can be 0, 1, 2 or 3.
S_k = Sub-criteria number 'k' which 'k' can be 0, 1, 2, 3, 4, 5, 6, 7 or 8.

Based on second definition of cyclability most used paths will show the grounded capacity of each path segment to be benchmarked in the area of study. Based on the score of each variable in 3rd layer ($F_iC_jS_k$), it is possible to propose the final priority of destination cyclability (meso-scale). The model results can be used as the benchmark for urban managers in their future neighborhood development/redevelopment and corrective actions. This process will provide walkability index for two applications, firstly, cyclability index for each destination (meso-scale), second, cyclability index for the overall neighborhood area (macro-scale).

The PACEX, the research formulated the below mathematical model to measure 'Path Segment Cyclability Index Score' (micro-scale) for each path segment (see Table 1).
Path Segment Cyclability Index Score:

$$F_i = \frac{\sum_{i=0}^{5} AcRVF_i}{46.4} = \frac{1}{46.6} \times$$

$$\left(\underset{\boxed{}}{\textbf{\textit{AcRVF}}\text{ of 'Sense of Safety and Security'}} + \underset{\boxed{}}{\textbf{\textit{AcRVF}}\text{ of 'Connectivity'}} + \underset{\boxed{}}{\textbf{\textit{AcRVF}}\text{ of 'Comfort'}} + \underset{\boxed{}}{\textbf{\textit{AcRVF}}\text{ of 'Convenience'}} + \underset{\boxed{}}{\textbf{\textit{AcRVF}}\text{ of 'Attractiveness and Aesthetics'}} \right)$$

Table 1: Indexing grades of PACEX

Cyclability Grades (Indexing Color Code)		*Description and recommendations*
▪ **Superior**	▪ (Thickness Degree 1) = for PACDEX Score 7.5 to 6.8	▪ Well-designed and pedestrian-friendly constructed sidewalk to which satisfies users; Minor improvements, if any, needed.
▪ **Good**	▪ (Thickness Degree 2) = for PACDEX Score 6.7 to 6.1	▪ Constructed sidewalk to which accommodates users; Minor improvements may improve to superior rating
▪ **Fair**	▪ (Thickness Degree 3) = for PACDEX Score 6.0 to 5.4	▪ Usable sidewalk to which some users do not feel high level of walkability; improvement, such as better facilities and amenities, almost needed.
▪ **Poor**	▪ (Thickness Degree 4) = for PACDEX Score 5.3 to 4.7	▪ Usable sidewalk to which many users do not feel high level of walkability; significant improvement, such as lack of facilities and amenities probably needed
▪ **Very Poor**	▪ (Thickness Degree 4) = for PACDEX Score 4.6 to 4	▪ Non-usable sidewalk to which users do not feel even medium level of walkability, and has sub-standard conditions combined with heavy traffic; Should be improved.

4.0 PACEX Implementation in Doha-Qatar Case Area

In 2006 Doha city hosted the 15th Asian Games. It was the first time that all 45 member nations of the Olympic Council of Asia took part in this event, planners in UPDA and ASHGHAL tried to find extra modes for transportation to cover the shortage in Taxis and Buses, In addition they tried to supply the country with all recommended facilities to support the sport tourist, unfortunately; shortage in money, time or information has prevented moving forward in the project, but it is still a good proposal for a necessary facility. This Proposal describes the Recommended Bicycle Network for the Qatar National Bicycle Master Plan. This network sets be implemented in 2006 in Greater Doha and the State of Qatar. By identifying the specific roadways and other corridors along which bicycle facilities should be built, all of the groups involved in development activities in Qatar – both on the public agency side and on the developer side – will be able to incorporate these facilities into their future development work. In 2022, the Doha city will host for FIFA World Cup 2022 in Qatar. Around 7 million people will travel and accommodate in Doha city during FIFA 2022 (Figure 7).

The infrastructural projects include the building and urban development of facilities such as stadiums, roads and freeways, an extensive railway network, housing projects, hotels, malls and even the brand new Hamad International Airport. Each of these will be world-class facilities that will offer an unparalleled quality of services. The FIFA function approached Qatari urban designers and developers to non-motorized city development, in particularly, cyclable urban design and development. Key opportunities include the chance to construct bicycle facilities as part of new major master planned developments and major roadway re-designs, linking existing and future park and recreation areas with a bikeway system, incorporating bikeways into proposed waterfront projects, and linking the bikeway network to the future rail system. Key constraints include high traffic volumes and speeds, motorist and bicyclist behaviour, hot summer weather, and continued new development planning that does not include bicycle facilities.

Figure 7: Doha city development for FIFA 2020 (Source: www.skyscrapercity.com)

4.1 Data Collection

The structured fixed format self-report questionnaire was designed to capture DTM of the cyclers to different parts inside the survey boundary in Doha city. The data for questionnaire have collected through the ‘Combined Scaling Method’ (CSM). The CSM obtains respondent’s perception through scoring and ranking the items (Stangor, 2007). In CSM, had a high potential to be integrated with the ‘Decision Tree Analysis’. The ‘Combined Scaling Method’ (CSM) is the combination of two scaling methods, ‘Categorical scaling’ and ‘Ordinal Ranking scaling’. The CSM assigns a separate number or letter to various index components from lowest to highest. The ‘Combined Scaling’ method provides a group of scores can be sorted by respondents; including, 1 = strongly favorable to the concept, onward, to n = strongly unfavorable to the concept. In CSM, every score is chosen just one time in each category of items. For example, if the category of items includes six (6) items, respondents are asked to sort them from one (1) (i.e. most important item) to six (6) (i.e. least important item).

4.2 Data Analysis Results of PACEX implementation in Doha-Qatar Case Area

The research comes up with output results for ‘cyclability index in overall neighborhood’ (Figure 8). Tables 2 and 3 have calculated the average of cyclability index of 3 destinations; and then sorted the estimated cyclability sub-criteria in a hierarchal list. This list determines the highest to the lowest percentage of the estimated cyclability sub-criteria for overall neighborhood.

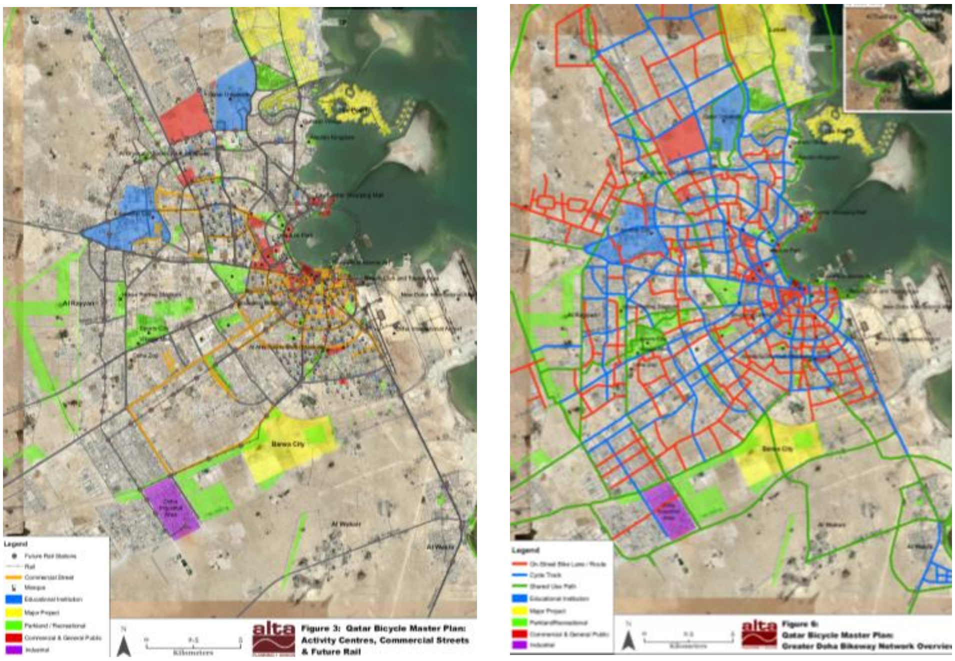

Figure 8: PACEX Implantation in Doha city, Qatar;
Left: identification of Potential urban area for cyclable street design and development
Right: Identification of Potential path (street) for cyclable design and development

4.3 Proposed Bicycle Highway system based on PACEX results

Doha to Al Khor, linking to the Lusail Circuit raceway, which is proposed to have a bicycle training circuit facility, as well as the Lusail Nature Preserve area near Simaisma which would be proposed for hiking.

- Doha to the Dohat Al Husain area along the Gulf of Bahrain, which could be a location for camping and hiking.
- Al Khor to the Al Ghuwairiya area and Biosphere Natural Preserve, where camping can occur.
- Connection to the Singing Dunes area off Route 55, a popular recreation and visitor destination.
- Connection to the Sealine Beach Resort area south of Messaieed.
- Additional connecting routes offering loop opportunities between these key destinations.

Table 2:Cyclability Sub-criteria analysis in three shopping centers destinations

Cyclability Features	**Cyclability Criteria**	**Cyclability Sub-criteria**	***D. A (%)**	***D. B (%)**	***D. C (%)**
F1. Sense of Safety and Security	**F1.C1.** Safety facilities at sidewalks	**F1.C1. S1** Driveway Curb-cuts	25.43	19.12	18.64
		F1.C1. S2 Existence of Pedestrian Crossing	27.54	19.42	25.8
		F1.C1. S3 Width of Utility Zones	24	16.73	11.25
		F1.C1. S4 Shelters	24	12.34	12.82
		F1.C1. S5 Length of Tree Canopies	15.53	10.68	10.28
		F1.C1. S6 Releasing visual Obstacles/	8.1	3.22	13.82
		Nuisances	21.67	11.56	7.57
		F1.C1. S7 Sidewalk Steepness	12.59	8.23	8.77
		F1.C1. S8 Existence of Bike Lanes	9.54	6.89	14.37
		F1.C1. S9 Existence of On-street Parking	4.76	6.87	9.04
		F1.C1. S10 Informing the intersection	10.05	18.78	16.94
		blindness	10.81	8.62	8.92
		F1.C1. S11 Mid-block crossing			
		F1.C1. S12 Providing over-bridge			
	F1.C2. Slowing traffic speed at pedestrian crossing	**F1.C2. S1** Existence of Pedestrian Crossing	24.96	8.23	17.66
		F1.C2. S2 Number(s) of Traffic Lanes	19.07	14.69	19.39
		F1.C2. S3 Traffic Signals	24.36	15.68	22.16
		F1.C2. S4 Traffic Calming Devices	3.7	4.70	11.42
		F1.C2. S5 Drivers' respect to pedestrian	4.76	5.48	7.90
		F1.C2. S6 Slow Traffic speed	11.78	12.67	19.47
	F1.C3. Security in day and nights	**F1.C3. S1** Sidewalk Lighting	19.07	6.97	12.64
		F1.C3. S2 Number of Intermediary	13.94	8.55	10.93
		F1.C3. S3 Length of Tree Canopies	9.58	9.49	14.57
		F1.C3. S4 Number of Street Trees	11.48	6.48	19.95
		F1.C3. S5 Releasing visual Obstacles/	8.4	4.6	5.57
		Nuisances	20.04	12.06	18.94
		F1.C3. S6 Not-crowded Route	6.35	2.97	5.14
		F1.C3. S7 Street Surveillance	22.87	7.87	14.78
		F1.C3. S8 Street-Facing Entrances	11.04	9.45	20.21
		F1.C3. S9 Street-level Façade Transparency	9.94	9.49	18.97
		F1.C3. S10 First Floor Use of Buildings	8.03	14.73	6.45
		F1.C3. S11 Upper-Floor Windows			
F2. Connectivity	**F2.C1.** Sidewalk accessibility	**F2.C1. S1** Sidewalks networking	22.92	16.48	18.96
		F2.C1. S2 Length of Sidewalks	22.5	15.03	24.64
		F2.C1. S3 Width of Walking Zones	21.9	17.18	27.49
		F2.C1. S4 Continuity to diverse activity	9.63	12.39	21.35
		F2.C1. S5 Length of Segments	11.36	10.96	16.04
		F2.C1. S6 Informing the Intersection blindness	25.67	8.26	15.50
		F2.C1. S8 Street signage	8.44	7.93	11.03
	F2.C2. Physical connectivity	**F2.C2. S1** Sidewalk steepness	19.85	20.7	13.05
		F2.C2. S2 Street-Facing Entrances	21.66	24.19	21.93
		F2.C2. S3 Street Signage	7.44	9.90	20.13
		F2.C2. S4 Length of Segment	21.40	22.89	18.90

Note: *D. Destination

Table 3:Cyclability Sub-criteria analysis in three shopping centers destinations (Continiued)

Cyclability Features	**Cyclability Criteria**	**Cyclability Sub-criteria**	***D. A (%)**	***D. B (%)**	***D. C (%)**
F3. Comfort	**F3.C1.** Physical comfort	**F3.C1. S1** Well-locating of service	21.37	17.47	25.88
		utilities	16.55	15.90	29.75
		F3.C1. S2 Amount of Street Furniture	15.80	12.92	14.67
		F3.C1. S3 Sidewalk Lighting	9.63	10.21	14.67
		F3.C1. S4 Number of Intermediary	10.38	10.65	11.66
		F3.C1. S5 Shelters	26.67	15.12	14.94
		F3.C1. S6 Planting deciduous trees	8.48	8.09	19.68
		F3.C1. S7 Existence and width of	7.82	10.08	13.80
		medians	18.65	9.45	8.62
		F3.C1. S8 Existence of On-street			
		Parking			
		F3.C1. S9 Human Ergonomic Scale			
		Design			
	F3.C2. Environmentally comfort	**F3.C2. S1** Width of Walking Zones,	24.29	13.52	16.84
		F3.C2. S2 Types of Sidewalk	21.37	21.27	13.39
		Pavement,	9.02	14.06	10.96
		F3.C2. S3 Number of Street Trees,	4.03	9.03	8.96
		F3.C2. S4 Sidewalk Steepness,	10.58	2.43	4.37
		F3.C2. S5 Windy climate,	19.07	21.35	13.54
		F3.C2. S6 Not-crowded Route,	24.36	16.04	11.68
		F3.C2. S7 Height and types of Fences,	5.47	19.04	9.07
		F3.C2. S8 Street reserve			
F4. Convenience	**F4.C1.** Functionality of diverse activities	**F4.C1. S1** Number(s) of Traffic Lanes	6.80	5.41	13.36
		F4.C1. S2 Existence and width of	2.07	13.09	25.09
		medians	1.08	3.89	11.31
		F4.C1. S3 Length of Segment	11.57	10.39	4.43
		F4.C1. S4 Width of Traffic Zones	9.03	16.68	7.05
		F4.C1. S5 Widths of Buildings			
	F4.C2. Easy access without obstacles	**F4.C2. S1** Releasing visual Obstacles	6.77	9.36	13.60
		F4.C2. S2 Traffic Signals	6.98	6.53	13.84
		F4.C2. S3 Sidewalk Steepness	4.38	7.73	10.50
		F4.C2. S4 Not-crowded Route,	5.13	8.83	10.74
		F4.C2. S5 Existence of On-street	3.41	5.44	6.65
		Parking	4.01	4.35	14.08
		F4.C2. S6 Mid-block crossing	2.74	4.36	13.36
		F4.C2. S7 Height and types of Fences	20.15	6.63	7.53
		F4.C2. S8 Public parking next to street	11.50	1.37	15.29
		F4.C2. S9 Slow Traffic speed			
F5. Attractiveness and Aesthetic	**F5.C1.** Street enclosure	**F5.C1. S1** Width of Curb-to-Curb	21.49	4.29	3.82
		Roadway	20.15	4.13	4.13
		F5.C1. S2 Width of Utility Zones	11.57	4.30	3.2
		F5.C1. S3 Building Setbacks	9.03	6.63	7.12
		F5.C1. S4 Width of buffer zone	6.94	6.63	7.53
		F5.C1. S5 Street reserve	4.63	11.37	15.29
		F5.C1. S6 Diversity of buildings	15.68	6.35	14.78
		F5.C1. S7 Functionality of next	22.94	13.84	11.40
		Buildings			
		F5.C1. S8 Enclosure ratio			
	F5.C2. Vibrancy and vitality	**F5.C2. S1** Planting diversity,	22.10	12.29	6.65
		F5.C2. S2 Sidewalk Lighting,	25.26	13.29	2.72
		F5.C2. S3 Width of Landscaping	15.79	9.56	4.03
		Strips,	20.8	8.39	4.43
		F5.C2. S4 Types of Sidewalk	6.55	6.43	7.05
		Pavement,	11.48	12.67	9.57
		F5.C2. S5 Intangible Senses,	8.4	16.95	8.77
		F5.C2. S6 Planting deciduous trees,	20.04	15.57	14.85
		F5.C2. S7 Length of Tree Canopies,	22.87	8.77	10.94
		F5.C2. S8 Number of Street Trees,	11.99	18.78	13.98
		F5.C2. S9 Vital Atmosphere in	15.79	12.67	13.30
		sidewalks,			
		F5.C2. S10 Street Interface,			
		F5.C2. S11 Heights of Buildings			

This mapping presents a recommended network of bicycle routes that connects to all of the major cycling destinations within Greater Doha, Al Khor, Al Wakra and Al Wukair. Recommended facilities include commuter-focused cycle tracks along major roadways, recreational-oriented bike paths within park areas, along linear greenbelt corridors, and along the Corniche, In addition the network within the urbanized communities, the recommended system includes a National network of recreational “Bicycle Highways” that link to major natural preserve areas and could be used as training and exercise facilities by beginner and experienced cyclists alike. With full buildout of this system Qatar would have one of the most extensive bicycle networks in the world, with the facilities rivalling the most innovative European cities. The recreational network would appeal to tourists and visiting cyclists looking for winter training routes. These improvements would certainly solidify Qatar as ‘The Centre of Cycling Culture and Sport in the Gulf Region.” (Qatar Bicycle Study Team, 2006).

Qatar is building a network of highways, flyovers and tunnels to ensure smooth traffic flow. The Ras Abu Aboud Tunnel linking Al Wakrah road to both the Corniche and Sana Roundabout is among the key road projects that have already been completed. The strategic location of the Ras Abu Aboud interchange – it is one of the vital projects of the New Doha International Airport (NDIA) and the first interchange new-comers to Doha will see once they get out of the airport - required special attention to its landscaping and beautification and the surrounding area. A task that has been handled well by Aljaber Trading & Contracting Company (JTC) (Figure 9). Together with the NDIA steering committee, JTC developed a unique landscape design for the project. JTC has also developed different professional specialties in different areas of the industry such as metal works, ready-mix, carpentry and joinery, heavy equipment, transportation and electro-mechanical services. The landscaping of the project will include, for the first time in Qatar, a 14-kilometer bicycle path starting from the new terminal.

Figure 9: JTC proposal for bicycle path in Doha-Qatar

5.0 Discussion

It's not just the bikers that benefit from this extensive and expensive infrastructure, for biking produces lots of positive social and economic externalities. It reduces pollution and eases traffic congestion. Biking promotes better fitness and health, lowering overall health costs. Bike-friendly cities are more attractive to young, educated, creative-class workers. And, beyond that, biking puts one in closer contact with the world, forcing closer contact with fellow citizens and the natural and manmade environment, subtly reinforcing a sense of community, belonging, and ownership. Cyclists who routinely ride on streets have no doubt noticed a steady stream of changes to the bicycle lanes where has been adding safe-hit posts and creating the impression of greater safety and dignity for cyclists on the corridor. The new lanes can be permissible even with the bicycle injunction because they are not technically considered traffic control devices, which are not allowed to proceed until the injunction is fully lifted. If creating visibility for cyclists is the most important thing for securing safety and attracting new riders, said Patel, these lanes are a step in the right direction.

Just reducing barriers slightly, providing a little nudge, is enough to change behavior-and allow people to do what they want to do. We can learn a lot from places like Hannover in terms of making the cities more bike-friendly. The bike lanes on streets are clearly marked. At intersections, there is a painted box on the street where bikes can move in front of cars when turning. Bikes often have their own light at intersections, and the choreography of stop lights and crossing signals is elaborate: the pedestrians' light turns green a few seconds before the others, and bikes too are given a few second head start (which is both safer and clears the intersection faster). On many one-way streets, two-way bike traffic is still allowed (more convenient for bikes and slowing cars down as well). Bike paths in the woods and surrounding countryside are well marked with directions and distances.

It’s every urban cyclist’s dream: to be able to cruise through the city completely unburdened by cars. In some places around town, bicycles far outnumber cars. Hence, the streets need necessarily bike lanes, usually with their own stop lights. There should be well-marked and maintained bike paths through the wooded areas, around the lakes and marsh, covering the urban planners' green space. There are tunnels under train tracks and bridges over highways for bikes. High petrol taxes discourage driving and traffic congestion and parking problems make biking more appealing.

The previous obstructions needs a creative thinking to solve them and come up with a suitable plan for Doha city, by looking to the global ideas and examples it seems that many countries with same conditions of wither, distances or time are getting over these difficulties and start using bicycles for daily transportation, for instance; The Elevated Bike Lanes is a proposal to supplement Toronto's major transit axis. These lightweight covered lanes would allow cyclists to travel across the city unimpeded by traffic lights or adverse weather conditions. The design also makes use of solar paneling to power the street lighting, which is integrated into the supporting columns. In a still experimental phase, a titanium dioxide-coated fine mesh canopy would stretch over the entire street and extend over most of the sidewalks as well. This canopy would use a thermally-activated wicking system to prevent snow from accumulating on the street, eliminating the need for fossil fuel intensive snow removal machinery and eventually allow these thoroughfares to become restricted to emission-free vehicle usage. With improved transportation options and a better pedestrian experience, the Yonge Street and Bloor Street corridors could accommodate further growth and perhaps enhance linear dynamism as a defining characteristic of the city. Many consider Bike riding long distances is not only a great sport but a great way to see the countryside. It is a way to get out and view your surroundings. In fact you will be getting exercise and working muscles without even realizing it, so it will be a habit step by step and will be easier even to Qatari locals to use bicycles if good services provided to them.

Existing bicycle demand is highly dispersed (as indicated by field reviews), and characterized by many short delivery trips within the dense central business areas, and some shorter commute trips to major employment generators to worker housing such as the industrial area. Recreational demand is currently concentrated at the Corniche (where bicycling is officially prohibited, but still occurs during off-peak hours), the Aspire area near Sports City, and along the road to Al Khor on weekends. Future demand for bicycle use in Qatar will be significantly different than the existing demand as the city's demographics change. This is due to Qatar's increasing development of higher density, middle- and upper-income housing, and development of rail and expanded bus transit systems. With future land use planning that concentrates higher density residential near transit, a large portion of future bicycle work commute trips would be multi-modal trips connecting to a transit stations. Future commuter demand focused around the educational institutions of Qatar University and Education City will also be important. Future recreational demand will take advantage of linear corridors and other opportunities to provide for an expansive network of bike paths (for road and mountain biking) as well as specialised training facilities for competitive amateur up to professional level cyclists. (Qatar Bicycle Study Team, 2006). According to these Information UPDA had Implement the first proposal for bike lane network depending on Activity Centres, Commercial Streets, Future Rail and recommended types of Bike lanes.

6.0 Conclusion

The research has developed the Path Cyclability Index Assessment model which is incorporating with New Urbanism, Smart Growth, and Sustainability principles and strategies. The model has a middle-out approach to enhance urban walkability. It considers both top-down and bottom-up approaches to boost urban walkability by engaging the participation of both government and private stakeholders in walkable urban growth and development. Hence, the proposed model is seen as an urban design decision-support tool that will be useful for urban designers and urban/transportation planners in deciding on future development/redevelopment and on corrective actions.

The case study (i.e. Doha city, Qatar) will keep lacking bicycles on its streets; unless some effort and voices call for healthy and sustainable living. Qatar needs a network of bicycle rental ranks, providing rides not just for leisure but also for commuting purposes. Bicycling for everyday travel can help Qatari locals' and expatrits need the recommended levels of physical activity and what role public infrastructure may play in encouraging this activity. This study data supports the needs for well-connected neighborhood streets and a network of bicycle-specific infrastructure to encourage more bicycling among adults. This can be accomplished through comprehensive planning, regulation, and funding. A comprehensive study of the roads network and transportation system to find out the most appropriate design of bike lanes in Qatar is required.

7.0 Future Research

The PACEX application, addresses downstream research in more detail and in continuation of further development of the current study. In the current research the framework was developed to be used by urban designers. However, the residents should use the final information as well. Sharing this information with the residents will influence their decision makings on walking to shopping centers.

Specifically, the tourist and tourist planners also may use the output information of this framework. In fact, one of the popular devices for sharing the information would be an application in Smartphone. Hence, further study may focus on;

- Descriptive study on cyclability index as the Smartphone Application
- Formulating cyclability index as the Smartphone Application
- Developing a framework to assess correlation of neighborhood cyclability through Smartphone Application

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