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From Segregated to Integrated Textile Industrial Cities: Adopting Green Industrial Policies in the Delta Region in Egypt

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ABSTRACT

This study evaluates the readiness of textile industrial cities in Egypt's Delta Region to adopt eco-industrial cluster policies, integrating economic, urban, and social dimensions. The Economic Readiness Index assesses the economic capabilities of cities and their rural hinterlands in the textile industry. The Urban Readiness Index evaluates infrastructure, such as road connectivity, airports, and utilities. The Social Readiness Index examines specialized labor, educational institutions, and industrial training facilities. A composite Readiness Index merges these indices to categorize cities into three levels of readiness. Results show that cities in the Northwest Delta, such as Alexandria and New Borg El Arab, exhibit the highest readiness due to strong infrastructure, connectivity, and industrial zones. On the other hand, cities with low readiness suffer from inadequate infrastructure and weak urban indicators, hindering policy implementation. These findings align with prior research highlighting the importance of comprehensive infrastructure for industrial growth and investment attraction. The study suggests targeted policies to support high-readiness cities through industrial R&D, institutional frameworks, and SME support. For cities with intermediate and low readiness, investment incentives and infrastructure upgrades are necessary to enhance their capacities. Future studies should explore supply chain dynamics and evaluate the impact of eco-industrial clusters on regional planning.

1. INTRODUCTION

The Green Industry represents a global approach aimed at achieving sustainable production and consumption by integrating environmental considerations across all industrial activities and their supporting sectors. These sectors include agriculture, research and development, transportation, supply chain management, and workforce training. Distinct from earlier approaches, such as Industrial Ecology, the Green Industry approach emphasizes resource efficiency - particularly in energy, water, and materials- while minimizing adverse environmental impacts. This integrated approach also designed to enhance productivity, economic efficiency, and overall competitiveness [1, 2].

To promote the advancement of the Green Industry globally, the United Nations Industrial Development Organization (UNIDO) has adopted a dual strategy: (1) Greening existing industries, which involves applying sustainability principles to all industries irrespective of sector, size, or location, and (2) Establishing new green industries, such as renewable energy technology firms and clean technology companies [3]. Concurrently, governments worldwide employ three primary strategies for industrial greening: (1) The Reward/Penalty Strategy, which utilizes financial and legislative tools, such as environmental taxes and subsidies, to encourage the adoption of green technologies. (2) The Incentive Strategy, which focuses on raising awareness and building capacities for cleaner production through training programs. (3) The Support Strategy, which empowers industries by providing essential infrastructure and financing mechanisms, including eco-industrial clusters and parks.

The eco-industrial cluster (EIC) policy has proven particularly effective in fostering sustainable industrial growth in countries such as China, India, Japan, Thailand, and Vietnam. EICs are defined as "a community of businesses; a geographic concentration of interconnected companies in a specialized field that cooperate with each other and the local community to efficiently share resources (information, materials, energy, water, infrastructure, finance, etc.), improving environmental quality, achieving economic gains, and enhancing human resources equitably for both businesses and the local community" [4].

Countries have embraced EICs as a key policy tool due to their capacity to address urban and rural challenges, including resource inefficiency and limited economic opportunities. EICs deliver numerous benefits, such as stimulating innovation, advancing technology, efficiently utilizing natural resources, reducing waste, and promoting competitive value-added processes. They also enable developing countries access global markets with sustainable products while supporting small and medium-sized enterprises (SMEs) and generating employment opportunities [1, 5]. Furthermore, EICs yield

significant social benefits, including poverty reduction, unemployment mitigation, skills development, and strengthening local social networks [3].

Successful implementations of EICs in countries like China, India, and Japan demonstrate common success factors, including effective stakeholder collaboration among businesses, universities, research institutions, and governments; advanced infrastructure supporting production and transportation; skilled human resources attracting investments; and government policies that incentivize innovation and foreign direct investments [5-8]. Notably, these clusters often focus on geographically concentrated industries, such as textiles in China and biotechnology in India, leveraging specialization to optimize economic and environmental benefits.

In Egypt, the shift toward a Green Industry aligns with the objectives of Egypt's Vision 2030, which prioritizes inclusive, sustainable growth and balanced local development. The National Strategy for Textile Industries 2025 outlines key goals, including strengthening the textile value chain, supporting SMEs, boosting exports, fostering innovation, and advancing policy reforms [9, 10]. Moreover, the Delta Region, characterized by a high concentration of textile industries in rural-urban areas, provides a promising context for EIC implementation. Similar to global examples, applying EICs in the Delta can address persistent challenges such as outdated technologies, fragmented value chains, and limited infrastructure, while fostering innovation, enhancing resource efficiency, and achieving value chain integration.

Building on international experiences, this study examines the readiness of cities to adopt the EIC policy as a cornerstone for green industrial strategies, thereby contributing to the sustainable transformation of the textile sector in the Delta Region.

2. BACKGROUND

2.1 Textile and garment industrial cities in the Delta Region

According to the Information and Decision Support Center (IDSC) [10], the textile and garment sector is one of Egypt's leading industries, ranking as the second-largest industrial sector after food industries. It employs 26% of the total industrial workforce and comprises 9% of the total industrial establishments, contributed 3% to GDP in 2020. Despite its significance, the sector has faced significant challenges in recent years. Notably, the number of newly established textile factories dramatically declined from 2,371 in 2017 to 603 in 2020. This sharp decrease can be attributed to factors such as the initial momentum of government-driven industrial development strategies and the adverse effects of the COVID-19 pandemic, which led to increased production costs and intensified competition from imported goods, ultimately undermining the sector's competitiveness [10].

Moreover, the sector is further hampered by structural issues, including inefficiencies in fundamental industrial processes such as spinning, weaving, dyeing, printing, and finishing. Additionally, there is a shortage of local fashion designers and skilled technical labor, coupled with limited investment in research and development. These challenges have weakened the textile value chain and constrained the sector's ability to meet both domestic and international market demands [10].

In addition to economic challenges, textile-focused cities in the Delta Region are facing urban and social deterioration. Between 2006 and 2017, these cities experienced outmigration rates ranging from 0.5% to 1%, reflecting a diminishing urban appeal. Furthermore, in 2017, unemployment rates in many of these cities ranged from 5% to 15% [11], exacerbating local economic struggles and limiting growth opportunities. Additional challenges include poor connectivity to major trade hubs, underutilized industrial zones, and inadequate urban infrastructure, such as transportation networks, water, and electricity supply.

Despite these issues, the Delta Region remains a cornerstone of Egypt's textile and garment industry, encompassing 78 specialized cities identified using the coefficient of localization for labor and establishment (Figure 1). These cities span the entire value chain, from raw material preparation (e.g., cotton, flax, wool, silk) to intermediate stages (e.g., spinning, weaving, synthetic fiber manufacturing, dyeing, printing) and final production stages (e.g., ready-made garments, home textiles, carpets) [12]. However, the region's ability to sustain and expand this specialization is threatened by the aforementioned challenges.

To address these pressing issues, this research promotes the adoption of eco-industrial clusters as a transformative framework for revitalizing the textile sector. EICs provide a holistic approach to addressing challenges across the entire production system while integrating supporting sectors such as logistics, research, and workforce training. This study evaluates the readiness of textile-focused cities in the Delta Region to implement EIC policies by analyzing critical components, including infrastructure, skilled labor, and governance structures. The primary objective is to identify priority city clusters and outline their specific requirements for successful EIC implementation, thereby contributing to the formulation of more effective and responsive regional urban development plans.

2.2 Eco-industrial clusters requirements

Eco-industrial clusters serve as a policy for sustainable regional development in inner regions, making them suitable for regions of small and medium-sized industries to achieve balanced development [4]. These clusters aim to make effective use of local resources, and their success relies on the existence of economic institutions that are constantly dedicated to build networks between companies, not only to conserve resources, but also to seek various innovations that contribute to the community growth and prosperity. EICs' policy has been implemented in several developing and developed countries across various industrial sectors, including India, Japan, China [5-8]. These countries host existing industrial clusters in industries such as textiles, Biotech, or woodworking, which have been transformed into EICs to reap the economic, social, and environmental benefits of this policy [5]. In this research, these international experiences have been critically reviewed (Table 1), with the aim of identifying key requirements and factors that contributed to their success.in order to be employed in assessing the readiness of the cities in the Egyptian context for the EICs policy.

Table 1. Analyzing international experiences to identify the success factors of the EICs policy

Aspect	China	India	Japan
Sector	Textile Industry	Biotech Industry	Wood Biomass Industry
Location Characteristics	Jiangsu and Zhejiang provinces, with 24 of 36 clusters in eastern and southeastern coastal areas; Zhejiang is a leading province.	Bangalore is the major hub, housing 40% of India's biotech companies.	Maniwa City, Okayama Prefecture, with forests covering 80% of the area and 34 timber factories.
Level	Regional	Regional	Local
Approach	Top-down policies	Top-down policies	Bottom-up approach
Success Factors	Strategic location, strong company cooperation, links with research institutions, low business costs, developed transportation infrastructure, special economic zones, annual exhibitions, government support through reduced taxes and customs duties.	Collaboration between diverse stakeholders, availability of skilled workforce, presence of leading research institutions, availability of capital, supportive central and state government policies, targeted private investment facilitation.	Social capital, company cooperation, strong alliances with local community and government, laws stimulating innovation, ministry coordination and support, specialized market for environmental products promoted through Maniwa NPO.

Source: The authors based on literature review [5-8].

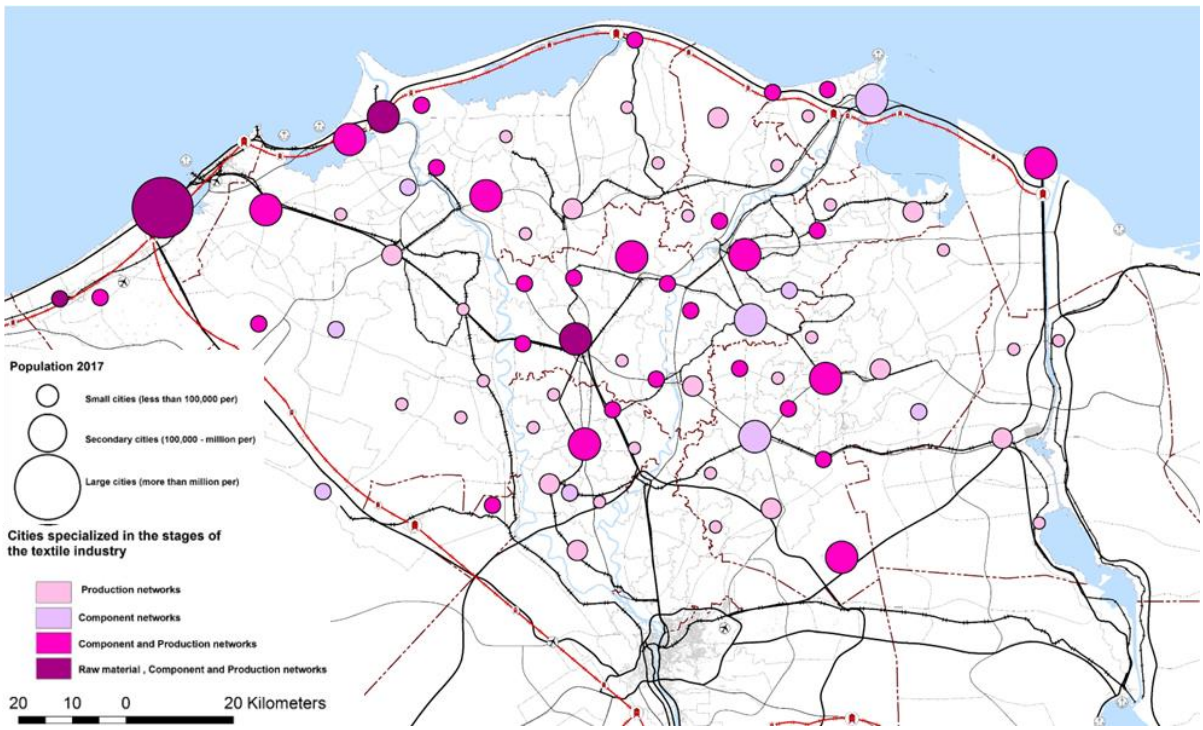

Figure 1. Textile industrial cities in Egypt's Delta Region
Source: The authors

2.2.1 Requirements for implementing eco-industrial clusters in textile industry cities

Research to date has not yet determined the requirements for implementing eco-industrial cluster policies in textile industry cities. As a result, this study has identified these requirements based on the literature discussing the components of the textile and apparel industrial cluster and the factors for the success of such policies, and strategies for developing existing or potential industrial clusters in cities [4, 6, 8, 13-18]. The concluded requirements were categorized into six groups economic, social, urban infrastructure, research and development, support and financing, and management and governance (Table 2).

1) Economic requirements

The economic foundations of the sector are expressed by the spatial concentration of economic institutions to identify the existing or potential industrial clusters. Potential stakeholders are identified based on the final product and the determination of the horizontal linkages in the production chain [14]. The primary institutions in the textile value chain can be divided into three sectors:

a) Raw Material Networks: including the regions cultivating cotton, linen, wool, and silk, as well as oil and natural gas, which are raw materials for synthetic fibers used in the textile industry.

b) Component and Production Networks: including specialized industrial establishments involved in all stages of the industry, such as ginning mills, weaving and dyeing/garment manufacturers, and producers of ready-made textiles. This network represents the core of the cluster, and it must include all stages of the industry within the cluster, in addition to complementary industries such as the petrochemical industry.

c) Trade and Export Networks: including wholesale, retail, and export trade areas [18].

Table 2. Framework for measuring the readiness of textile industrial cities to implement eco-industrial clusters

Level	Economic Dimensions	Urban Infrastructure	Social Dimensions
City-Level Indicators	Size of establishments in the textile, apparel, and garment industries	Connectivity to the road network and ease of access for labor mobility between cities	Availability of skilled and trained labor (size of workforce in textile, garment, and apparel industries)
	Number of specialized sub industries located in the city (employment-establishments)	Connectivity to global trade flows (proximity to ports and airports)	Education attainment levels (percentage with at least secondary education)
		Connectivity of buildings to infrastructure networks (electricity, water, sewage, and telecommunications)	Ratio of factory and assembly production workers to total industry employment
	Size of industrial establishments (petrochemical industries)	Availability of industrial zones (vacant land for industrial expansion)	Number of vocational and industrial secondary schools, and professional training centers
		Availability of special economic zones (export processing zones)	Percentage of workers trained on modern production technologies in the textile and garment industry
	Availability of small and medium-sized enterprises (average employment per establishment)	Availability of logistics areas and dry ports	
		Availability of land for expansion	Number of civil society organizations contributing to local community development (specialized in textile and garment activities)
	Cost of business (labor wages, transportation, electricity, land costs)	Availability of financial institutions (banks)	
		Availability of trade and distribution centers	
		Availability of specialized universities, institutes, and research centers	
	Research and Development	**Support and Financing**	**Management and Governance**
Regional and National-Level Indicators	Percentage of spending on industrial research and development	Percentage of support directed towards the development of the textile and garment industries (incentives and assistance for small and medium-sized enterprises)	Impact of regulations and laws on investment in the textile and garment sector
	Degree of linkages between universities, research institutes, and the industrial cluster	Availability of employee skills development programs within the industrial cluster	Existence of institutional structures that ensure cooperation between different organizations within the industrial cluster
		Support for export promotion of the actors in the industrial clusters	
		Facilitation of export procedures	
		Reduction of taxes imposed on the textile and garment industries	
	Basic industry requirements	Sustainability requirements	Policy success requirements

Source: The authors based on literature review [6-8, 14-18].

The formation of networks among economic institutions, specifically the effective cooperation between all elements of the textile industry value chain, is considered a fundamental pillar of industrial clusters [4]. The geographical proximity and shared strategic interests among institutions and their supporting organizations facilitate mutually beneficial cooperative activities. These activities include collective procurement of inputs, joint advertising, collaborative research and development and innovation projects, and shared use of equipment. In addition, they also encompass the provision of technical assistance by business associations and public sector investments in infrastructure [16]. Successful industrial clusters prominently feature substantial participation from SMEs, which are integrated into supply chains with large enterprises [6, 14].

2) Urban infrastructure requirements

The availability of urban infrastructure significantly influences the efficiency of industrial clusters. This infrastructure includes transportation networks, such as roads and railways, that facilitate the movement of labor and goods, as well as ports and airports to reduce transportation costs for exports. Additionally, it encompasses essential utilities such as electricity, water, telecommunications, and information networks, along with logistics zones, dry ports, and export processing zones [6, 16]. Moreover, industry-supporting services such as education and training services (universities, vocational secondary schools, training centers), as well as business associations (business development service providers, financial service providers including banks) are vital components of the urban infrastructure requirements [15].

3) Social requirements (social capital)

The success of industrial clusters is heavily dependent on the cohesion of the local community and the presence of social relationships and networks among its members, which facilitate cooperation within the cluster. The availability of skilled labor is also a crucial factor that attracts enterprises to operate within the cluster [15, 17].

4) Research and development requirements (R&D)

The presence of universities, institutes, and specialized research centers in the textile industry is critical for fostering innovation and development. Also, establishing connections between these academic institutions and industry is essential. For example, the success of the textile cluster in Zhejiang Province, China, can be attributed to robust links with both

local and international research institutions and universities, which enhanced innovation capability at a low cost [6].

5) Support and financing requirements

The availability of a supportive investment environment is one of the important requirements for the growth and formation of industrial clusters, through the provision of financial support to enhance the textile industry clusters from the public and private sectors, the implementation of innovative market-based incentives (such as tax reductions, subsidies, and incentives) for small and medium-sized enterprises to develop the equipment and train employees, in addition to facilitating access to international financing (for example, establishing green funds at the national level, facilitating clean development mechanisms, and the Global Environment Facility) [8], and facilitating export procedures to attract investment in the textile sector are essential government actions [6].

6) Governance and management requirements

The role of government is crucial in establishing and ensuring the success and continuity of industrial clusters. This involves developing and implementing necessary plans and policies, building cluster relationships with other governmental entities and provides financial support to enhance these clusters [16]. Additionally, the formulation of laws and regulations that encourage the adoption of eco-industrial cluster policies and green industry, where environmental laws and regulations have been the main driver of innovation in some countries [8]. Effective governance also requires professional administrative structures comprising competent and experienced individuals [15].

2.2.2 Criteria for measuring the readiness of textile industrial cities to implement eco-industrial clusters

Table 2 shows the framework for assessing the readiness of textile industrial cities to implement eco-industrial clusters. The framework illustrates various indicators at both city and regional/national levels. The city-level indicators include economic, urban, and social dimensions, while the regional and national-level indicators encompass aspects of research and development, support and financing, and management and governance. Derived from international best practices, these indicators are organized into three categories based on their relevance: basic industry requirements, sustainability requirements, and policy success requirements.

3. METHODS

3.1 Selection of textile industry cities in the Delta Region

The selection of textile industry cities in the Delta Region was systematically determined using the coefficient of localization cities.

3.2 Data collection

The data collection process was systematically organized into three groups, corresponding to the identified indicator groups. First, the economic and social data were sourced from Federation of Egyptian Industries (Textile Industries Chamber) [12] and the Central Agency for Public Mobilization and Statistics (CAPMAS Population Census) [11]. The urban indicators were derived from a variety of sources including the Central Agency for Public Mobilization and Statistics (CAPMAS Building Census) [11], the Annual Bulletin of Maritime and Air Transport [19], the General Authority for Investment and Free Zones [20], Ministry of Transport (Maritime Transport & Logistics Sector, Land and Dry Ports Authority) [21, 22], and the statistical directories of the governorates.

3.3 Data analysis

A structured approach was employed to analyze the data using statistical methods in the SPSS software, with the goal of formulating a Readiness Index for textile industrial cities to implement eco-industrial cluster policy. The following steps outline the process:

Step 1: Standardizing Measures:

To address the differing scales of the indicators used to create the index, the Z-score calibration method was utilized. This method is appropriate for quantitative data and accounts for the presence of outliers in some cities. It involves subtracting the indicator's value from the mean value (the overall average of the indicator) and then dividing by the standard deviation.

Step 2: Utilizing Factor Analysis:

Factor analysis was employed to reduce the number of indicators and eliminate those that do not significantly contribute to the index. This analysis was conducted separately for economic, urban, and social indicators. The KMO test values for the indicator groups were found to be greater than 0.5, indicating the adequacy of the sample size for factor analysis. The Component Matrix analysis results led to the exclusion of certain indicator groups, as shown in Table 3.

Table 3. Results of factor analysis of the indicators

Results	Economic Indicators	Urban Indicators	Social Indicators
KMO test	**0.5**	0.718	0.569
No of Total indicators	**8**	**13**	**5**
No of Final indicators	**5**	**7**	**3**

Source: The authors based on the SPSS analysis.

Step 3: Utilizing Neural Network:

In this research, neural network analysis was employed due to the extensive volume of data associated with the readiness indicators for cities. This method was selected for its effectiveness in identifying the most influential factors in forming the Readiness Index and categorizing cities into groups with similar characteristics. The analysis utilized quantitative data for the indicators, which had been standardized in Step 1 and refined by eliminating non-significant indicators in Step 2. A total of 15 indicators were included in this process.

Based on the results from SPSS and neural network analysis, the relative weights (importance) of each indicator were determined. These weights, which collectively sum to one, were subsequently applied to develop the sub-indices of readiness -economic, urban, and social- as well as the overall Readiness Index. The assigned weights and their corresponding results are presented in Table 4.

Step 4: Calculating the Readiness Indices:

The value of each indicator was multiplied by its respective

weight derived from the neural network method. These weighted values were aggregated for each city to form the sub-indices (Economic Readiness Index, Urban Readiness Index, Social Readiness Index). The aggregated factor values for each dimension were then multiplied by their respective weights to form the overall Readiness Index for textile industry cities.

Step 5: Categorizing the Indices:

All indices were subdivided into statistical categories based on their values. Outlier cities were excluded to facilitate the categorization of cities into similar groups based on the index values. For each index, the categories were divided using the mean value method into three groups (high, intermediate, low).

Table 4. Weights of indicators to form the sub-indices of Readiness Index

Economic Index		Urban Index		Social Index		Readiness Index	
Indicators	**W**	**Indicators**	**W**	**Indicators**	**W**	**Factors**	**W**
1) Size of establishments in the textile industries (City)	0.425	1) Percentage of buildings connected to the water network	0.185	1) Percentage Employment of textile industry (city)	0.464	1) Urban factor	0.38
2) Number of specialized sub industries located in city (employment-establishments)	0.239	2) City connectivity to airports	0.183				
		3) Availability of industrial areas	0.178	2) No. of industrial education and training institutions in the city	0.275	2) Economic factor	0.342
3) Number of specialized sub industries located in hinterland (employment-establishments)	0.126	4) Percentage of buildings connected to the electricity network	0.125				
		5) Connectivity and accessibility to the city (labor movement)	0.123				
4) Size of establishments in the textile industries (hinterland)	0.107	6) Availability of land for expansion (new city - desert hinterland)	0.105	3) Ratio of factory and assembly production workers to total industry employment	0.261	3) Social factor	0.278
5) Number of specialized sub industries located in hinterland (establishment)	0.103	7) Availability of special economic zones	0.1				

Source: The authors based on the SPSS analysis.

4. RESULTS

A Readiness Index has been formulated for textile industrial cities to assess their preparedness for implementing eco-industrial clusters policy. Sub-indices have been created to measure readiness across economic, urban, and social dimensions. The research findings are as follows:

4.1 Economic Readiness Index

The Economic Readiness Index (ERI) reflects the current economic capabilities of cities and their rural hinterlands in the textile industry. Cities have been categorized based on the values of the ERI into three groups:

4.1.1 High economic readiness cities

This group includes 17 cities that exhibit the highest in economic indicators in the textile industry, representing 22% of the total textile industrial cities with an index value greater than 0.14. The distribution of these cities is concentrated in the central and northwest areas of the Delta. Notably, three cities excel significantly in the ERI: Alexandria (3.49), Al-Mahalla El-Kubra (3.48), and the Tenth of Ramadan (2.22), as they are considered major industrial hubs in Egypt, hosting over 60% of the total textile industry establishments in cities.

Alexandria encompasses a wide range of textile facilities, including spinning, weaving, dyeing, printing, and final production stages such as ready-made clothing, furnishings. Tenth of Ramadan city includes most stages of textile industry, such as synthetic fiber production, dyeing, printing, and final production stages like ready-made clothing, furnishings, and carpets. On the other hand, Al-Mahalla El-Kubra, known as a pioneer in the textile and garment industry for a long time, it has a strong industrial sector both in the city and its rural hinterland, which accounts for 30% of the textile industry establishments compared to other cities.

Other cities in this group are governorates capitals, new cities, or cities closely linked to these three major cities mentioned earlier. These cities are subdivided into two groups based on the characteristics of their industrial sectors: the first group comprises cities with significant industrial sector differences between the city and its rural hinterland, such as Damanhur, Kafr El Dawar, and Desouk, where the percentage of textile industry establishments ranging from 0.3% to 3.5%. Yet, the second group comprises cities with rural hinterland significantly different from the city, such as Aga, Berket El Sabaa, Quesna, Samanood, Tanta, Mansoura, and Deyarb Negm, where the rural hinterland hosts a higher percentage of industrial establishments, ranging from 1.1% to 20.5%, and comprising more than four stages of textile industry.

4.1.2 Intermediate economic readiness cities

This group consists of 24 cities, accounting for 31% of the textile industrial cities with index values ranging from 0.14 to -0.17. These cities predominantly exhibit rural hinterland superiority in economic indicators for the industry. The percentage of textile industry establishments in their rural hinterlands ranges from 0.1% to 3%, and they encompass between two to four stages of the industry. Examples include Abu Al-Matamir, Ashmun, El Santa, Zifta, Kafr El-Zayat, Qatour, Mit Ghamr, Abu Hammad, Belbeis, Abu Kabir, and Kafr El-Sheikh. Most of these cities are concentrated in the Al-Gharbia, Al-Sharqia, and Al-Dakahlia governorates. Major cities in this group include Port Said and the New Borg El Arab City, which lack a rural hinterland and mainly host final stages of the industry such as apparel production, and furnishings.

4.1.3 Low economic readiness cities

This group comprises 37 cities (47%) with low economic indicators for the textile industry. These cities share the

characteristic of having a weak industrial sector, with their rural hinterlands accounting for less than 0.1% of the textile industry establishments. Additionally, they typically host one or two stages of the textile industry. Examples of these cities are Shibin Al-Kom, Ismailia, Damietta, New Damietta, Housh Eissa, Menouf, Beila, Al Ibrahimia, and Nabruh.

4.2 Urban Readiness Index

This Urban Readiness Index (URI) evaluates the availability of urban infrastructure necessary for implementing eco-industrial clusters policy in textile industrial cities. It highlights the need for additional land to accommodate other elements of the incomplete textile and garment industry system in these cities. Additionally, it assesses the availability of essential infrastructure elements such as connectivity to road networks for labor mobility, airports and the connectivity of buildings to electricity and water networks. The results are as follows:

4.2.1 High urban readiness cities

This group includes 21 cities with the highest urban infrastructure availability, accounting for 27% of all specialized cities with an index value greater than 0.08. These cities are distributed across the Delta coast and central Delta. Remarkably, three cities exhibit higher values than others: Alexandria (2.31), Port Said (1.57), and Ismailia (1.23). These cities are distinguished by a large number of industrial zones, special economic zones, and nearby new cities capable of providing activities and services. Moreover, these cities benefit from high connectivity through airports, seaports, and railways. Other cities within this group include coastal cities (Rosetta, Damietta, Borg El Arab), new cities (Tenth of Ramadan, Al-Sadat, New Borg El Arab), and cities associated with international airports (Quesna, Kafr El Dawwar, Edko, Fayed). All cities in the group share high connectivity of buildings to water and electricity networks, above 95%, with high connectivity capabilities.

4.2.2 Intermediate urban readiness cities

This group consists of 22 cities, accounting for 28% with an index value between 0.08 and -0.11. These cities are spread across all areas of the Delta and share moderate urban infrastructure capabilities, including moderate building connectivity to basic infrastructure networks (electricity, water), as well as moderate labor movement connectivity. These cities are located within the range of an international airport or a local airport (Cairo Airport, Borg El Arab Airport, and Port Said Airport). Key cities in this group include Shibin Al-Kom, El Bagour, Wadi El Natrun, Tanta, Desouk, Menuf, El Santa, Kafr Saqr, Talkha, Belbeis, and East Qantara.

4.2.3 Low urban readiness cities

This group contains the largest number of cities, with 35 cities accounting for 45% of the total specialized cities. These cities are also spread across most Delta areas, away from the Delta coast with an URI value of less than -0.11, indicating weaker connectivity compared to other cities in other groups. Furthermore, these cities lack industrial zones, new cities, or desert hinterlands that provide land for industrial expansions or economic activities related to the textile industry. Examples include Zefta, Damanhur, Mit Ghamr, Ashmoun, Kafr El Sheikh, Zagazig, Qatour and Dekernes.

4.3 Social Readiness Index

This Social Readiness Index (SRI) assesses the robustness of social factors in specialized cities, particularly within the textile industry. This includes the presence of specialized labor in the textile industry, general industrial labor, and educational and industrial training institutions. Cities are classified into three groups according to the SRI:

4.3.1 High social readiness cities

This group comprises 18 cities, accounting for 23% of the total specialized cities. Five cities within this group exhibit significantly higher values: Alexandria (3.77), Tenth of Ramadan (3.18), Al-Mahalla Al-Kubra (2.97), Port Said (1.71), and Mansoura (1.54). These cities host over 70% of the textile industry labor contain more than 14 educational and industrial training institutions. Other cities in this group share the same predominant feature of high percentages of factory workers relative to the city's labor structure, with the percentage of textile industry workers ranging between 0.2% and 6% of the workforce, as they host between 7 and 14 educational and training institutions. Some examples include Kafr El Dawwar, Borg El Arab, Tanta, Damietta, AL-Sadat, Kafr El Sheikh, Zagazig, Belbeis, Edko, and Zefta.

4.3.2 Intermediate social readiness cities

This group includes 23 cities, accounting for 29% of the specialized cities. These cities are primarily located in Al-Dakahlia, Al-Gharbia, and Al-Beheira governorates. Cities in this category have intermediate SRI values, with the percentage of textile industry workers ranging from 0.006% to 0.7%, and the percentage of factory workers ranging from 6.7% to 18%. The number of educational and industrial training institutions in these cities ranges from 2 to 10. Significant cities in this group include Samanood, Wadi El Natrun, Al-Mahmoudiya, Kafr Saad, Kafr El-Zayat, El Santa, and Rosetta.

4.3.3 Low social readiness cities

This group consists of 37 cities, representing 47% of cities specialized in this sector. These cities are characterized by low SRI for the textile industry, with the textile and garment industry labor less than 0.4%. and factory workers less than 12%. In addition to the absence of industrial education and training institutions in these cities. Examples include Dekernes, Abu Kabir, Badr, El Bagour, Eitay El Barud, Fayed, Faqus, Menouf, and Tala.

4.4 Readiness Index

The Readiness Index (RI) combines economic, social, and urban indicators to provide a comprehensive evaluation of cities' preparedness for implementing eco-industrial cluster policy. from the previous indices. Cities were statistically classified into three groups according to the values of the Readiness Assessment Index (Figure 2). The results were as follows.

4.4.1 High Readiness Index cities

This group, including 18 cities (23%), represents the highest readiness level in RI for implementing eco-industrial clusters policy, where these cities are distributed across three zones. The first zone, the Northwest Delta Zone, includes seven cities: Alexandria, Borg El Arab, New Borg El Arab, Kafr El

Dawwar, Damanhur, Edko, and Rosetta. Most cities in this zone exhibit high in the sub-indices of readiness, with the exceptions of New Borg El Arab and Damanhur, which have moderate social and economic readiness indices. Therefore, this zone is well-integrated in its components for policy implementation and is considered a priority area.

The second zone, the Central Delta Zone, includes Al-Mahalla Al-Kubra, Mansoura, Tanta, Aga, and Quesna. Al Mahalla Al Kubra is the main industrial center in the Delta Region, characterized by significant economic and social assets for the textile industry, including a high concentration of establishments and workforce. However, it has a low Urban Readiness Index (URI) due to the lack of industrial zones, limited land availability for expansion, and weak connectivity to international airports. Cities like Aga and Quesna have a moderate SRI. The third zone spreads on the outskirts of the Delta and the Suez Canal, including Al-Sadat, Tenth of Ramadan, Belbeis, Port Said, Ismailia, and Damietta. This zone includes new cities like Al-Sadat and Tenth of Ramadan with high readiness levels in all aspects. However, Ismailia, Port Said, and Damietta have the highest URI. Thus, the second zone will integrate with the third zone to provide the elements of the value chain for the textile industry as a result of the availability of industrial areas and lands available for expansion in the third zone (logistics areas and warehouses, etc.). In Table 5, the classification of sub-indices for cities in the category of the highest readiness to implement the eco-industrial cluster policy, is presented.

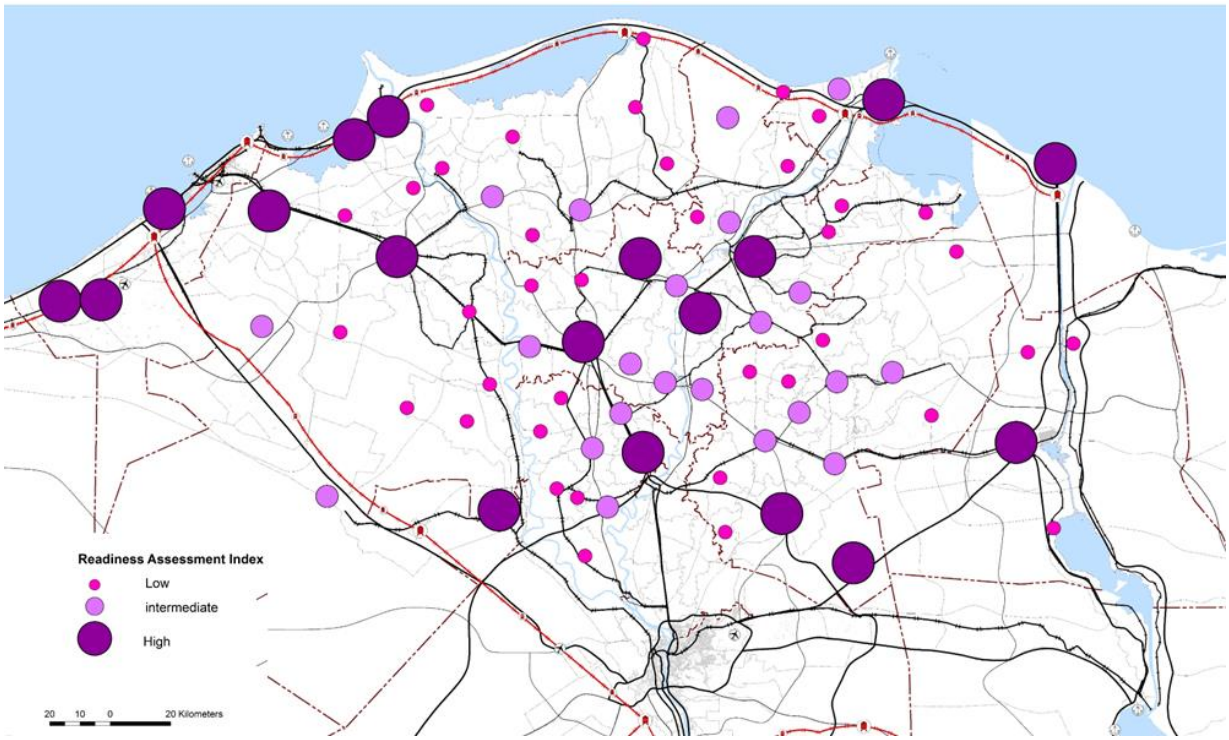

Figure 2. Classification of readiness assessment index for textile industrial cities to implement EICs policy
Source: The authors

Table 5. Classification of sub-indices for cities with the highest readiness to implement eco-industrial clusters policy

No.	Cities	Economic Index ERI	Urban Index URI	Social Index SRI	R Index
1	Alexandria	√	√	√	3.14
2	. Al Mahalla Al Kubra	√	-	√	1.9
3	Tenth of Ramadan	√	√	√	1.76
4	Port Said	*	√	√	1.16
5	Mansoura	√	√	√	0.73
6	Kafr El Dawar	√	√	√	0.49
7	Borg Al Arab	√	√	√	0.4
8	Ismailia	-	√	*	0.39
9	New Borg Al Arab	*	√	√	0.31
10	Al-Sadat	√	√	√	0.31
11	Tanta	√	*	√	0.29
12	Damanhour	√	-	√	0.24
13	Edco	√	√	*	0.22
14	Rosetta	-	√	*	0.16
15	Aga	√	√	*	0.16
16	Quesna	√	√	*	0.12
17	Belbeis	*	*	√	0.11
18	Damietta	-	√	√	0.08

High: √; Intermediate: *; Low: -.
Source: The authors based on the SPSS result

4.4.2 Intermediate readiness assessment index cities

This group consists of 22 cities, accounting for 28% of the total number of cities. Most cities are concentrated in Al-Dakahlia, Al-Gharbia, and Al-Sharqiya governorates. These cities exhibit moderate readiness, with some having high values in one of the sub-indices. For example, ERI is high in cities like Samanood, Berket El Sabaa, Talkha, and Desouk, while cities like Belqas, Abu El Matameir, New Damietta, Faqus, and Hehia have higher URI.

4.4.3 Low readiness assessment index cities

This group represents the lowest overall Readiness Index for implementing eco-industrial cluster policy, comprising 38 cities, and accounting for 49% of the total. Most of these cities generally exhibit low RI in two of the sub-indices and only moderate readiness in one sub-index (economic, urban, or social).

5. DISCUSSION

The findings of this study provide a comprehensive assessment of the readiness of textile industrial cities in the Delta Region to adopt EICs policies. By integrating economic, social, and urban dimensions, the analysis offers a holistic understanding of cities' capabilities and challenges. The Readiness Assessment Index, alongside its sub-indices (Economic, Urban, and Social Readiness), highlights critical insights into the strengths and areas requiring improvement, categorizing cities into three distinct readiness groups.

The first group, comprising cities with high readiness, demonstrates substantial capabilities across economic, social, and urban dimensions. Cities in the Northwest Delta Zone, such as Alexandria, Borg El Arab, and Kafr El Dawwar, exhibit strong infrastructure and integration, making them highly suitable for immediate EIC policy implementation. This finding aligns with Yasheva et al. [14], who emphasize the necessity of integrated production stages as a foundation for EICs. While the Central Delta Zone displays overall readiness, specific urban deficiencies - such as land shortages in Al-Mahalla Al-Kubra - highlight the need for brownfield redevelopment strategies to support industrial expansion. In new cities like Al-Sadat and Tenth of Ramadan (Outskirts of the Delta and Suez Canal Zone), exceptional urban connectivity enhances readiness, and consistence with Yulin and Qazi [6], who emphasize on the critical role of infrastructure in attracting investments and driving industrial growth. To further enhance readiness in these cities, targeted urban development policies should be introduced, alongside strengthened institutional frameworks, support for SMEs in adopting advanced production technologies, and promoting sustainability initiatives such as renewable energy integration and green building standards. The Northwest Delta Zone, identified as the most prepared, benefits significantly from its high connectivity via road and rail networks, ports, airports, and the availability of special economic zones, as highlighted in previous research [6]. These factors collectively position the region for achieving value chain integration in the textile industry.

The second group includes cities with intermediate readiness, such as those in Al-Dakahlia, Al-Gharbia, and Al-Sharqiya governorates. These cities exhibit mixed scores across sub-indices, with notable economic strength in Samanood and Talkha, and higher urban readiness is more pronounced in Belqas and New Damietta. These findings echoe Yulin and Qazi's [6] conclusions on the significance of localized infrastructure and educational institutions in fostering economic activities. To unlock their full potential and align with the sustainable growth model proposed by Yasheva et al. [14], these cities require tailored interventions. Key strategies include improving road networks, water, and electricity infrastructure, expanding educational and training institutions to develop a skilled workforce, and offering targeted economic incentives to attract industrial investments.

The third group comprises cities with low readiness and accounting 49% of the total, faces critical challenges. These include weak industrial infrastructure, limited labor availability, and inadequate connectivity. Urban deficiencies, such as the lack of industrial zones, poor transportation links, and insufficient water and electricity networks, align with Yasheva et al. [14], who identify these factors as fundamental barriers to textile sector integration. Similarly, the findings support Yulin and Qazi [6] emphasis on the importance of special economic zones and transport infrastructure in attracting investments. Addressing these challenges requires phased interventions, starting with infrastructure improvements and better connectivity between industrial zones and main transportation networks. Additionally, ensuring access to essential services and offering short-term training programs, coupled with private sector incentives, can enhance workforce skills and stimulate industrial expansion.

The study also identifies certain limitations, including limited the lack of detailed data on supply chains, production linkages, business services (e.g., financial institutions), and the textile sector's integration with R&D services. These gaps hinder deeper analysis of horizontal and vertical integration within textile production value chain.

6. CONCLUSIONS

The integration of economic, social, and urban dimensions into the readiness assessment framework provides a comprehensive and robust approach to guide policy decisions for fostering eco-industrial clusters. This research highlights the varying readiness levels among textile industrial cities in the Delta Region, offering insights into their capacities and challenges. High-readiness cities, particularly those in the Northwest and Central Delta Clusters, are well-positioned for immediate policy implementation. However, they face challenges, such as a shortage of industrial land for expansion in cities like Al-Mahalla Al-Kubra, Mansoura, and Tanta. Addressing these challenges necessitates policy shifts toward brownfield redevelopment to optimize land use.

Intermediate and low-readiness cities, which are more widely distributed across the Delta, encounter significant urban and social challenges, including inadequate infrastructure, limited labor availability, and weak connectivity. To overcome these barriers, targeted interventions are essential. These include upgrading infrastructure, connecting industrial zones to main transportation improving connectivity between industrial zones and main transportation networks, ensuring access to essential services such as water and electricity, introducing short-term training programs to enhance workforce skills, and providing economic incentives to attract private sector investments Such measures will facilitate a smoother transition to EICs, promote sustainable industrial growth, and

align with national green industrial policies.

Future research should investigate the supply chain dynamics within high-readiness clusters and evaluate the effects of EICs policies on regional and local planning frameworks. Additionally, it is essential to examine the economic relationships and institutional linkages that are pivotal for the successful implementation of EICs. Such efforts will enhance understanding of how EICs can foster sustainable development and bolster industrial competitiveness in the Delta Region.

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