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DEVELOPING PERFORMANCE CRITERIA FOR SELECTING SUSTAINABLE HOUSING CONSTRUCTION SYSTEMS IN EGYPT

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ABSTRACT

Egypt's vision 2030 for the housing construction sector has aimed to achieve sustainable housing buildings that are able to face disasters, alleviate poverty by enhancing affordability, meet people's requirements, and improve their health and safety. Many initiatives have emerged to adopt prefabricated construction systems for Egyptian buildings. However, the decision to adopt such new construction systems for building Egyptian housing still depends on the economic performance. With the increased awareness of the beneficial effects of adopting the sustainability concept, sustainability indicators: social, environmental, and economic dimensions have become drawing the major framework of the Egyptian housing prospective vision. This research aims to identify and develop the comprehensive performance criteria that control the selection of the appropriate construction systems for building Egyptian housing. To achieve the research objective, 28 performance criteria were developed based on an in-depth review of previous studies. A questionnaire survey was conducted using the Likert Five-Scale of importance. The 28 performance criteria were divided into 4 categories (i.e., economic, environmental, social, and technical). The questionnaire targeted Egyptian housing construction practitioners from engineers, architects, designers, contractors...etc. The authors found that the most important criteria have belonged to the economic, social, and technical categories. The environmental criteria ranked lowest among the criteria. Despite that, the relative importance indices for all the environmental criteria were higher than the medium range. That indicates the increasing interest of Egyptian housing construction practitioners in environmental aspects.

KEYWORDS: Egyptian Housing, Construction System, Sustainability, and Performance Criteria.

تطوير معايير الأداء لاختيار أنظمة بناء المساكن المستدامة في مصر

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الملخص

تهدف رؤية مصر ٢٠٣٠ لقطاع تشييد المساكن إلى تحقيق مباني إسكان مستدام قادرة على مواجهة الكوارث ، وتخفيف حدة الفقر من خلال تعزيز القدرة على تحمل التكاليف ، وتلبية متطلبات الناس ، وتحسين صحتهم وسلامتهم. ظهرت العديد من المبادرات لتبني أنظمة البناء الجاهزة للمباني المصرية. ومع ذلك ، فإن قرار تبني مثل هذه الأنظمة الإنشائية الجديدة لبناء المساكن المصرية لا يزال يعتمد على الأداء الاقتصادي. مع زيادة الوعي بالآثار المفيدة لتبني مفهوم الاستدامة ، أصبحت مؤشرات الاستدامة التي تضم الأبعاد الاجتماعية والبيئية والاقتصادية ترسم الإطار الرئيسي للرؤية المستقبلية للإسكان المصري. يهدف هذا البحث إلى تحديد وتطوير معايير الأداء الشاملة التي تتحكم في اختيار أنظمة البناء المناسبة لبناء الإسكان المصري. لتحقيق هدف البحث ، تم تطوير ٢٨ معيار أداء بناءً على مراجعة متعمقة للدراسات السابقة. تم إجراء استبيان باستخدام مقياس ليكرت الخماسي للأهمية. تم تقسيم معايير الأداء الـ ٢٨ إلى ٤ فئات (اقتصادية ، وبيئية ، واجتماعية ، وتقنية). استهدف الاستبيان ممارسي بناء المساكن المصريين من مهندسين ومعماريين ومصممين ومقاولين ... إلخ. وجد المؤلفون أن أهم المعايير تنتمي إلى الفئات الاقتصادية والاجتماعية والتقنية. جاءت المعايير البيئية في المرتبة الأدنى بين المعايير. وعلى الرغم من ذلك ، كانت مؤشرات الأهمية النسبية لجميع المعايير البيئية أعلى من النطاق المتوسط. يشير ذلك إلى الاهتمام المتزايد من جانب ممارسي بناء المساكن المصريين بالجوانب البيئية.

الكلمات المفتاحية : نظام تشييد الإسكان المصري, الإستدامة, معايير الأداء.

1. INTRODUCTION

The housing construction sector is one of the main drivers of economic, social, and environmental development in Egypt. Housing not only provides shelter but also, strengthens the local communities and gives the sense of future security [1]. However, the Egyptian housing construction sector has faced many challenges in the last few decades because of the rapid growth of population that has exceeded the border of 100 million with a 2.13% annual growth rate and a 32.5 % poverty rate in 2018 [2] in addition to, the increase in the informal poor areas [3]. The current and future housing needs in Egypt were estimated at 7.5 million units, with an average annual need of 470,870 units over the period (2007-2022) [2]. With the serious tries in Egypt to improve the environmental aspect, the construction sector was found greatly responsible for the greenhouse gas "GHG" emissions, air pollution, energy consumption, resource depletion, waste production [4]. Central Agency for Public Mobilization (CAMPS) reported that the Egyptian building and construction sector is producing about 6 million tons/ year of solid waste in 2016 [5]. Shamseldin also, showed that the construction sector is one of the most energy-consuming sectors as it consumes 15% of the total energy in developing countries [6]. Since over 70% of buildings in Egypt are residential, the development in housing construction will have positive effects on society and the environment [5]. Therefore, the strategy of Egypt's vision 2030 has robustly adopted improving the housing construction sector. The government announced in this vision its commitment to achieve sustainable development goals in the housing sector (i.e., citizens have a right to adequate housing). It expands building new cities guided by principles of sustainability to achieve the greatest profit and value to provide the present needs with maintaining the limited resources to meet the need of the future generation. The vision also confirmed the necessity to achieve the balance between demand and supply of housing and reduce the number of people living in unsafe areas [7, 8]. Abdallah stated that Egypt needs to go towards modern construction systems, explore the latest construction technologies, and create innovative sustainable building systems. That has the potential to bring high-performance affordable housing within reach [9]. Lately, prefabricated housing construction systems have been highlighted as a promising and sustainable eco-friendly innovation because of their various advantages such as; reducing construction waste & construction time, improving energy &materials consumption, workers' safety &health [10, 11]. However, there is no clear vision to evaluate the impact of using such new construction methods in building Egyptian housing [12]. The decision to adopt new construction methods for building Egyptian housing is considered a big challenge for stakeholders. Defining the decision criteria to assess these construction methods is considered a crucial factor to make a reliable decision, as well [13]. In the Middle East, the key performance criteria to select the appropriate construction method for the construction buildings projects are only based on its ability to reduce cost, ease of construction, and availability of experience and skills [14]. That is not enough to make a robust decision. Therefore, decisions to adopt these new construction systems should be subjected to the holistic performance concept that depends on technical, functional, economic, aesthetic, social, and environmental considerations [12]. With the heightened awareness of the positive effects of applying sustainability principles, these principles have become the best potential performance to make an effective decision [13]. This research aims to define comprehensive performance criteria (decision criteria) that control the selection of the appropriate construction systems for building Egyptian housing.

2. METHODOLOGY

To achieve the research objective, the methodology of this study was conducted through the next developed steps as shown in **Fig. 1.**

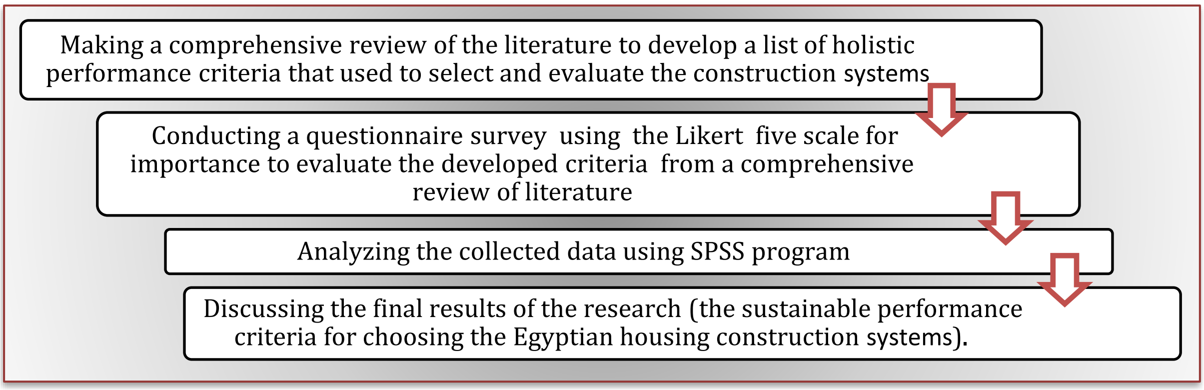

Fig.1: Research Methodology

2.1. Exploring Criteria Related the Selection of Housing Construction Methods

To check the effectiveness of using any construction system, it is important to define holistic performance criteria. The assessment and acceptance of these construction systems are based and agreed with the organization's vision and achieve its desired mission. Egypt's vision 2030 showed that sustainability indicators are the major framework of the Egyptian housing prospective vision. Hence, the affordability to meet the demand for adequate housing is its pivotal mission [7]. Thus, to enhance the application of sustainability for Egyptian housing, the Ministry of Housing Utilities and Urban development in 2019 published an approved act to work using the green pyramid rating system "GPRS" to assess buildings sustainability [14]. The evaluation using GPRS was divided into seven categories with a specific weight for every category, including sustainable site, accessibility, ecology 15%, energy efficiency 25%, water efficiency 30%, materials and resources 10%, indoor environmental quality 10%, management, innovation and added value bonus 10% [15]. Despite the importance of structural design performance, it was neglected in the green pyramid rating system. Chaudhary and Piracha said that the aspects that related to the structural design such as the used material, robustness of the structure and resilience to disasters, structural adaptability and reuse, durability, and longevity can help to achieve sustainability goals because of its substantial impact on materials, resources, environment, and energy. In addition, the efficient design of the structural system help to improve the financial aspect of the building cost [16]. Bansal et al. stated that holistic criteria should be employed to capture sustainable performance when evaluating and selecting construction methods [13]. Literature has shown that many diverse criteria were developed by researchers around the world to assess different alternatives of construction methods as shown in **Table 1.**

Table 1: The Latest Significant Studies of Performance Criteria for Selection Construction Methods**.**

Author, country	Criteria
Chen et al. [17] ▪ U.S	• Economic criteria; construction time, initial construction costs, constructability, material costs, lead-times, loading capacity, durability, labor costs, the speed of return on investment, integration of building services, life cycle costs, defect and damage, maintenance cost, integration of supply chains (logistics), flexibility (adaptability), disposal costs, • Environmental criteria; energy efficiency in building use (thermal mass), recyclable/ renewable contents, site disruption, construction waste, energy consumption, reusable/recyclabl elements, material consumption, pollution generation, water consumption • Social criteria; workers' health and safety, aesthetic options, health of occupants (indoor air quality), physical space, Labor availability, community disturbance, traffic congestion, influence on job market.
Yunus &Yang [18] ▪ Malaysia	• construction time, production, waste generation, constructability, knowledge and skills, defect and damages, labour cost, waste disposal, procurement system, durability, working condition, standardization, usage efficiency, labour availability, material consumption, legislation, project control guidelines, maintenance operation costs
Agrama et al. [19] ▪ Egypt	• Construction Cost, Design efficiency, Finance, Resource availability, Implementation Time, Ease of Construction, Maintenance cost, Service Life
Shahat et al. [20] ▪ Egypt	• Economic and financial criteria; project budget, net present value which considers project life cycle cost, Payback period, Market supply and demand, benefit/cost ratio, financial risk. • Environmental criteria: Energy saving, water use efficiency, friendly material, waste management (reuse, reduce, recycle), Effects on air quality, Using renewable energy, Reduction land pollution, Reduction noise pollution. • Social criteria: improvement to achieve occupant productivity, Safety standards, effects of local development, improvement the public health, human rights and conformability, Cultural and heritage conservation
Kamali & Hewage [21] ▪ Canada	• Economic criteria; design and construction time, design and construction costs, operational costs, maintenance costs, end of life costs, durability of the building, investment and related risks, flexibility, integrated management. • Social Criteria; health, comfort and well-being of occupants, influence on the local economy, functionality and usability of the physical space, aesthetic options and beauty of the building, workforce health and safety, community disturbance, influence on local social development, cultural and heritage conservation, affordability, safety and security, user acceptance and satisfaction, neighborhood accessibility and amenities • Environmental criteria; site selection, alternative transportation, site disruption and appropriate strategies, renewable energy use, energy performance and efficiency strategies, embodied energy, water, and wastewater efficiency strategies, regional (local) materials, renewable materials, waste management, greenhouse gas emissions, material consumption in construction

Daget & Zhang [22] ▪ Addis Ababa-Ethiopia	• Expertise and experience, Construction proficiency, sustainability features, financial conditions, culture and acceptance, structural and behavioral factors, investment, Flexibility, Regulatory laws, Affordability, efficiency, waste disposal, Quality

Finally, based on the review of all these previous studies the author developed 28 criteria including 8 economic criteria, 4 criteria social, 8 environmental criteria, and 8 technical criteria to design the questionnaire of the study as shown in **Table2.**

Table 2: The preliminary developed performance criteria to evaluate construction methods

Decision Criteria		Code	Definition
Economic Criteria	1. Construction Cost	(CC)	It comprises the total cost of preconstruction and construction operations like; drawings, materials, workforce, transportations, site overhead, etc., until the final completion of the product.
	2. Construction Duration	(CD)	The total time that is taken in design and construction (e.g., design, planning, constructing, or manufacturing installation until finishing).
	3. Maintenance Cost	(MC)	The cost of repairing and maintaining the building during the use phase to restore the required performance.
	4. Disposal Cost	(DC)	Cost of demolition, dismantling and waste treatment.
	5. Affordability	(A)	The financial ability of the users/clients to afford the cost of purchasing or renting the unit.
	6. Speed of return on investment	(IR)	The speed to pay back the invested money and the return on it.
	7. Resource availability	(RA)	The possibility to find any needed element or thing within the region to complete the construction process efficiently such as; materials, equipment, skilled workers, etc.
	8. Structure future value	(FV)	It measures how much the given construction will be worth at a specific time in the future (financial value).
Social Criteria	9. Previous experience of practitioners and knowledge availability	(EK)	The level of previous experiences of practitioners in dealing with different construction methods.
	10. Influence on job market	(JM)	To what extent the industry can provide more stable jobs or decrease job opportunities
	11. Customer acceptance and perception	(CP)	It describes to what extent customers can accept the construction system to be used in building housing
	12. Health &safety of workers	(HS)	The risks related to health and safety that workers' exposure in the workplace (e.g., injuries, damages, or death)
Environmental Criteria	13. Efficiency of Energy consumption	(EEC)	The amount of the used energy during the construction phase such as electricity, petrol, etc.
	14. Efficiency of Water consumption	(EWC)	The amount of the used water during the construction phase
	15. Efficiency of Materials consumption	(EMC)	The amount of fabricated, natural or any type of materials that used in the construction

	16. Use Eco-friendly materials	(EFM)	The materials that can reduce the construction impacts on the environment (i.e., reduce the depletion of finite raw material, it can be reused again at the end of its life cycle)
	17. Waste reduction	(WR)	The amount of remaining, unwanted and wasted materials after the construction process
	18. Pollution generation reduction	(PGR)	It describes the negative environmental emissions such as; noise, air pollution from CO2 or other gas emissions, dust, etc.
	19. Efficiency of acoustic insulation	(AI)	The ability of the construction components to insulate sound
	20. Efficiency of construction thermal conductivity	(ETC)	The ability of the construction components/ elements to absorb heat and keep it
Technical Criteria	21. Standardization availability	(S)	It describes the availability of local specifications, building codes, and standards guides to create a safe, quality, durable, and approved building.
	22. Loading capacity	(LC)	It describes the construction's ability to withstand various loads without breakdowns (its weight, people, winds, earthquakes, etc.).
	23. Life spans	(LS)	The expected service life of the structure during normal or low maintenance
	24. Construction quality control	(QC)	The ability to achieve the required specifications without causing any damage or defects to the building during the construction phase until the completion.
	25. Constructability	(C)	It describes the efficiency and quality of the design to ease building the structure and reduce or prevent mistakes, delays, and cost overruns.
	26. Flexibility to modify	(F)	The ability to make changes on design during and after construction phase
	27. Building's aesthetic options	(BAO)	The various design choices to the building appearance that achieve the internal or external beauty for the building
	28. Transportation constrains	(TC)	The ability/ease to transport materials, construction components, equipment, etc., to the construction site

2.2. Conducting the Research's Questionnaire Survey

After reviewing the previous studies related to the performance criteria to choose construction methods and examining a set of published and attached questionnaires by previous studies at the same specialized, a questionnaire was designed for this study based on the obtained information from these previous studies. The questionnaire aimed to evaluate the developed performance criteria for the selection of Egyptian housing construction systems. The Likert five-scale of importance was used to evaluate the criteria where 1=very low importance, 2=low importance, 3= important, 4=important, and 5=very important. The interactive Google electronic form was used to design the questionnaire. The questionnaire was divided into three parts; the first part contains a full description of the purpose of the questionnaire and the way to answer the questionnaires' questions, in addition, a commitment from the researcher to keep the participants' personal data, the second part is asked about general information of participants like; name, age, level of education, profession and company name. The third part was concerned with the main aim of the questionnaire i.e., evaluation of the performance criteria for choosing Egyptian housing construction systems. The questionnaire left an area and encouraged the respondents to submit any other suggestions about other performance criteria to obtain comprehensive knowledge. The questionnaire targeted the experienced Egyptian construction practitioners from engineers, architects, contractors, consultants, researchers, academicians, etc., especially Egyptian housing builders' who have experience and are familiar with both traditional and prefabricated housing construction methods. However, prefabrication was found in Egypt but in a limited context [23]. Therefore, it is necessary to carefully select the participants of the questionnaires to ensure getting valuable outcomes to support the study. For the research sample size, Singh and Masuku stated that researchers should choose an adequate size for the sample as it represents the entire population [24]. Kamali and Hewage showed that the sample size in literature is commonly calculated and used at a 95% confidence level and 5% margin of error [22]. According to the published table by Singh & Masuku, and Krejcie &Morgan in the case of the population that more than 1000 to 10,000 the sample size is taken in the range from 280 to 385, and if the population exceeds 100,000 the sample size reaches 400 at 95% confidence level and 5% of margin of error [24, 25]. Also, the sample size according to Cochran's equation 1963 at a 95% confidence level and a 5% margin of error is estimated by 385. Therefore, the sample size of this research was determined as 385[24]. To reach the targeted participants on the questionnaires, the researcher depended on deep research in the scientific web databases and pages that interested in the construction world and previous reviews to gather information about Egyptian academicians, researchers, organizations, pioneers that have good knowledge of habitations construction, prefabricated housing construction methods, and sustainability. The researcher also tended to some government agencies such as; Egyptian national housing and building research center (HBRC), Egyptian Federation Construction and Building Contractors, the academy of scientific research& technology, and some of the academicians from engineering colleges. The questionnaire was distributed by sending it via email and by mobile applications like; WhatsApp, Linkedin, and Facebook. Also, the researcher printed the questionnaire and delivered it by hand to some of the participants.

2.4. Methods of Data Analysis

The study used SPSS program to analyze the collected data depended on imitating similar previous studies (e.g., Akadiri et al. [26]; Chen et al. [17]; Kamali and Hewage [22]) which used the analysis of Cronpah's alpha coefficient to check reliability and the relative importance index to make the ranking analysis to rank order the criteria. These analyses were found suitable to analyze the collected data to obtain and discuss the final results of the evaluation of the performance criteria in a simplified form.

3. Data Analysis Results and Discussion

3.1 Participants' Demographic Data

After the questionnaires were delivered to the participants, 4 reminders were sent for the participants because the rate of response was very slow.102 responses to the questionnaire were returned. Only 90 responses were accepted for analysis and the rest of the questionnaires were refused because of some reasons like; giving the same degree to all the criteria, and the participant didn't complete the questionnaire. The analysis found that 87.8% of respondents were civil engineers and 12.2% were architects with different occupational positions as shown in **Fig.2**. Most of the respondents were obtained additional educational degrees higher than the bachelor where 32.22% of them obtained a doctorate "Ph.D.", 12.22% had a master "MSC", 3.33% got a master’s in business administration "MBA", and 5.56% had a diploma while 46.67% had a bachelor. For the years of experience, the analysis found that more than half of the participants (52.88%) have experience more than 16 years while the percentage of participants with 7-10 years of experience was 31.11% and the percentage of participants with 11-15 years of experience was 16.67% as shown in **Fig.3**. This diversity of the participants' level of experiences, jobs, and level of education can help to ensure obtaining a holistic list of criteria.

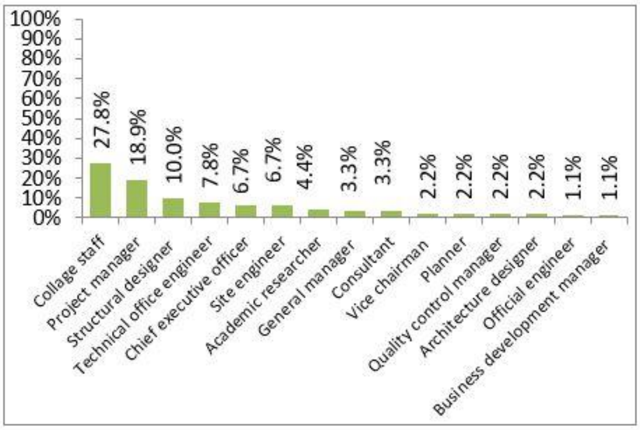

Fig. 2: Participants' Job Description

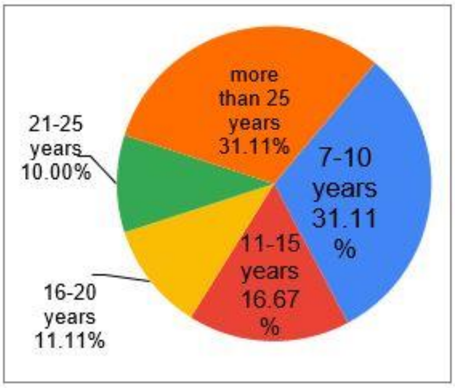

Fig. 3: Participant's Years of Experience

3.2. RELIABILITY ANALYSIS OF THE QUESTIONNAIRE.

The reliability analysis of Cronpah's alpha coefficient was used to examine the internal consistency to make sure that the responses on the questionnaire scale (5 likert scale) give the same results over time if it is repeated another time [22, 23, 27]. The value of Cronbach's Alpha of the reliability test is in the range from 0 to 1. All values of alpha that are from .7 to 1 are acceptable. The more increase of Cronbach's Alpha value to be more than .7 and closer to 1 the more increasing in internal consistency of the questionnaire's responses [22, 23, 27]. The reliability analysis of this questionnaire was performed 5 times where four times were performed based on the criteria category and the fifth one was performed for all the categories together. All Cronbach's Alpha values were found more than 0.7 so they are acceptable and the internal consistency of all the criteria, in general, is considered excellent as it is close to 1. See **Table 3.**

Table 3: Cronbach's Alpha Values of Reliability Analysis of The Decision Criteria

Cronbach's Alpha values according to 28 criteria and 4 category				
Valid Responses of Questionnaire N=90				
Economic (8 items)	Social (4 items)	Environmental (8 items)	Technical (8 items)	Total Categories (28 items)
0.732	0.708	0.819	0.809	0.903

3.3. RANKING ANALYSIS

This analysis was used to rank order the developed performance criteria according to their importance based on the relative importance index (severity index in other studies) since the scoring system of the Likert scale was ordinal in nature. The relative importance index can be calculated according to the next equation [22, 23, 27];

$$\text{Relative Importance Index (RII)} = \left(\sum_{i=1}^{5} \boldsymbol{wi} * \left(\frac{fi}{n}\right) * \mathbf{100}\right) / (\boldsymbol{a} * \mathbf{100}) \qquad \text{Eq. (1)}$$

Where; i =the point given to each criterion by the respondent ranging from1 to 5, wi = the weight that the participants were given for each criterion, fi = the number of responses of each weight of the scale on each criterion, n = the total number of responses, $\boldsymbol{a}$ = the highest weight, in this study, $\boldsymbol{a}$ =5. The 5 points importance of the Likert scale were transferred into 5 relative values on an interval where; Low (L): 0<RII ≤0.2, Medium–Low (M-L): 0.2<RII≤ 0.4, Medium (M): 0.4<RII≤ 0.6, High–Medium (H–M): 0.6≤ RII≤0.8, High (H): 0.8<RII≤1 [22, 23, 27]. The ranking analysis of the criteria was presented in descending order for the overall categories as shown in **Fig. 4** and ranking by category in **Tables 4, 5, 6 and 7.**

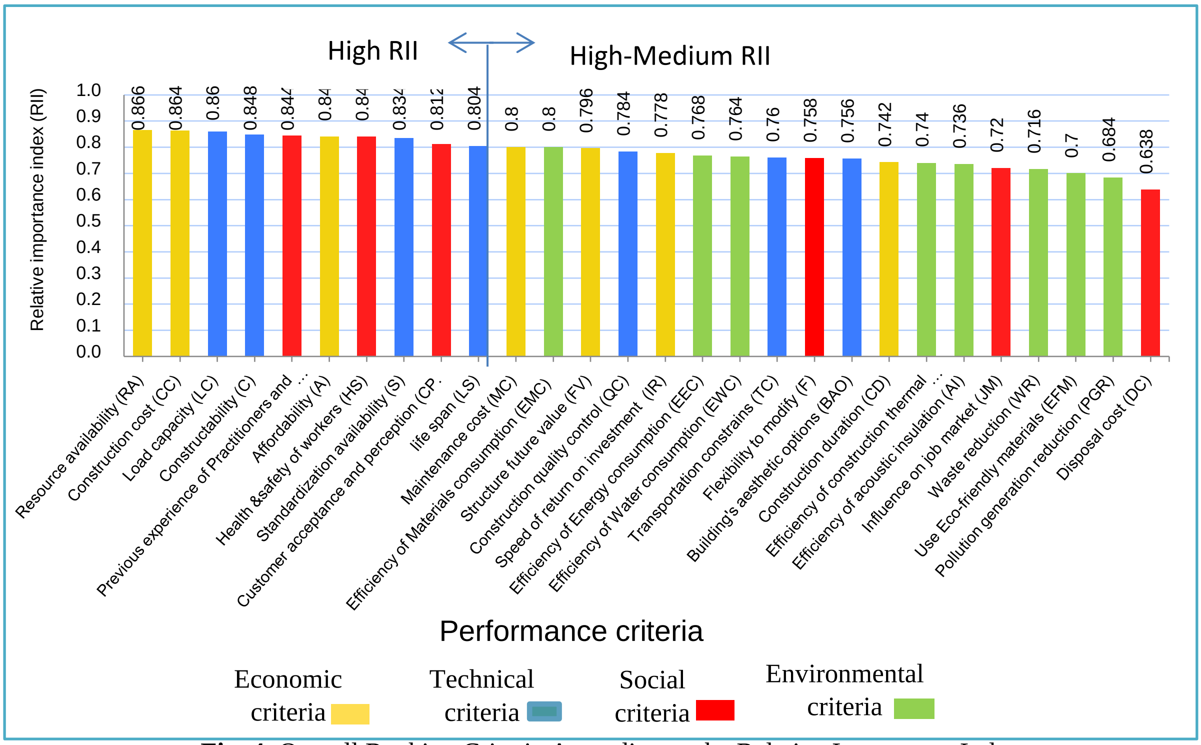

Fig. 4: Overall Ranking Criteria According to the Relative Importance Index

3.3.1. Economic Criteria

The ranking analysis showed that the most important economic criteria that were highlighted by Egyptian construction practitioners participated in the questionnaire were resource availability (RA), construction cost (CC), affordability(A) with a high range of relative importance index of 0.866, 0.864, and 0.840 respectively. The resource availability (RA) and construction cost (CC) criteria also were ranked the highest among all over the 28 developed criteria. The rest of the economic criteria were found to belong to the high–medium range of relative importance. The maintenance cost criterion was ranked as the highest criterion in the high-medium range group in the economic criteria category and among all the criteria with 0.8 of relative importance; it is nearly close to the range of criteria with the highest relative importance index. Despite the importance of the time factor to the housing construction sector in Egypt due to the backlog in affordable housing construction, the construction duration criterion was rated in the last two economic criteria in relative importance and in the lowest criteria among all 28 developed criteria when evaluating construction systems. While the last ranked criterion was the disposal cost criterion in the economic criteria and all the developed criteria. See **Table 4.**

Table 4: Ranking Analysis of Economic Criteria

Economic Criteria	Relative importance index (RII)	Level of importance	Ranking by category
1. (RA)	0.866	H	1
2. (CC)	0.864	H	2
3. (A)	0.84	H	3
4. (MC)	0.8	H-M	4
5. (FV)	0.796	H-M	5
6. (IR)	0.778	H-M	6
7. (CD)	0.742	H-M	7
8. (DC)	0.638	H-M	8

3.3.2. Social criteria

Three of the four social criteria including previous experience and knowledge availability, health safety of workers, and customer acceptance &perception (CP) were found through the analysis placing in the high range of the relative importance index with values of 0.844, 0.840, and 0.812, respectively which indicating their importance in the perception of the Egyptian construction practitioners in evaluating construction systems. For the fourth social criterion of the influence on the job market (JM), it was assigned in the lowest criteria of the high-medium range of the relative importance index with a value of 0.72. See **Table 5**.

Table 5: Ranking Analysis of Social Criteria

Social Criteria	Relative importance index (RII)	Level of importance	Ranking by category
1. (EK)	0.844	H	1
2. (HS)	0.84	H	2
3. (CP)	0.812	H	3
4. (JM)	0.72	H-M	4

3.3.3. Environmental criteria

All the environmental criteria were assigned in the high-medium range of the relative importance index. However, they have recorded the lowest score among all the 28 developed criteria except the environmental criterion of efficiency of materials consumption was highlighted because it was almost close in its rank to the most important ten criteria, this criterion is related directly to the construction cost. In general, the top-rank criteria in the environmental category criteria were; Efficiency of Materials consumption (EMC), Efficiency of Energy consumption (EEC), and Efficiency of Water consumption (EWC) with relative importance index values of 0.8, 0.768, and 0.764. Despite Egypt suffering from the effect of the huge amount of construction waste on the environment, the waste reduction criterion was ranked in the lowest criteria in importance among the environmental criteria and in the total 28 criteria overall ranking. See **Table 6.**

Table 6: Ranking Analysis of Environmental Criteria

Environmental Criteria	Relative importance index (RII)	Level of importance	Ranking by category
1. (EMC)	0.8	H-M	1
2. (EEC)	0.768	H-M	2
3. (EWC)	0.764	H-M	3
4. (ETM)	0.74	H-M	4
5. (AI)	0.736	H-M	5
6. (WR)	0.716	H-M	6
7. (EFM)	0.7	H-M	7
8. (PG)	0.684	H-M	8

3.3.4. Technical criteria

The analysis found that the technical criteria of load capacity (LC), constructability(C), standardization availability(S), life spans (LS) were set in the highest range of the relative importance index with values of 0.860, 0.848, 0.834, and 0.804 respectively. Also, the load capacity (LC), constructability(C) criteria were recorded the third and fourth rank respectively between the overall 28 developed criteria while standardization availability (S) and life spans (LS) criteria were recorded in the eighth and tenth rank. For the rest four criteria of the technical category, they were found to belong to the high–medium range of the relative importance index. Although the crucial role of flexibility to modify(F) criterion, it was ranked the penultimate level of importance among the technical criteria and the twentieth level among all the 28 criteria. See **Table 7.**

Table 7: Ranking analysis of technical criteria

Technical Criteria	Relative importance index (RII)	Level of importance	Ranking by category
1. (LD)	0.86	H	1
2. (C)	0.848	H	2
3. (S)	0.84	H	3
4. (LS)	0.8	H-M	4
5. (QC)	0.796	H-M	5
6. (TC)	0.778	H-M	6
7. (F)	0.742	H-M	7
8. (BAO)	0.638	H-M	8

Conclusion

There are many construction systems either traditional or prefabricated ones. In Egypt, there is no clear vision to make effective decisions for the most sustainable construction systems to select the appropriate ones. The decision is often based on construction cost without checking the different aspects of the construction systems' performance. This research has developed 28 performance criteria based on the sustainability concept to control evaluating construction systems suitable for the Egyptian environment. These developed 28 performance criteria were divided into four categories, which are economic, environmental, and technical with 8 criteria for each category, and social category with 4 criteria. A questionnaire survey was conducted to evaluate these criteria and targeted the Egyptian housing construction practitioners with different occupational positions from architects, designers, contractors, etc. The ranking analysis using the relative importance- index found that 10 criteria from the 28 criteria have placed in the high range of the relative importance index and the rest of the criteria were placed in the high medium range. These 10 criteria were highlighted by the Egyptian construction practitioners as the most important criteria when control the selecting and evaluating housing construction systems. They belonged to the economic, technical, and social categories which are resource availability (RA), construction cost (CC), load capacity (LC), constructability (C), previous experience and availability of knowledge (EK), affordability (A), health safety of workers (HS), standardization (S), customer acceptance, and perception (CP), life spans (LS). For the environmental criteria, it is found that most of these criteria have taken the lowest ranks in relative importance index values among all the developed criteria except the efficiency of materials consumption as it is almost close in its rank to the most important ten criteria. Despite the dominance of the economic and technical criteria on the top ranks in relative importance, social criteria have greatly attracted the attention of construction practitioners. In general, 28 developed criteria are belonged to the high and high-medium range of the relative importance index. That indicates the increasing interest of construction practitioners in achieving sustainable performance in housing construction. These sustainable developed criteria will induce authors to use them for making a better decision in evaluating different alternatives of the housing buildings construction systems. So, this research will be extended to evaluate the adoption of prefabricated construction systems in addition to traditional ones in building Egyptian housing.

REFERENCES

1. Everhart, S., Heybey, B., Carleton, P. (2006). Egypt: Overview of The housing Sector. Housing Finance International, Vol. 20 (4), 9.
2. Egypt-un-Habitat, 2018,[Cited June 2020]. Egypt Housing Profile 2018 [Online]. Available At: <https://unhabitat.org/sites/default/files/download-manager-files/1525977522wpdmEgyp t%20housing%20ENHighQ_23-1-2018.pdf>.
3. Built Environment Deprivation Indicator (BEDI), Affordability. [Cited June 2020], [On Line]. Available At: <https://10tooba.org/bedi/en/affordability/>
4. Abd El-Hameeda, A. K., Mansourb, Y. M., & Faggalc, A. A. (2017). Challenges and Issues for Affordable Housing in Egypt: A Review. Ain Shams University mimeo.[Online]. Available At: <https://www.researchgate.net/publication/320183965 Challenges and Issues for A ff ordable_ Housing_in_Egypt_A_Review>.
5. CAPMAS, 2016 (Central Agency For Public Mobilization) ,[Cited Apr 2020]. The Statistical Yearbook – Environment 2016 [Online]. Available At: <https:// www.capmas.gov.eg/Pages/Pu blications.aspx?page_id=5104&YearID=23371>
6. Shamseldin, A. (2003). Energy Consumption during The building Construction Phase. M.Sc. Thesis, Architecture Engineering, Ain Shams University, Egypt. (2003).

7. Egypt Vision 2030, [Cited Jan 2019], [Online]. Available At :< https://www.greengrowthknowledge.org/national-documents/sustainable-development-strategy-egypt-vision -2030 >.
8. Egypt's Voluntary National Review. 2018, EGYPT Vision 2030, [OnLine]. Available At: < https://sustainabledevelopment.un.org/content/documents/20269EGYVN R2018 _final with _Hyperlink_9720185b45d.pdf>.
9. Abdallah, A. (2007). Relevant Codes and Regulations: Effects On The Design Of Industrial Construction. Technological and Economic Development Of Economy, 13(3), 215-222.
10. Brandon, P., Hampson, K. D. (2004). Construction 2020-A Vision For Australia's Property And Construction Industry. (CRC) Cooperative Research Centre for Construction Innovation.
11. Jaillon, L., Poon, C.S. (2008). Sustainable Construction Aspects Of Using Prefabrication In Dense Urban Environment: A Hong Kong Case Study, Construction Management And Economics, 27(9),953-965.
12. Khafajy,A., Hussain,A., Abood,A. (2018). Building Performance: A Study for Evaluating Prefabricated Residential Buildings Performance El-Salam Neighborhood. Iraqi Journal of Architecture and Planning.
13. Bansal, S., Biswas, S., & Singh, S. K. (2017). Fuzzy decision approach for selection of most suitable construction method of Green Buildings. International Journal of Sustainable Built Environment, 6(1), 122-132.
14. Egyptian waqaa Gazette, act No.294 of 2017. Published in No.85 of 11 April 2019.
15. Green pyramid rating system, 2011, HBRC. Egypt.
16. Chaudhary, M. T. A., & Piracha, A. (2013). Examining the role of structural engineers in green building ratings and sustainable development. Australian Journal of Structural Engineering, 14(3), 217-228.
17. Chen, Y., Okudan, G. E., Riley, D. R. (2010). Sustainable Performance Criteria for Construction Method Selection In Concrete Buildings. Automation in Construction, 19(2), 235-244.
18. Yunus, R., Yang, J. (2012). Critical Sustainability Factors In Industrialized Building Systems, Construction Innovation, 12(4): 447-463.
19. Agrama, F. A., Abdo, M. A. & Al-Nemr, M. T., (2014). Value engineering for low-cost housing construction in Egyptian expansion urban. Advanced Research in Engineering Sciences “ARES, 2(2), 1-6.
20. Shahat, S. (2016).Management And Assessment Model For Sustainable Construction Project During Feasibility Stage, In Proceeding Of: 1st International Conference On Sustainabale Construction And Project Management. Hbrc. Egypt.
21. Kamali, M., & Hewage, K. (2017). Development of performance criteria for sustainability evaluation of modular versus conventional construction methods. Journal of cleaner production, 142, 3592-3606.
22. Daget, Y. T., & Zhang, H. (2018). Decision-making for evaluation and selection of suitable industrialized housing system. International Journal, 15(50), 167-173.
23. Mostafa, S., Dumrak, J., Chileshe, N., & Zuo, J. (2014, November). Offsite manufacturing in developing countries: current situation and opportunities. In The 5th International Conference on Engineering, Project, and Production Management.

24. Singh, A. S., & Masuku, M. B. (2014). Sampling techniques & determination of sample size in applied statistics research: An overview. International Journal of economics, commerce and management, 2(11), 1-22.
25. Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. Educational and psychological measurement, 30(3), 607-610.
26. Akadiri, O. P. (2011). Development of a multi-criteria approach for the selection of sustainable materials for building projects. University of Wolver Hampton, UK (Doctoral dissertation, PhD Thesis).