Infrastructure Projects for Green Cities between Implementation Challenges and Efficiency Indicators

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Abstract The world's population will be 9.2 billion in 2050, which is 2.2 billion more than today, with most of the increase in Africa, the Middle East, and South Asia. That will negatively affect the availability of arable land, infrastructure, and environmental performance of cities, furthermore, achieving sustainability pillars (environmental, economic, social) becomes mandatory for all countries after signing in the recommendation of the 2015 UN Summit, many initiatives and concepts were adopted to face these challenges and accomplish sustainable development. The green cities concept (GCC) and its strategies are considered an optimum approach to achieve sustainable development objectives and overcome these challenges, by enhancing performance for the existing infrastructure, reducing natural resource consumption, decreasing CO_2 emission, and engaging citizens in decision-making. On another hand, infrastructure projects are vital for achieving (GCC) concept because it reflects the progress and economic performance of countries. This study discusses the green cities, conventional and green infrastructure challenges, then presents Public-Private Partnership (PPPs) as a tool for implementing and overcoming its challenges from the green economy and green contracts perspectives. In addition, concluding an Operational Framework for implementing infrastructure projects by (PPPs) which determines the main phases in (PPPs), allocates the most important strategies for each phase, and indicates the main internal stockholders who share in decision-making. Finally, the study assigns (53) efficiency indicators and obtains a weight for each indicator by identifying the Relative Importance Index through an online questionnaire evaluated by (15) experts to track the achievement of the operational framework.

Keywords Infrastructure Projects, Green Cities, Implementation Challenges, Efficiency Indictors

1. Introduction

Regarding the 2015 UN summit under title (Transforming our world: Sustainable Development plan 2030) recommendations, which adapted 17 goals [1], the newly agenda concentrates on issues related to sustainable urbanization within specific a goal as: (Goal 11) "make cities and human settlements safe, inclusive, resilient and sustainable and strengthen implementation of the international partnership (Goal 17). As well, a number of other goals are related to this issue, those on clean water and sanitation (Goal 6), and affordable and clean energy (goal 7). In fact, most of the countries adopted different initiatives to achieve this agenda. Green Cities Concept (GCC) and its strategies are considered an optimum approach to achieve sustainable development objectives and overcome these challenges, where, The (GCC) not only affects the urban development growth but also the economic and social growth of the cities as by its aspects which aim to achieve a reduction in natural resources and

energy consumption, decrease CO2 emission, promote infrastructure projects, in addition, enhance social equity, encourage civil society participation in decision making. Also, it opens the way for the development of other concepts such as green infrastructure, and green economy. From another hand, and to achieve (GCC) concept, infrastructure development becomes certain because it reflects directly the overall sustainable development pillars, however, various challenges are associated with implementing this approach, the most important challenges related to the development and establishment of infrastructure projects are funding and technology. The governments recognize that gate to bridge these challenges is the partnership with the private sector as a smart substitute to develop and expand the resource of infrastructural facilities through the green Public-Private Partnership (PPPs) approach. The study presents an Operational Framework for implementing infrastructure projects by (PPPs) which determines the main phases in (PPPs), allocates the most important strategies for each phase, and indicates the main internal stockholders who share in decision making. Finally, the study assigns (53) efficiency indicators and obtains a weight for each indicator by identifying the Relative Importance Index through an online questionnaire evaluated by (15) experts to track the achievement of the operational framework.

2. Research Objectives and Methodology

As a result of the rapid growth of the world population and to achieve the (17) goals of the UN summit (transforming our world), the world governments adopted many concepts and strategies to achieve sustainable development, green cities concept is one of the initiatives which could participate in promoting the sustainable development pillars.

2.1. Research Objectives

This study is carried out to discuss the green cities concept, starting from its definitions, implementation strategies, and challenges, also, suggest operational framework and efficiency indicators to improve the effectiveness of executing infrastructure projects and measure its performance, whether conventional or green through (PPPs).

2.2. Research Methodology

The research focuses on three axes, **(A)-**The first axis is a literature review by: identifying green cities, introducing infrastructure implementation challenges for green cities using the inductive method. **(B)-**The second axis is suggesting an operational framework for infrastructure

implementation; it was concluded from the literature review analysis using the analytical method. **(C)-**The third axis is collecting the data: a quantitative study based on a surveying technique (online questionnaire) prepared by the authors, the study summarized (53) indicators, classified on (38) indicators related to the green city concept, and (15) related to the potential risks. After selecting the indicators, an online questionnaire is prepared and evaluated by (30) experts specialized in environmental planning and project management as illustrated in **Table(1)** to obtain a weight for each indicator by identifying the Relative Importance Index.

Table 2.   Participant of online questionnaire

Participants	Number
Academic stuff	6
Environmental planning professional	9
NOGs	4
Regional authorities	3
Central authorities	5
Project manager (developers)	3
Total	30

Source: by the author

3. Literature Review

3.1. Green Cites

There are many initiatives for the green cities concept (GCC) mentioned in the literature reviews, most of them concentrate on the environmental treatments to reduce the environmental impact on the urban spaces[2], nowadays another definition is associated with green " green means different things to different peoples"[3]. In this study, we adopt a comprehensive definition for green cities as "cities that have already achieved or are going toward environmental, social, and economical sustainable development in all of its aspects"[4] by enhancing performance for infrastructure, reducing costs and resource consumption, and engaging citizens and civil society in decision making. On the other hand, the implementation of (GCC) requires strategies to carryout, which must reflect the three pillars of sustainability, therefore, the most important strategies are:
- Strategies related to the environmental pillar as: (a) energy consumption and co2 emission, (b) water conservation, (c) waste management, (d) air quality, (e) land use, *green* infrastructure, and (f) public transport **[5,6]**.
- Strategies related to the economical pillar as: (a) *green* economic, (b) *green* contracts approach, (c) infrastructure risk management, and (d) private sector participation.

● Strategies related to the social pillar as: (a) governance, and (b) citizens health,

In fact, to foster such strategies, four principles must be applied, *the first* is (Reuse, Reduce, Recycle, and Recovery) or (4R) for resources[7], *the second* is information, communication, and technology (ICT) approach for infrastructure development [8], *the third* is science, technology, and innovation (STI) instead of value for money (VFM) in evaluation the projects especially infrastructure projects[9], *the fourth* is "use less and do more" [10].

3.2. Infrastructure for Green Cities

Indeed, Infrastructure projects are considered the main approach to achieve sustainable development [11], and the indicators related to infrastructure growth reflect directly the progress and economic performance of countries. However, there is no unique definition of infrastructure across urban or economic studies, because each study defines and classifies infrastructure according to the nature of its effect, most of the literature reviews especially in urban studies define infrastructure as the basic public capital which provides essential needs, and services or solves problems for specific society[12], regarding this definition infrastructure can be classified: *economic* infrastructure, directly promotes productive activities like (water network, sewer network, roads, railways, airports,…..), and *social* infrastructure, directly improves the social comfort and to enhance the economic productivity like (schools, hospitals, green areas, planet of waste disposal,….) [13]. In parallel, and to achieve sustainability pillars, environmental infrastructure terminology was emerged as a sub-dimension under social infrastructure classification in 2006 by the Italian national institute of statistics (ISTAT)[14], and it includes (waste disposal, green areas, water purification planet).

Furthermore, and with the rapid growth of communities and to reduce the accelerated consumption of open land (parks and green area), a new term was introduced as a strategic approach for land conservation for green cities, this term is green infrastructure.

Green infrastructure benefits have expanded during the last decade to include [15,16,17]:
● link parks and other green spaces for people benefits,
● promote smart conservation and smart growth,
● protect and restore naturally functioning ecosystems,
● support a diversity of economic, ecological, and social functions,
● provide cleaner air and improving water quality, therefore, improve health,
● promote collaborative partnerships,
● reduce combined sewer overflow (CSO),
● flood mitigation,
● reuse wastewater,
● reduce energy consumption,
● link natural areas to counter fragmentation and preserve biodiversity.

Planning of conventional or green infrastructure projects requires the following six strategies in a way of that are: proactive not reactive; multifunctional not single purpose; systematic not haphazard; multi-jurisdictional not single jurisdictional; and multiple scales not single scale [18].

3.3. Green Cities and Infrastructure Challenges

In spite of the numerous benefits of conventional and green infrastructure for communities growth and welfare, various challenges are associated with implementing this approach, the key aspects of these challenges for both infrastructures are illustrated in **Table (2) and Table (3),** as well as, the actions to deal with and overcome these challenges.

Table 2. Conventional Infrastructure Challenges

Challenge	Actions
Population Growth	• Determine and describe the actual needs, • Determine priorities for the community, • Accelerate the urban infrastructure planning documents and implementation to meet the expected population growth.
Population Awareness	• Promote governance models, • Include citizens in decision making, • Enhance performance for governmental organizations, • Strengthening civil society (NGO) participation.
Projects Funding	• Promote private sector to participate in this investment, • Allocate risks to reduce the project's cost, • Optimum use of resources, • Analysis of cost efficiency and (benefit/cost), • Foster creditworthiness, • Identify the stakeholder's roles.
Technology	• Dependent science, technology, innovation (STI) approach, • Dependent smart technologies • Use environmental management plans and tools, • Encourage scientific research.
Skills Gaps	• Identify projects stakeholders, • Provide stakeholder's management plan, • Improve communication between stakeholders.

Source: Summarized from **[19, 20, 21]** & by the author

Table 3. Green Infrastructure Challenges

Challenge	Actions
Gap between Theory and Practice	• Adaptation of green infrastructure concept in local conditions, • Provide smart governance model, • Take the resident perspectives into consideration, • Encourage local initiatives for this concept, • Decline social inequities.
High Risks in Implementation	• Determine people's priorities, • Address acceptable quality level (AQL), • Provide long- term maintenance plan, • Use environmental mechanisms and tools in evaluation, • Transfer knowledge for the private sector, • Define the potential risks, • Lack on the organized laws, formal planning, and empirical frameworks, • Include citizen participation to share the risks, • Identify the gaps to prioritize investment opportunity.

Source: Summarized from **[22, 23**] & by the author

3.4. Infrastructure Implementation for Green Cities

Development and establishment infrastructure are considered one of the major concerns in most countries, both developed and developing countries face huge challenges in implementing it, as the study mentioned above, and to merge the conventional and green infrastructure concepts in the development process is considered in itself an enormous challenge. Funding, technology, and high risks are the most important challenges in implementing both conventional and green infrastructure concepts.

Governments recognized that the bridge to overcome these challenges is the partnership with the private sector as a smart substitute to develop and expand the resource of infrastructural facilities **[24]**. The *World Bank* defines Public-Private Partnership (PPPs): "The partnership between the government and the private sector through cooperation between governmental entities such as local authorities and central governments with private companies in many areas such as health, education and infrastructure, and the degree of partnership varies in terms of responsibility and authority" **[25].** In fact, Standard Public-Private Partnership (PPPs) agreements normally did not take social and environmental aspects in its consideration, thus, the term of green economic and green contracts must be appended in order to close this gap.

UNEP defines Green economy as "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. In its simplest expression, a green economy can be thought of as one which is a low carbon, resource-efficient and socially inclusive" **[26]**.

From this point of view, the green economic strategies to accomplish green (PPPs) agreements are **[27, 28]**:

- *Reduce* the consumption of natural resources, and investment in natural assets,
- Provide clean water and sanitation services, and efficient delivery for services,
- *Reduce* carbon emission,
- *Reduce* environmental risks,
- Dependent on renewable energy,
- Promote long term maintenance agreements for projects,
- Enable private sector to finance projects,
- Science, technology, and innovation (STI),
- Waste management through, *reduce, Reuse and Recycle* wastes from industry,
- Prevent the loss of biodiversity and ecosystem services.

As a result of the shift in (PPPs) strategies to promote the green economic term, that was reflected directly in the contractual relationship between parties to be green by involving environmental and social strategies in it. In this context, Sherpa defines the green contract as "all contracts which aim and execution conditions combine economic, environmental, and social aspects, to promote fundamental rights and environmental protection [29]." From this point, the green contract clauses must include:

- Apply Triple bottom line: people (social), planet and energy (environmental), and profit (economic),
- Organize a balance between economic, social, and environmental implications,
- Rise to obligations of prevention and compensation to social and environmental harm,
- Remedy the effects of the contract concerned on public interest considerations brought about by the research of sustainable development,
- Promote mechanisms to prevent disputes and damages,
- Achieve the balance of power between the contract's parties referring in particular to the idea of a sphere of influence,
- Encourage purchasing renewable energy or recycled materials,
- Reduce expenditure and waste; increase resource efficiency,
- A life cycle assessment of the environmental impacts (EIA) of products or services is required,
- Compare price, technology, quality, and the environmental impact of the product, service, or contract.

4. Result

4.1. Conceptual Frame Work for Implementing Infrastructure Projects

Based on the discussion and analysis for green city definition, infrastructure challenges, infrastructure implementation by (PPPs), green economic, and green contract in the literature review. That led the study to conclude the Operational Framework for implementing infrastructure projects by (PPPs) based on the green cities objectives as illustrated in **Figure (1)** below**.** The operational model's main objective is achieving "green infrastructure project through (PPPs)" as well as:

- Determining the main phases in (PPPs),
- Allocating the most important strategies for each phase,
- The main output from each stage,
- Indicating the main internal stockholders, who share in decision making for each phase.

4.2. Efficiency Indicators for Green Infrastructure Projects

In order to achieve the green cities approach, and to evaluate the operational framework outputs through the (PPPs) phases and track the achievement of it, the study assigns the indicators according to the following criteria: the indictors should reflect the features of the green city concept, the index should represent the sustainable three pillars (environmental, economic, social), and (PPPs) potential risks in the project phases. Using the above criteria, the study summarized (53) indicators, classified on (38) indicators related to the green city concept, and (15) related to the potential risks.

After selecting the indicators, an online questionnaire is prepared and evaluated by (15) experts specialized in environmental planning and project management to obtain a weight for each indicator by identifying the Relative Importance Index. The collected data were analyzed and concluded the Mean Value for Each Indicator using the Statistical Analysis Program (SPSS), then calculated the Relative Importance Index (RII) using (Likert) classification (k) as [30]: "5" extremely high, "4" high, "3" medium, "2" low, and "1" extremely low, and examined the results by the equation below:

$$RII (\%) = n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5 / 5(n_1 + n_2 + n_3 + n_4 + n_5)*100$$

Where n1, n2, n3, n4, and n5 are the numbers of the students who scored "1" extremely low, "2" low, "3" medium, "4" high, and "5" extremely high. Then the study set the Importance level as follow [31]:

- RII = 0 : 0.20 = Importance level (Low = L)
- RII = 0.21 : 0.40 = Importance level (Medium low = M-L)
- RII = 0.41 : 0.60 = Importance level (Medium = M)
- RII = 0.61 : 0.80 = Importance level (Medium high = M-H)
- RII = 0.81 : 1.00 = Importance level (High = H)

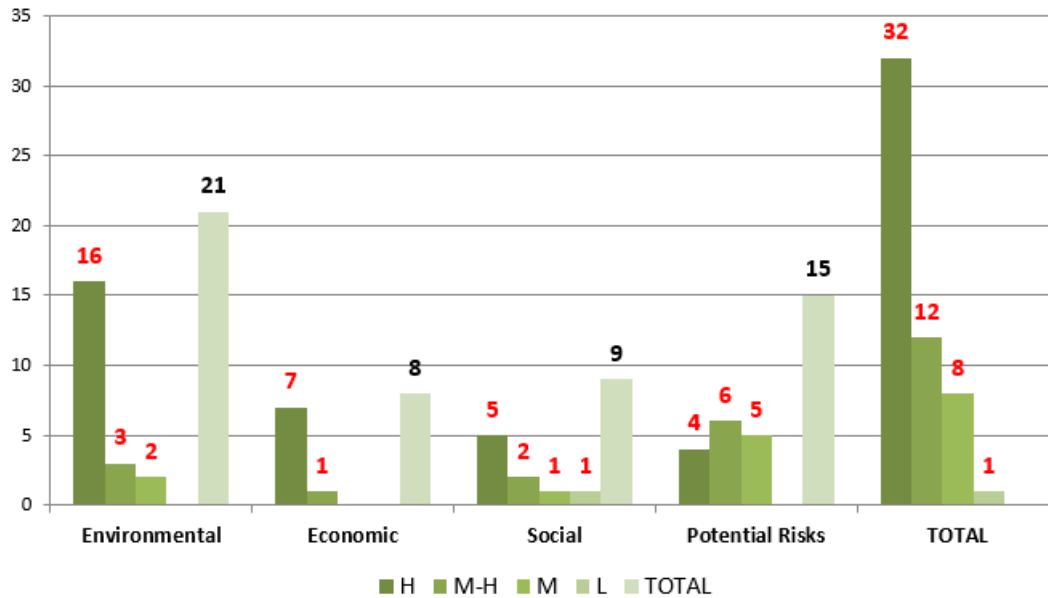The results of the Questionnaire were summarized as shown in **Table (4)**.
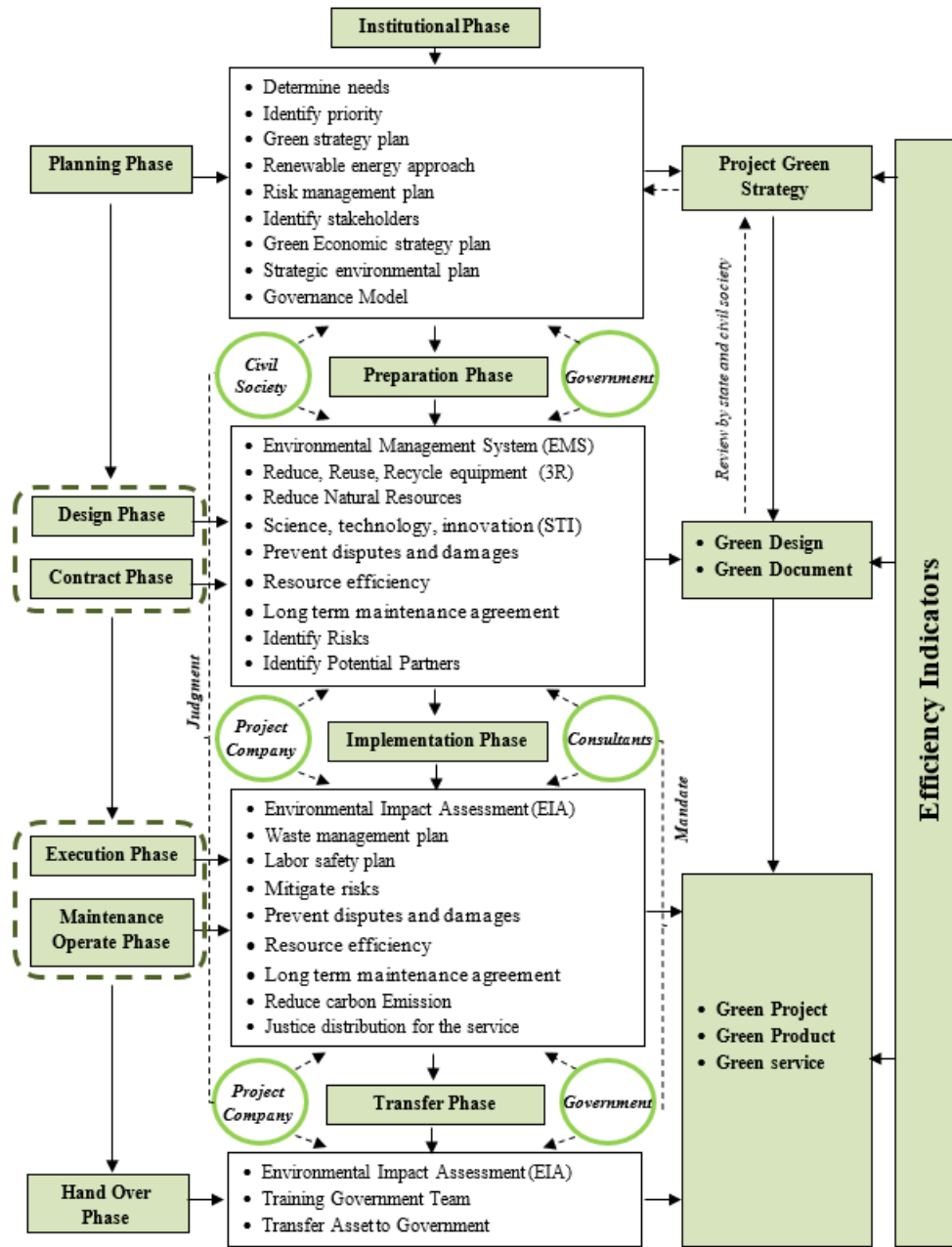
Source: by the author

Figure 1.   Operational Framework for Green (PPPs)

Table 4. Efficiency Indicators

Project Phase	Classification	Efficiency Indicators	Mean	RII	Importance level	Relative Ranking
Initiation Phase	Environmental	CO2 Reduction strategy	4.174	0.849	H	5
		Clean and efficient energy policy	4.604	0.921	H	2
		Congestion reduction policy	4.143	0.798	M_H	9
		Water efficiency and treatment policy	4.563	0.910	H	3
		Waste reduction policy	4.665	0.931	H	1
		Clear air policy	4.542	0.910	H	3
	Economic	Green economic strategy	4.297	0.859	H	4
		Green procurement policy	4.532	0.910	H	3
		(PPPs) policy	4.194	0.839	H	7
	Social	Civil society participation (NGOs)	2.711	0.542	M	11
		Governance policy	4.245	0.849	H	6
		Identifying actual priority	4.614	0.921	H	2
	Potential Risks	Poor public decision-making process	2.302	0.460	M	12
		Delay in project approval and permits	4.583	0.921	H	2
		Corruption and lack of law respect	4.092	0.818	M_H	8
		Changes in related laws	3.908	0.777	M_H	10
Preparation phase (design & contracts)	Environmental	Environmental Management System (EMS)	4.583	0.921	H	2
		Expected Energy consumption	4.358	0.870	H	4
		Expected Natural Resources consumption	4.859	0.972	H	1
		Smart technology application	4.348	0.870	H	4
	Economic	Resource efficiency	4.297	0.859	H	5
		Cost efficiency (Benefit / Cost)	4.542	0.910	H	3
	Social	Civil society participation (NGOs)	0.706	0.133	L	9
		Citizen interaction with the government	3.826	0.767	M_H	8
	Potential Risks	High finance cost	4.194	0.839	H	6
		Inflation rate	3.887	0.777	M_H	7
		Providing investors	3.908	0.777	M_H	7
Implementation Phase (execution & operate &maintenance)	Environmental	CO2 emission	4.205	0.839	H	7
		Energy consumption	4.174	0.839	H	7
		Renewable energy consumption	4.491	0.900	H	4
		Water consumption	4.358	0.870	H	5
		Water system leakage	3.724	0.747	M_H	11
		Waste water treatment	4.614	0.921	H	2
		Waste production	4.143	0.798	M_H	9
		Waste recycling	2.916	0.583	M	12
		Nitrogen dioxide	4.532	0.910	H	3
		Particulate matter	2.465	0.491	M	14
	Economic	Service tariff	4.205	0.839	H	7
		long term maintenance agreement	4.818	0.962	H	1
	Social	Stakeholder communication	4.123	0.829	H	8
		prevent disputes and damages	4.307	0.859	H	6
		Justice distribution for the service	3.939	0.788	M_H	10
	Potential Risks	Construction cost overruns	3.979	0.798	M_H	9
		Quality failure	2.394	0.481	M	15
		Construction time delay	2.302	0.460	M	16
		Change in market demand	4.010	0.798	M_H	9
		Maintenance quality	2.834	0.563	M	13
		Environmental Impact Assessment (EIA)	4.552	0.910	H	3
Transfer phase	Environmental	Environmental Impact Assessment (EIA)	4.297	0.859	H	3
	Economic	Overall profit for all stockholders	4.092	0.818	M_H	4
	Social	Client satisfaction	4.818	0.962	H	1
	Potential Risks	Renewal risk	4.491	0.900	H	2
		Transfer asset to government	2.55	0.51	M	5

Source: Summarized from **[32, 33, 34, 35, 36]** & by the author

Figure 2.   The Importance Level for the Efficiency Indicators

5. Analysis and Discussion

Efficiency indicators were distributed according to the infrastructure projects phases, each phase was included indicators reflecting the 3 pillars of sustainability and the potential risks related to this phase. The overall indicators for all categories were (53), (32) indicators ranked high importance (H), (12) indicators ranked medium-high (M-H), (8) indicators ranked medium (M), and (1) indicator ranked low (L). The distribution of the ranks for the 3 pillars and the potential risks was illustrated in **Figure (2).**

- Regarding *Initiation Phase*: the total efficiency indicators for this phase were **(16)**, the most important indicator related to the relative ranking for this phase is *Waste reduction policy*, and it was distributed as: (6) for environmental pillar, (3) for economical pillar, (3) for social pillar, and (4) for potential risks as illustrated in **Figure (2)**. The expert's evaluation range was (H) for (11) indicators, (M-H) for (3) indicators, and (M) for (2) indicators. That reflects the importance of this phase where (14) indicator's range was between (H)and (M-H) which represents (87.5%) from the phase indicators, therefore, identifying the sustainable strategies and policies is essential in this phase, also, the stability in laws and the acceleration of administrative procedures for the project by the government are considered critical issue in this phase.

- Regarding *Preparation Phase*: the total efficiency indicators for this phase were **(11)**, the most important indicator related to the relative ranking for this phase is *Expected Natural Resources consumption*, and it was distributed as: (4) for environmental pillar, (2) for economical pillar, (2) for social pillar, and (3) for

potential risks. The expert's evaluation range was (H) for (7) indicators, (M-H) for (3) indicators, and (L) for (1) indicators. In fact, all the environmental indicators' ranks were (H), which reflects the importance of the environmental role in this phase, therefore, including it as parameters in the design process and in the signed agreements with the private partner is too important to achieve green cities concept. Particularly, the expected natural recourses consumption and dependent on smart technologies.

- Regarding *Implementation Phase*: the total efficiency indicators for this phase were **(21)**, the most important indicator related to the relative ranking for this phase is *long term maintenance agreement*, and it was distributed as: (10) for environmental pillar, (2) for economical pillar, (3) for social pillar, and (6) for potential risks. The expert's evaluation range was (H) for (11) indicators, (M-H) for (5) indicators, and (M) for (5) indicators. As a result of the nature of this phase that considers the longest phase of the project lifecycle because it includes execution, operation, and maintenance agreements, it acquires (39.6%) from the efficiency indicators. Application of the environment role by assessing all the environmental aspects during this phase is crucial, especially co2 emission, energy and water consumption. Any defect in the result of these indicators is considered a failure for the project, therefore, environmental impact assessment (EIA) in this phase was a high potential risk.

- Regarding Transfer Phase: the total efficiency indicators for this phase were **(5)**, the most important indicator related to the relative ranking for this phase is *Client satisfaction*, and it was distributed as: (1) for environmental pillar, (1) for economical pillar, (1) for

social pillar, and (2) for potential risks. The experts' evaluation range was (H) for (3) indicators, (M-H) for (1) indicators, and (M) for (1) indicators. This phase is the final phase in the project lifecycle, if the implementation phase achieves its goals that means a safe transfer for the asset to the government in a good condition, and arriving to the customer satisfaction.

6. Conclusions

Green city is an important concept to achieve sustainable development pillars, it is not only green urban spaces or green building but also expands to green economic and social aspects, many strategies were adopted to achieve this concept, the most important strategies related to this concept are reducing the natural resources consumption, reusing and recycling water and waste, and promoting the use of smart technologies. Infrastructure development considers the main pivot for achieving this concept, where, the development in this sector reflects communities' growth and welfare, from another hand, the implementation of this concept faces numerous challenges particularly in funding, providing technology, and the high potential risks. The green Public-Private partnership (PPPs) approach is the gate to overcome these challenges through green economy, green agreements, improve communication between stakeholders, and encourage civil society participation in decision making.

Finally, the suggested operational framework and efficiency indicators for green infrastructure could enhance the implementation of the green city concept through reducing the gap between theory and practice, mitigating the potential risks, and identifying the sustainable strategies and policies thus, achieving sustainable development.

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