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Adoption of Fuzzy Logic to Assess the Environmental Quality of Urban Development

استخدام المنطق الضبابي في تقييم الجودة البيئية للتنمية العمرانية

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KEYWORDS:

Urban Development Plans, Fuzzy based Assessment and Environmental Quality.

المخلص العربي:- أدى التطور التكنولوجي الملحوظ في برامج الحاسب الآلي المستخدمة في التصميم والتخطيط العمراني إلى طفرة كبيرة في شكل ومضمون مخططات التنمية العمرانية. لذلك ظهرت العديد من التحديات التي أدت إلى تقليل كفاءة ودقة نتائج عمليات التقييم الخاصة بتلك المخططات. بالإضافة إلى ذلك، أصبحت عمليات اتخاذ القرار الخاصة بتنفيذ مشروعات التنمية العمرانية أكثر صعوبة وذلك لأنها حيث اتسمت في الأونة الأخيرة بالكثير من التعقيدات والتضاربات مما أدى لظهور عوامل عدم التاكيد أو الضبابية الناتجة عن عدم الاستقرار على اتخاذ قرارات محددة ومبنية على معايير مؤكدة وواضحة تجاه تلك المشروعات. إن عملية التصميم العمراني عملية معقدة في حد ذاتها وذلك لتأثرها بالكثير من العوامل الطبيعية والاجتماعية والتقنية التي لا تخلو من المعالجات النقدية المستمرة، والكثير من تلك العوامل يحتوي على نسب كبيرة من عدم الدقة والوضوح وتسمى أحيانا الضبابية وعدم التاكيد. لقد تم اختيار المنطق الضبابي لمعالجة هذه المشكلات، حيث أنه أثبت في العقود الأخيرة كفاءة عالية ودقة متناهية في التعامل مع عوامل الضبابية وعدم التاكيد. في هذا السياق، يهدف البحث إلى صياغة نظام خبير يعتمد على نظرية المنطق الضبابي وذلك لتقييم عنصر الجودة البيئية في منطقة المشاية السفلية بمدينة المنصورة، وتم اختيار هذه المنطقة لأطالقتها المتميزة على نهر النيل واحتوائها على الكثير من الاستخدامات المتنوعة ولقربتها من جامعة المنصورة. ويهدف الباحثون إلى بناء هذا النظام واختباره من أجل تسليط الضوء على كيفية استخدام المنطق الضبابي في التعامل مع عوامل عدم التاكيد والضبابية المصاحبة لاتخاذ القرارات بشأن معايير الجودة وذلك من أجل الحصول على نتائج محددة وبارقام أكيدة وصحيحة.

Abstract—In recent years, the rapid advances of computer applications used in urban design and planning have largely changed the essence and soul of urban designs and drawings. Therefore, many challenges exist to delay the efficiency and accuracy of assessing urban design and development plans. Furthermore, the process of assessment of urban design and planning becomes full of overlapping and intertwined stories that have made continuous changes, complexities, and uncertainties for its results and decisions. Urban development has been considered to be complex because it consists of different physical, social and technical elements and confronts continuous evaluation and decision making processes. All of urban

development factors contain ambiguity, impreciseness, and uncertainty in their data, while fuzzy logic has been proved to shed a new light on the management and assessment of these factors. The purpose of this research is to develop an expert system based on fuzzy logic to assess the Environmental Quality of Mansoura Waterfront, one of the most important areas in the city because of its included mixed uses and its adjacency to Mansoura University. The researchers intend to manage the uncertainties associated with decision-making processes through employing fuzzy logic in obtaining precisely enumerated, quantified and computerized assessment results for this area.

I. INTRODUCTION

URBAN Development is the science of managing and directing city growth with respect to the discipline of land utilization planning which explores a very wide range of aspects of the built and social environments. Urban development process is a highly complicated process containing various phases (World-Bank,

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2014). As a main core of the process, urban design gives numbers of proposed plans that are called "development plans". The decision making concerning environmental quality is one of the most crucial items in urban development; as it negatively or positively influences the adaptation and implementation of its plans (Madanipour, 1996; Rangwala, Rangwala, & Rangwala, 2005).

The assessment of environmental quality is an important part of decision making concerning urban development process (Pleho & Avdagic, 2008). A numbers of famous assessment methods in urban planning spread to be recognized in the field of urban assessment. Each method of them has its own advantages and disadvantages (Sevcikova, Rafteryb, & Waddellc, 2012). The most of assessment methods participate in that they cannot deal with the uncertainties and fuzziness accompanying the parameters and variables of environmental items and properties. Therefore, the researchers try to find a new strategy that is capable of handling the ambiguity and uncertainty of urban values. They chose Fuzzy Logic as it can shed a new light on urban Assessment; Fuzzy logic is widely used in the analysis and assessment research because of its ability to handle imprecise, insecure and ambiguous terms (Pleho & Avdagic, 2008).

II. PROBLEM IDENTIFICATION

The traditional methods used in assessing urban planning depend on using some factors for criteria such as economic impacts, quality of life, sustainability and environmental health impacts, etc (Moraes & Abiko, 2008). The Use of these methods led to loss of numerous information and more inaccurate results. Urban development plans are complex as they consist of different physical, social and technical elements, and confronts continuous analysis and decision-making processes (DTPLI, 2015). In addition, urban planning terms have ambiguous, imprecise, and uncertain data. The research intend to manage problems related to subjective, uncertain or ill-identified concepts, which is usually represented in qualitative scales of measurement, and described by linguistics, such as accessible, distance, homogenous, singularity, contrast, or the like (See table 1).

TABLE I.
ENVIRONMENTAL QUALITY TERMS AND LINGUISTICS

Items	Linguistics		
	Bad	Average	Good
Air Quality	Bad	Average	Good
Noise Pollution	Low	Medium	High
Green Areas	Poor	Average	Rich

Source: Compiled by authors from different sources

III. CASE OF STUDY

The city of Mansoura has a distinctive riverfront, about 8 kilometers long, which can owe a magnificent opportunity to occupy a good position among internationally well-known waterfront projects such as waterfront of Toronto, Barcelona, Tokyo, or the like. The study area of the research is the zone of the Western Waterfront which is located on the western side of the city of Mansoura, (see figure 1). This area was selected because of its characteristics, vitality, and its position in the focus of attention of city dwellers and city leaders. The area includes Mansoura University, one of the most important and vital zones of Mansoura, and is oriented by the local government to enhancing the aspects of mixed uses and commercial attitudes more than taking into account improving the waterfront environment. The researchers aim at making a computerized assessment of the environmental quality aspects associating the mentioned development plan by using some criteria of environmental quality processed in Matlab software, a computer application providing an inference system using fuzzy logic for assessments.

IV. RESEARCH METHOD

The research depends on using an expert system designed by (Thabet, Shita, & Hegazy, 2015), inspired by a computer application called "Mamadani" provided in Matlab software, to assess environmental quality aspects in the development plan of the study area. This method shows a new technique that can transform any qualitative and linguistic concepts related to urban planning to quantified measures and accurate values. The model is based on using fuzzy logic mathematics to convert urban linguistics and its technical terms of the assessment criteria chosen for the process (see figure 2). The criteria are compiled by the researchers from different sources in the field of urban environmental assessment. The criteria items are treated using fuzzy sets representing the system of inputs and outputs used in assessment.

V. ASSESSMENT CRITERIA

There are three criteria used in the assessment model, air quality, noise pollution, and green areas. This set of criteria is chosen because it matches the typology of the project needed to be assessed; this means that the criteria is relying on a careful study of project components and objectives (see figure 3). Moreover, Pleho & Avdagic (2008) and Wang, et al. (2013) declared that human perception for some elements such as visual factors, textures, colors, forms, and planting would be taken into account when using the mentioned criteria. This set of criteria is flexible by its nature as it can be adjusted by adding more items which may be seen important by other related experts may use the assessment model composed in this research (OzlemOzer & Kubat, 2013)

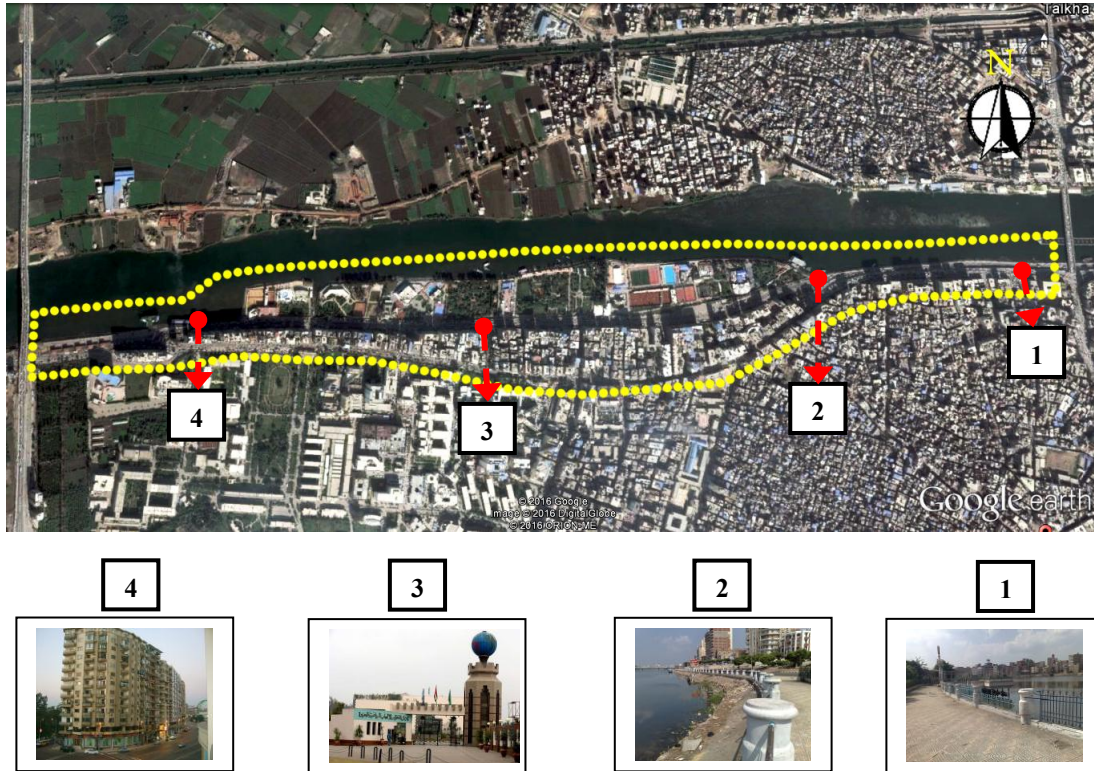


Fig 1: The research study area, Mansoura Waterfront
Source: (boulderblueline, 2015)

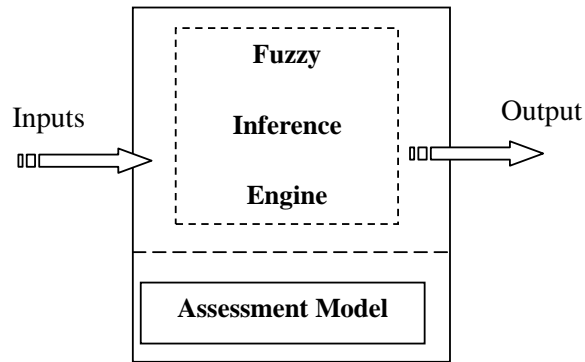


Figure 2: Research Methodology,
Source: The Authors

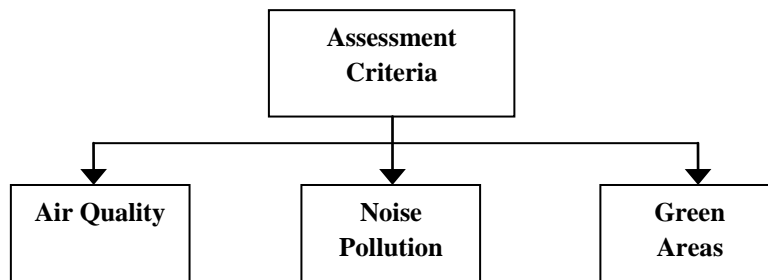


Fig 3: Elements of criteria
Source: (Pleho & Avdagic, 2008)

VI. ASSESSMENT PROCESS

The model is constructed to be based on assessing the development plan using a number of linguistics outlining the features and factors forming the criteria of environmental quality. This set of linguistics is processed by the researchers in the research assessment model. In order to manage and deal with the fuzziness and uncertainty included in this linguistics, the researchers have used the fuzzy mathematics in adapting the linguistics of the criteria to be in forms of fuzzy sets (see figure 4). The model is processed as shown in the following three steps

A Fuzzification

The researchers used their technical experience to refine the criteria elements and to transform them into equivalent fuzzy sets. The elements of the criteria are qualitatively categorized in fuzzy sets and subset (see figure 5). The membership functions defining these fuzzy sets are defined quantitatively for the system input through covering a specified domain of value. These functions are intersecting with each other and are often represented by trapezoidal shapes, triangular, delta, or rectangular shaped functions (see figure 5). As a result, the three elements have been fuzzified in fuzzy sets of membership functions based on the researchers' experience.

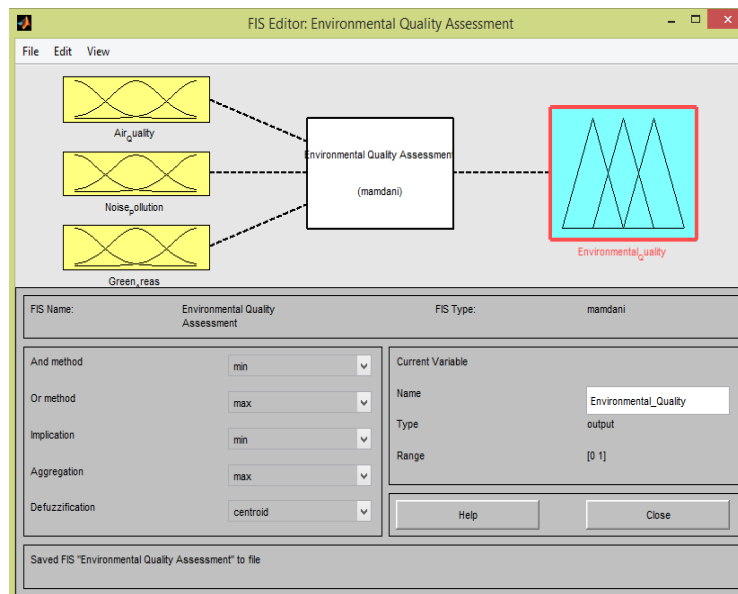


Figure 4: Fuzzification of assessment criteria - Source: Processed in MATLAB by authors

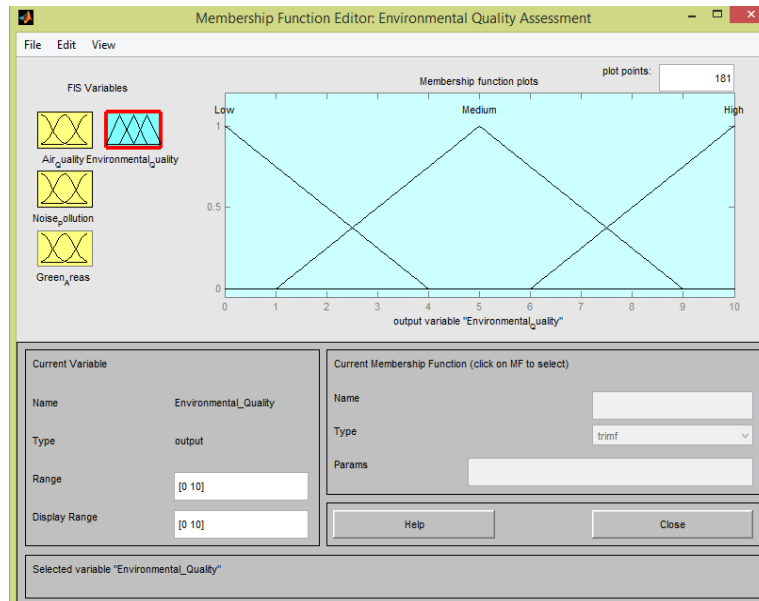


Figure 5: Processing the fuzzy sets using FIS Editor tab of MATLAB - Source: Processed in MATLAB by authors

B If-Then Rules Formulation

A number of rules called "If-Then" rules are developed using the experience of their developer (the researchers) to identify the relationship between criteria elements and resulting assessments. "If-Then" rules mean that if a criterion A is X and if criterion B is Y, then assessment result C is Z. The fuzzy sets and subsets categorized in the system produce the total number of rules. In this research, there are three items associated with the air quality criterion, three with noise pollution, and three with green areas. Therefore, the total number of rules developed in the model is $3 \times 3 \times 3 = 27$ rules. This If-Then system is flexible and can expand according to its inputs and its associated fuzzy sets. The if-then rules are created using MATLAB FIS Editor and stated (see figure 6).

C Difuzzification and obtaining results

After developing the If-Then Rules, the MATLAB Fuzzy Inference Engine becomes ready to be used by the researchers to put their judgment values concerning the assessment case of study. The output values will be obtained will be obtained in accurate quantities by processing input values in the developed if-then rules by using the MATLAB Fuzzy Inference Engine (see figure 7). There are three common methods which are used by inference engine, centroid, max-min, and max-max. Mamadani's max-min inference method is absolutely used is the fuzzification phase of the model. The min operator is useful for modeling the conjunction of rules, and the max operator is useful for the aggregating the fuzzy sets. Finally, the output of the model can be obtained in numerically quantified assessment results representing the environmental quality implied in the current state of Mansoura Waterfront

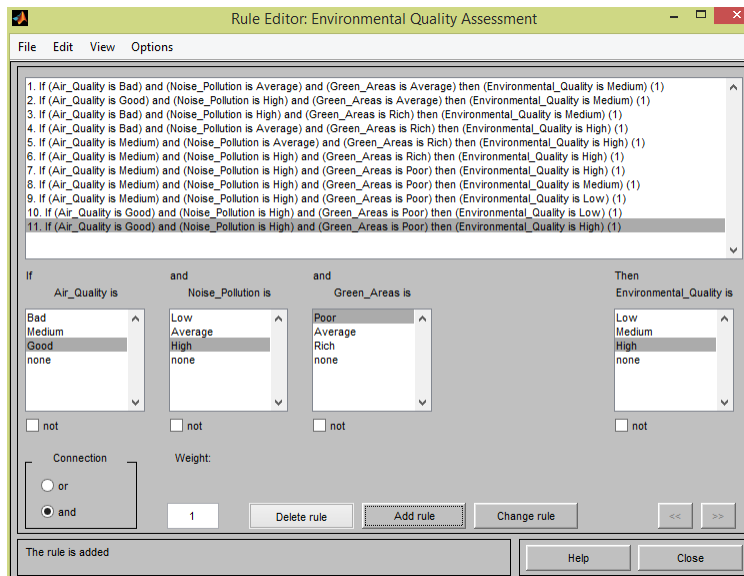


Figure 6: Developing If-Then rules regulating the assessment criteria and results - Source: Processed in MATLAB by authors

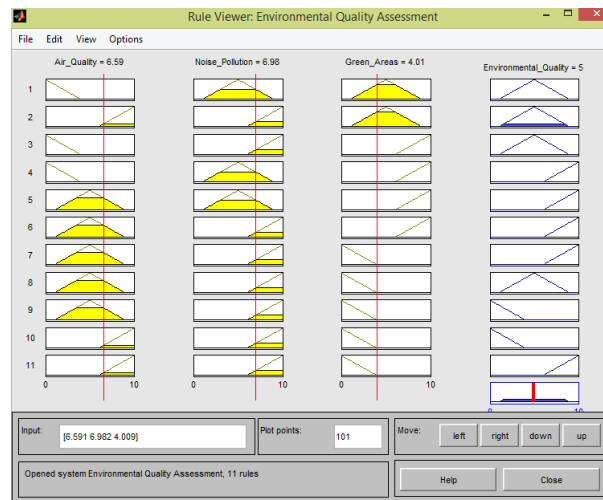


Figure 7: Rule viewer tab of matlab which is used by expert to assign their judging values - urce: Processed in MATLAB by authors

VII. RESULTS

The total aggregated score of assessing the current state of Manoura Waterfront is twofold, an assessment is done manually by experts and the other is done by using the proposed model of MATLAB Mamadani. The environmental quality are recorded manually as 4.68 of a maximum of 10.00, and recorded by using MATLAB as 4.71 of a maximum of 10.00 (see table 2). By comparing the two types of results, it is noted that the model results are approaching traditional method result. Therefore, the model proved that it is succeeded and valid for usage.

TABLE 2. RESULTS OF ASSESSMENT

Subject	Criteria	Linguistics		
		Items	Manual Results	MATLAB Results
Urban Environmental Quality	Air Quality	Bad	3	5.48
		Average	5	
		Good	7	
		Aver.	5	
	Noise Pollution	Low	4	3.59
		Medium	3	
		High	6	
		Sum.	4.33	
	Green Areas	Poor	3	4.37
		Average	3.5	
		Rich	8.5	
		Sum.	5	
Aggregate		4.78	4.48	

Source: the authors

VIII. CONCLUSION

The paper showed that converting qualitative terms and linguistics used in urban design and planning into quantitative scales would add more complexity and uncertainty to the process of urban assessment. Furthermore, fuzzy logic and fuzzy set theory introduce an efficient method to manage and deal with impreciseness and uncertainties accompanied urban environmental concepts and values. Fuzzy set theory could deal with vagueness, ambiguousness, subjectivity, and uncertainty coming with linguistics and technical language. Some tools were identified in fuzzy logic literature to be used in urban evaluation processes. The paper used MATLAB fuzzy inference system as a new approach used in urban planning and it is justified according to the experience of its developer and the typology and properties of subjects in use.

The study examined a way to transform qualitative values into numerical values without impreciseness and uncertainty

to be involved in a model which can be used in similar applications for decision making in urban design and planning. The research opens the way to discuss the application of using the proposed model in dealing with other subjects with different levels of uncertainty in the field of urban design and planning, such as post occupation evaluation processes, environmental impact assessments, urban simulations and predictions, urban monitoring and evaluation, or the like. This will give a good chance to calibrating and testing the model with its capabilities to handle uncertainty in different situations. Furthermore, more studies are needed for implementing the model to be transformed to a comprehensive software which is defining quantification standards for urban values that can be generally used in urban design and planning.

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