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Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context

D. Sakr [a,*], L. Baas [b], S. El-Haggar [c], D. Huisingh [d,e]

[a] Erasmus Universiteit Rotterdam, International Ph.D. Program on Cleaner Production, Cleaner Products, Industrial Ecology & Sustainability, The Netherlands
[b] Industrial Ecology, IEI – Department of Management and Engineering, Div. Environmental Technology and Management, Linköping University, Sweden
[c] Energy & Environment, Mechanical Engineering Department, American University in Cairo, Egypt
[d] Sustainable Development, Institute for a Secure and Sustainable Environment, University of Tennessee, Knoxville, USA
[e] Cleaner Production in International Off-Campus Ph.D. Programme on Cleaner Production, Cleaner Products, Industrial Ecology & Sustainability, Erasmus University, Rotterdam, The Netherlands

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ABSTRACT

The trend of clustering industries into regional estates or cities was adopted in the mid 1900's. At present, the number of industrial estates in the world is estimated to be between 12,000 and 20,000 (UNEP, 1997) and this trend is continuing to rise in both developed and developing countries. The implementation of the EIP concept continues to evolve especially with the environmental threats and impact on climate change that industries pose. However, there is not yet a fully developed EIP that is operating; although some successful examples of regional by-product exchanges are functioning (Lowe, 2001; Peck, 2002; Lowe et al., 1995; Chertow, 2000). Actually, a significant number of projects have failed or have abandoned the goal of becoming an EIP. Furthermore the current body of knowledge on industrial ecology is not sufficient to provide practical solutions to the obstacles facing EIPs.

This paper is based upon the Ph.D. Doctoral thesis research of D. Sakr. It was prepared to examine means to improve the uptake of cleaner production & industrial symbiosis in industrial areas in Middle East & North Africa Region focusing on Egypt as a case study. An extensive literature review was performed on eco-industrial development projects' experiences around the world, in order to identify the critical driving and limiting factors for EIPs. This paper summarizes the lessons learned from worldwide EIP experiences as a basis for the planning and implementation of future EIPs. The paper reflects as well upon the Egyptian context for the identified EIP success and limiting factors. The identified key success and limiting factors are: the creation of symbiotic relationship, information sharing and awareness, financial benefits, organizational structure, and legal and regulatory framework.

1. Introduction

The trend of clustering industries into estates or cities was adopted in the mid. 20th century (UNEP, 1996). At present, this trend is continuing in both developed and developing countries especially when there is rapid industrialization. The number of industrial estates of various types in the world today could be above 20,000. According to the International Development Council (IDRC) and the Association of Southeast Asian Nations (ASEAN), there are around 8800 in the US; 1200 in Canada; 200 in the UK; 300 in Germany; 130 in the Netherlands; 19 in Indonesia; 23 in Thailand; more than 150 in Malaysia; and more than 600 in Japan (UNEP, 1996).

Although individual industries in many countries have taken major steps to address environmental pollution through pollution prevention, cleaner production, and environmental management systems; nevertheless many industrial estates have not systematically addressed environmental issues in a comprehensive way as revealed by UNEP studies (UNEP, 1996). These studies indicated that few estates have an explicit environmental management capability or any environmental plan at the estate level.

The industrial sector in Egypt represented 34% of GDP in 2003 and employed about 20% of the active labor power (Mobarak, 2001; EEAA, 2005). Consequently, it is considered the dynamic engine for growth essential for rapid economic and social development in Egypt. Currently, there are about 80 industrial cities and zones in Egypt as listed in Table 1 (IDA, 2010). The geographical distribution of these industrial centers is mainly concentrated in Greater Cairo, where 41% of the industrial production exists. The Delta Region has

* Corresponding author.
E-mail addresses: daliaskr@aucegypt.edu (D. Sakr), leenard.baas@liu.se (L. Baas), elhaggar@aucegypt.edu (S. El-Haggar), dhuising@utk.edu (D. Huisingh).

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Table 1
List of industrial cities and zones in Egypt (IDA, 2010).

Governorate	Industrial city		Industrial zone	
Cairo	1	Badr city industrial city	1	Torah and Shaq Al Tho'ban industrial zone
	2	15th of May industrial city	2	South Helwan industrial zone
			3	Katamia industrial zone
	3	New Cairo industrial city	4	Shaq Al Tho'ban industrial zone (taken hold of)
			5	Al Robeiky industrial zone
Alexandria	4	Borg Al Arab industrial city	6	New Manshia industrial zone
			7	Al Nasseria industrial zone
			8	Upper and Lower Mergham industrial zone
			9	The industrial zone in K 31, Desert Road
			10	Seibco Industrial Zone
			11	Ajami industrial zone
			12	Al Nahda industrial zone and its expansions
Port Said		/	13	The industrial zone C 1
			14	The industrial zone C 6
			15	The industrial zone C 8
			16	The industrial zone C 9
			17	The Northwest Bortex industrial zone
			18	Al Reswa Fish Basin industrial zone
			19	The industrial zone C 7
			20	The industrial zone C 11
Suez	5	Ataka industrial city and its expansions	21	The industrial zone for light industries
Demeitta	6	New Damietta industrial city		/
Dakahlia		/	22	Southwest Gamasa industrial zone
			23	Asafra industrial zone
Sharkiya	7	New Salhia industrial city	24	Belbeis-10th of Ramadan road industrial zone
	8	10th of Ramadan industrial city		
Kaliubia	9	Al Obour industrial city	25	Al Shorouk industrial zone
			26	Al Safa industrial zone
Kafr El Sheikh		/	27	Balteem industrial zone
			28	Metobas industrial zone
Menoufia	10	El-Sadat industrial city	29	Mubarak Industrial Zone and its expansion
Beheira	11	Nubaria industrial city	30	Natron Valley industrial zone
			31	Boseili Desert industrial zone
Ismailia		/	32	Al Qantara Shark industrial zone
			33	The 1st industrial zone
			34	Technology Valley
			35	The 2nd industrial zone
Giza	12	6th of October industrial city	36	Abu Rawash industrial zone and its expansions
			37	Baiad Al Arab industrial zone
Beni sueif	13	New Beni Sueif industrial city	38	Kom Abu Radi industrial zone
			39	The industrial zone 1/31
			40	The industrial zone 2/31
			41	The industrial zone 3/31
			42	The industrial zone 4/31
Fayoum		/	43	Kom Oshim industrial zone
			44	Bakouta industrial zone
Minya	14	New Minya industrial city	45	Al Matahra industrial zone, east of the Nile
Assiut	15	New Assiut industrial city	46	Al Awamer Abnoub industrial zone
			47	Al Zarabi industrial zone in Abu Tig
			48	Al Safa industrial zone (Beni Ghaleb)
			49	Sahel Selim industrial zone
			50	Dairout industrial zone
			51	Badari industrial zone
Sohag		/	52	Al Kawthar District industrial zone
			53	Al Ahaiwa industrial zone in
			54	Beit Dawood industrial zone, west of Gerga
Kena		/	55	West of Tahta industrial zone
			56	Kalaheen industrial zone
			57	Hu industrial zone
Aswan		/	58	Al Alaki Valley industrial zone
The New Valley		/	59	Al Kharga industrial zone
			60	El Dakhla industrial zone
Matrouh			61	The industrial zone in K 26
North Sinai		/	62	Bir Al Abd industrial zone
			63	Al Masa'eed Artisans' Industrial Zone
			64	The industrial zone for building materials, south of El Arish

Table 2
Eco-Industrial Parks in Europe (Gibbs and Deutz, 2007).

	Operational	Pre-operational	Planned[a]	Attempted[b]
BCSD-NSR, national industrial symbiosis programme, UK (Various sites)		X		
Closed project, Tuscany, Italy	x			
Crewe green business park, UK	x			
Dagenham sustainable industrial park, UK		X		
Dyfi eco-park, Wales, UK	x			
Eco park Oulu, Finland	x			
Ecosite du Pays de Thau, France	x			
Ecotech, Swaffham, UK		X		
Emscher park, Germany	x			
Green park, Cornwall, UK				x
Hartberg Okopark, Austria	x			
Herning-Ikast industrial park, Denmark				x
Kalundborg, Denmark	x			
London remade eco-industrial sites, UK	x			
Montagna-Energia Valle di Non, Italy	x			
Parc Industriel Plaine de l'Ain, (PIPA) Lyon	x			
Righead sustainable industrial estate, Scotland, UK		X		
Rotterdam harbour industrial ecosystems programme			x	
Selkirk eco-industrial project, Scotland, UK				x
Sphere EcoIndustrie d'Alsace, France	x			
Stockholm, environmental science park, Sweden			x	
Styrian recycling network, Austria	x			
Sustainable growth park, Yorkshire, UK			x	
Turin environment park, Italy	x			
Value park, Schkopau, Germany	x			
Vreten, Sweden	x			

[a] This category includes both existing industrial parks developing 'green' practices and new EIPs that are under construction and/or recruiting tenants.
[b] Sites in this category range from those that failed in the planning stages to those that are now fully operational but have abandoned the 'eco' and or 'industrial' themes.

17%, Alexandria has 16.8% and finally the Canal Zone has 14.2% of the industrial production. Only 11% of the industrial production is located in the Upper Egypt region, while 89% is in Cairo and Northern regions (Mobarak, 2001). No eco-industrial parks were developed in Egypt yet.

2. Research objectives

This paper reports upon the process and results of the lead author's PhD research that is designed to examine means to uptake cleaner production & industrial symbiosis[1] in industrial areas in Middle East & North Africa Region focusing on Egypt as a case study. As part of the in-depth literature review, this thesis researcher has developed a holistic insight into eco-industrial development project experiences around the world. The researcher has identified key EIPs' success and failure factors and approaches to overcome crucial limitations of many of the currently operated EIPs. In addition, the paper sheds the light on the Egyptian context for the identified EIP success and limiting factors based upon preliminary interviews of key stakeholders (i.e. Egyptian authorities, consultants, academia, investors associations, etc.), literature review, and professional experience.

3. Eco-industrial parks in practice

Today industrial ecology is being pursued with unprecedented vigor and is gaining recognition not only in academic communities, but in business and government circles as well as a 'natural' stage for industrial system development (Erkman, 1997; Erkman, 2001). One of the main and most immediate applications of industrial ecology is Eco-Industrial parks (EIP). By early 2001, at least forty communities in the US and sixty eco-industrial projects in Asia, Europe, South America, Australia, and South Africa have initiated eco-industrial development projects (Desrochers, 2001; Lowe, 2001). The status of some EIPs developments in Europe, North America, and Asia Pacific regions is highlighted based on published literature and other available information.

3.1. EIPs in Europe

There are several eco-industrial parks in various countries in Europe, some are operational, others are in pre-operational, planned, or attempted phases as listed in Table 2. One of the most cited EIP case studies in the world is the industrial symbiosis network in Kalundborg, Denmark.

3.2. EIPs in North America (United States and Canada)

Adopting industrial ecology concepts and developing EIPs gained significant attention in the USA and Canada in order to retain existing firms and attract new businesses, where a number of EIPs (as listed in Table 3 and Table 4) were established simultaneously. More than 60 eco-industrial networking projects in Canada and the United States have been identified; but only about 17 are operational with completed projects (Peck, 2002). Most of the EIPs in the US have been developed through a national initiative to develop and foster applications of industrial ecology to industrial parks through the President's Council on Sustainable Development (PCSD) and US Environmental Protection Agency (USEPA). In 1994, the USEPA announced the availability of $300,000 for eco-industrial park design and development and in 1995 it funded the preparation of the Fieldbook for the Development of Eco-Industrial Parks (Lowe et al., 1995; Chertow, 2000).

3.3. EIPs in the Asia Pacific region

In Asia, both private and public sector real estate developers are adopting eco-industrial strategies far beyond most of their counterparts in North America with the strongest creative force in

[1] In this paper the terms *Industrial Symbiosis*, *Eco-Industrial Parks/Estate*, and *Eco-Industrial Networking* are used interchangeably to refer to the same concept. For clearer distinctions between each refer to the definitions in Lowe (2001).

Table 3
Eco-Industrial Parks in US (Gibbs and Deutz, 2007).

	Operational	Pre-operational	Planned[a]	Attempted[b]
Anacostia ecogarden project, prince georges county, Maryland				x
Avtex redevelopment project, front royal, Virginia			x	
Bassett creek, Minnesota			x	
Brownsville eco-industrial park, Brownsville, Texas				x
Buffalo, New York			x	
Cabazon resource recovery park, California	x			
Civano industrial eco park, Tucson, Arizona				x
Coffee creek center, Chesterton, Indiana			x	
Computer and electronics disposition eco-industrial park, Austin, Texas			x	
Eco-industrial Park, Cowpens, South Carolina				x
Devens planned community, Massachusetts	x			
Dallas ecopark, Dallas, Texas		x		
Alameda county eco-industrial park, San Francisco, California			x	
Eco-industrial Park, Cheney, Washington State				x
Fairfield ecological industrial park, Baltimore, Maryland	x			
Franklin county eco-industrial park, Youngsville, North Carolina				x
Hyder enterprise zone, Hyder, Alaska				x
Intervale community food enterprise center, Burlington, Vermont		x		
Londonderry eco-industrial park, Londonderry, New Hampshire		x		
Menomonee valley, Wisconsin			x	
Northwest Louisiana commerce center, Shreveport, Louisiana				x
Phillips eco-enterprise center, Minneapolis, Minnesota	x			
Plattsburgh eco-industrial park, New York				x
Port of Cape Charles Sustainable technologies industrial park, Northampton County, Virginia	x			
Raymond green eco-industrial park, Raymond, Washington				x
Red hills ecoplex, Choctaw County, Mississippi		x		
Renova EIP, Puerto Rico			x	
River city park, Newburgh, New York				x
St. Peter, Minnesota				x
Skagitt county environmental industrial park, Skagitt County, Washington				x
Shady side eco-business park, Shady Side, Maryland				x
Springfield, Massachusetts			x	
Trenton eco-industrial complex, Trenton, New Jersey				x
Triangle J Council of Governments regional IS project	x			
Volunteer Site, Chattanooga, Tennessee				x

[a] This category includes both existing industrial parks developing 'green' practices and new EIPs that are under construction and/or recruiting tenants.
[b] Sites in this category range from those that failed in the planning stages to those that are now fully operational but have abandoned the 'eco' and or 'industrial' themes.

eco-industrial development (Lowe, 2001). Chiu and Yong (2004) indicated that some EIPs in the Asia Pacific region were developed without planning where economic benefits were the main driver, such as the Guitang agro-business industries in China or the Naroda by-product exchange network in India; while others were introduced through partnerships with international organizations, such as the United Nations Development Programme (UNDP), the PRIME project in the Philippines, United Nations Environmental Programme (UNEP) project in China, the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) involvement in Thailand and China, and an ADB project in Sri Lanka as summarized in Table 5.

China is one of the leading countries to adopt industrial ecology in the Asia Pacific region. In 2002, China's central government formally adopted the concept of a 'circular economy' (CE), which originates from the IE paradigm, building on the notion of loop-closing emphasized in German and Swedish environmental policy. The CE is being pursued by China's environmental policy makers as a central strategy to solve existing environmental problems (Yuan et al., 2006). Eco-Industrial networks, at the meso level, for achieving CEs, are actively promoted in China by the State Environmental Protection Administration (SEPA). As of 2006 leaders of more than 100 regions stated that they are developing CEs (Yuan et al., 2006) (See Table 5 for details.)

3.4. The Egyptian experience

In Egypt, there are no eco-industrial parks that exist yet. However it is worth mentioning two important national projects that targeted the improvement of environmental performance on the scale of an industrial estate: the Environmentally Friendly New Industrial Cities Program (NICs) and the Integrated Industrial Solid Waste Management in Egypt project (IISWM).

The NICs Program was a national, phased program, launched in August 1998 under the auspices of the Ministry of State for Environmental Affairs (MSEA). The NICs participating in the program were expected to provide productive environments for its manufacturing establishments, support activities, and inhabitants without imposing unsustainable demands on local resources and infrastructural services. The first phase, completed in December 2000, involved five industrial cities, namely: 10th of Ramadan, 6th of October, El-Sadat, El-Obour, and Borg El-Arab (Hamed and El-Mahgary, 2002; Ebeid and Hamza, 2000). During 2000/2001, the program was expanded to include another seven cities and zones, which are: Badr, New Damietta, El Saleheya, New Beni Sueif, Abou Rawash, Mubarak and El Kawthar. The industrial cities and the industrial establishments within their geographic boundaries had to comply with requirements of the Egyptian environmental Law No. 4/1994 and other pertinent legislation. On the company level, the criteria to qualify an industrial city as an 'Environmentally Friendly' was that at least 90% of the operating facilities would achieve full compliance with the standards of the executive regulations of Law 4/1994 (Ebeid and Hamza, 2000). The project achieved much attention and good environmental regulatory compliance in the beginning. Unfortunately, after a few years there was a sharp decline in the companies' compliance level.

The IISWM project was started in May 2001 with funding by the EU LIFE Third Countries in cooperation with the Egyptian Environmental Affairs Agency (EEAA). The objective of the project was

Table 4
Eco-Industrial Parks in Canada (Côté and Cohen-Rosenthal, 1998; Fleig, 2000).

Sites	Characteristics
Eco-Industrial Parks in Canada	
1. Burnside industrial park, Nova Scotia, Canada	Research and development subject of a university; large site, 1200 small and medium sized companies; creation of materials and energy cycles, imbedding into the natural environment, renewable energy use, information center, communication loops.
2. Sarnia, Ontario, Canada	Industrial symbiosis between oil refineries, a synthetic rubber plant, petrochemical facilities and a steam electrical generation station.
3. Bruce energy center, Ontario, Canada	The park organized around a nuclear power station in order to use its waste heat and steam generation capacity for processes such as dehydration, concentration, distillation etc.
4. Portland industrial district, Toronto	Research and development on an industrial area involving enterprises in a variety of sectors in manufacturing and services with the potential of material and energy exchange.

to formulate a master plan of Integrated Industrial Solid Waste Management (IISWM) that can be readily implemented instead of the current improper solid waste practices. The '6th of October' industrial city was chosen for testing this model due to various advantages it has such as housing a wide spectrum of industries and its proximity to Cairo. The project was implemented in four phases. The first phase included a review of the institutional and legislative framework and development of an industrial solid waste inventory through an intensive data gathering survey. In the second phase the development of an information database system and an assessment of the solid waste management practices including waste collection mechanisms as well as the disposal techniques. In the third phase, the former assessment of the waste management practices in comparison with prospective available techniques for IISWM was used to develop an Action Plan following the European Commission's standards. Finally, the fourth phase was comprised of support and dissemination actions for the reinforcement of the administrative structures and the promotion of the Action Plan.

One of the most important outcomes of the IISWM project was the waste exchange system program. The waste exchange system program was the first of its kind in Egypt and was planned to be expanded to eventually operate at a national level. It included a database that would host all system components covering the management needs for a viable waste exchange. The database could be initially operated by EEAA. The topic was published through seminars, workshops etc. throughout the project's duration. Interested parties could contact the EEAA for information or access it via he Agency's web page. However, the waste exchange system program wasn't successful and was discontinued.

4. Success and limiting factors

Although there have been several EIP developments, implementation of the concept is still emerging and there is not yet a fully realized operating EIP despite the fact that some successful examples of regional by-product exchanges do exist (Lowe, 2001; Chertow, 2000). Actually, a significant number of projects have failed or have been abandoned. Consequently, the goal of developing an EIP with a comprehensive environmental management system at the estate level is a relatively new concept. However at present in spite of a growing body of knowledge on IE there is not sufficient experience to provide practical solutions for all of the obstacles facing EIPs (UNEP, 1997; Lowe, 2001; Koenig, 2005).

The identified EIP success and limiting factors based on worldwide experiences can be categorized under (i) *symbiotic business relationships*, (ii) *economic value added* (iii) *awareness and information sharing, (iv) policy & regulatory frameworks, (v) organizational and institutional setups,* (vi) and *technical factors*. These are addressed in the following paragraphs.

Table 5
Eco-Industrial Parks in the Asia Pacific region (Chiu, 2004).

Asian economies (source reference)	Some participating agencies	Location of some EIP initiatives
Australia (3,4)	Western Australian water corporation, University of Canberra	Shenton sustainability park, synergy park Brisbane
China (1)	SEPA, UNEP, Dalian University of technology, Tsinghua University of IE Team, Dalhousie, Indigo, GTZ	Dalian, Yantai, Soo Chow, Tianjin, Guiging, Yixing, Taihu, Shanghai, Chong Yuan, Guiyang and Jiangsu
Philippines (1,2)	UNDP PRIME and EPIC projects, Yale University, USAEP	Laguna international industrial park, light industry and science park, Carmelray industrial park, LIMA, Laguna Technopark, Philippine National oil company petrochem industrial park, clean city center project (USAID).
Indonesia (1)	Kaiserslautern University	Lingkungan (LIK), Tangerang; Semarang; Industri Sona Maris
India (1)	Kaiserslautern University, ICAST, technology exchange network	Naroda; Tirupur textile sector; Tamil Nadu tanneries; Calcutta foundries; Tamil Nadu. paper/sugar; Bangalore water project; Ankleshwar, Nandeseri, Thane–Belapur.
Malaysia (1)	USAEP	LHT resources linkage.
Japan (1,2)	UNEP, Tokyo–Osaka–Toyo University, Japanese government	16 ecotowns (e.g. Kitakyushu, Itabashi), Fujisawa, Toyota city.
Korea (3)	NCPC Korea	15 year three-phase Master EIP Plan launched in 2003.
Taiwan (1,2)	ITRI, Taiwan government, Academe	Tainan technology and industrial park, Changhua Coastal industrial park; CSS II (corporate synergy system II) projects, Hua Lian and Kaohsiung (2003)
Vietnam (1)	Amata developer, USAEP, University of Natural Sciences	Amata (environment management), Hanoi Sai Dong II (feasibility study).
Thailand (1)	GTZ, IEAT	Industrial estate authority of Thailand plans (Map Ta Phut, northern region, Amata Nakorn, eastern sea-board, Bang Poo); Samut Prakarn province CPIE, project (ADB-funded); Bangkok (Panapanaan).
Singapore (2,4)	JTC developer, National University of Singapore Architecture Department.	
Sri Lanka (1)	Ministry of Economic and Industrial Development	ADB supported major policy studies in 2002

Source: Corresponding author's communications with the network of (1) IEAsia Conference 2001, (2) International Society of Industrial Ecology, (3) Asia Pacific Roundtable for Cleaner Production, and this issue of, Journal of Cleaner Production article entries.

4.1. Symbiotic business relationships

In contrast with the wide-spread image that EIPs' essential element is the establishment of "physical" by-product exchanges; it is not the most important feature of EIP development (Heeres et al., 2004). From the technical point of view, potential match-making between companies could exist, but the lack of companies' interest is deadly to initial EIP development since they are the ones who must invest money and time in planning and designing the exchange infrastructure. Based on the experiences of several EIP projects, issues of trust, good personal relationships, and cooperation between companies were crucial factors for the initial stages of EIP development and for the subsequent implementation (Gibbs and Deutz, 2007). Unfortunately, the situation in most industrial estates is a collection of companies in one location, which are socially isolated from one other. This is far from the concept of a "community" and in this case relational assets have to be built from the beginning of the process of establishing an EIP.

Cooperation between companies cannot be mandated through policy intervention and regulations but has to evolve over time through the motivation of an invested leader or "champion". According to Herees et al. (Heeres et al., 2004), initial research indicates that the Dutch EIP projects are more successful than their US counterparts. This difference in success can be, mostly, attributed to the fact that the US projects were initiated by local and regional governments that saw the project as a way to improve the local/regional economy with access to substantial government funds. Because of this heavy government involvement, US companies were in general not interested in the EIP projects. The more successful Dutch projects, on the other hand, were mostly initiated by the companies themselves with financial and advisory support from the local and regional government and from university faculty. Moreover, the Kalundborg industrial symbiosis (IS), which is considered to be one of the most successful EIPs, was a 'community' evolutionary process that developed over 30 years based upon several independent, bilateral relationships that evolved into a complex web of symbiotic interactions (Erkman, 2001; Lowe, 2001; Jacobsen, 2006). Besides companies, successful EIP development requires broad community support and active participation of major stakeholders, such as:

- Local, regional, and national government agencies;
- Business associations;
- Labor unions;
- Educational & research institutions;
- Multi-disciplinary experts and consultants; and
- Non-governmental organizations (community and environmental NGOs).

Then the real challenge for eco-industrial parks projects seeking successful initiation and implementation is how to encourage companies & stakeholders' collaboration and to develop a healthy balance among all stakeholders' interests. Despite the fact that "champions" are key actors for developing the community relationships and networks; regrettably the IE literature has given little attention to their roles. Champions are charismatic and visionary leaders that have credibility to inspire and guide people, resolve conflict, and keep people motivated toward a common vision. This requires an on-going process of building personal trust and developing buy-in. A champion should be an invested leader who lives and works in the community, is fully engaged in it, and is passionate about it. The champions are not dependent on their technical knowledge but on their emotional intelligence, specifically their ability to develop humanistic connections as opposed to emphasizing technological connections (Hewes, 2005). The champion(s) can be an individual, a group of individuals, or an institution. For example, in the Kalundborg IS system, one of the invested leaders is Valdemar Christensen the former facilities manager of the Asnaes coal-fired powerplant, which was the anchor company (Hewes, 2005). In the Netherlands the local entrepreneurs'/employers' association, acting on behalf of its member companies, is the initiator of the project and acts as the local champion (Heeres et al., 2004; Baas and Boons, 2004). In Korea, the three-phase 15-year eco-industrial park (EIP) initiative evolved under the leadership of the Korean National Cleaner Production Center (Park and Won, 2007).

There is very little published literature that examines the business–social relationships between the Egyptian companies in the planned industrial areas. Based on experience with the Egyptian industry, business–social relations are minimal due to lack of trust and resistance to exchange information between companies for fear that it may be used against them by the regulatory authorities. Business cooperation between companies could be more likely among clusters of the same industrial sector through local industry associations (e.g. Aluminum smelters in Met Ghamr). Both the NICs and IISWM projects were mandated by a governmental authority not through an invested 'champion' that was personally involved in the community to develop trust & buy-in among companies and the other stakeholders to guarantee sustainability of the EIP.

4.2. Economic value added

While trust and cooperation between the firms involved is very important, on the other hand both parties to an agreement need to gain something (Gibbs and Deutz, 2007). The economic value added could be ranked as the second most important EIP success factor. Chertow (2007) and Desrochers (2002) point out that conventional business interests in reducing expenses and/or in profit increases are strong motivations for companies to develop EIPs, because the anticipate benefits from resource sharing, increasing the availability of critical resources (i.e. water, energy, or particular raw materials), and in response to regulatory pressure requiring industrial operators to increase efficiency of resource use, reduce emissions, and eliminate waste.

Originally, in the Kalundborg IS system, the motivation behind most of the exchanges was to reduce costs by seeking income-producing uses for "waste" products and for achieving improved compliance with local, stringent, environmental legislation. Based on published information on the economic benefits of the Kalundborg IS, it is clear that the firms have saved US$160 Million by 2001 ($15 Million in annual savings) as return on the total investments of $75 Million in the 18 projects established up to and including 1998; therefore, the average payback time for all projects was less than five years. (Erkman, 2001; Lowe, 2001; Jacobsen, 2006). A simplified estimate of material and energy savings is illustrated in Table 6.

In the Moerdijk EIP in the Netherlands, the achieved environmental and economic benefits were strong incentives for other companies in the region to also identify potential exchange opportunities (Heeres et al., 2004). In contrast, the majority of companies located in both the Fairfield and Brownsville EIP cases in the US did not want to invest in the establishment of EIP exchange relationships with other enterprises located in their vicinity because they considered them to be financially risky. Additionally, there was a lack of trust toward the local government, which acted as the project promoter (Heeres et al., 2004). Another case was in Cape Charles in the US, where several firms abandoned EIP activities because they considered that approach to be 'unrealistic' since it entailed relocation to another site close to by-products that were of minor importance as input materials to the company due to their

Table 6
Estimates of the Material and Energy Exchanges at Kalundborg IS (Lowe, 2001).

Material	From	To	Sold/free	Began	Quantity [T/yr]
Fuel gas (x-flare gas)	Statoil	Gyproc	Sold	1972	8000
Sludge	Novo nordisk	1000 farmers	Free	1976	1,100,000
Fly-ash & clinker	Asnæs	Aalborg Portland	Sold	1979	200,000
Steam	Asnæs	Kalundborg	Sold	1981	225,000
Steam	Asnæs	Novo Nordisk	Sold	1982	215,000
Steam	Asnæs	Statoil	Sold	1982	140,000
Water (x-cooling)	Statoil	Asnæs	Sold	1987	700,000
Hot sea water	Asnæs	Fish Farm	Free	1989	NA
Sulfur (liquid)	Statoil	Kemira	Sold	1990	2800
Water, biotreated	Statoil	Asnæs	Free	1991	200,000
Fuel gas (x-flue gas)	Statoil	Asnæs	Sold	1992	60,000
Gypsum	Asnæs	Gyproc	Sold	1993	85,000
Total annual quantity:					2.9 million

Note: by volume water is the material exchanged the most, almost 85% is water, in either liquid or gaseous (steam) form.

relatively low procurement costs (Gibbs and Deutz, 2007). Consequently, a good entry point to EIP is to market first projects perceived by firms as low risk and high benefit as it would encourage participation in further EIP developments with greater risk after the economical and environmental rewards of the early projects would have been realized (Gibbs and Deutz, 2007).

Based on previous experience from implementing environmental programmes in Egypt, the economical benefits derived from pollution prevention has been usually associated with external donor funds. Since the launch of the NEAP of 1992 in Egypt, the country has been assisted by 19 international organizations to help it implement its environmental agenda. The total amount of donor funds allocated to the field of Environment and coordinated through MSEA/EEAA is equivalent to 7.22 billion Egyptian Pounds (about 915 million Euros), while 23.01 billion Egyptian Pounds (72.4% of total investments) were financed by local resources. The highest percentage of donor support (42.9%) was channeled through policy support and environmental management programs while industrial pollution abatement and air pollution together accounted for 26% of the total support, while solid and hazardous waste management was the least support (1.8%). Almost 91% of the total assistance was in the form of grants while 9% was in the form of loans (Mobarak, 2001).

The donor funds were intended to serve as seed money and as a driving mechanism for environmental protection & conservation of natural resources in Egypt, however it had its negative consequences where EEAA and industries became almost totally reliant on gradually shrinking foreign aid for environmental actions without the existence of local sustainable financing mechanisms. Informing companies' owners with the potential economic benefits of resources & energy efficiency, pollution reduction, and voluntary funding mechanisms such as the clean development mechanism, could help to simulate self-action by industries to develop EIPs without heavy dependence on external financial support.

4.3. Awareness and information sharing

During the stage of building-up the social networks and before proceeding with the business contracts, very few companies are aware of EIP concept or of it potential benefits. Therefore, it is important that champions educate the community at an early phase to disseminate basic EIP principles and to present successful case studies. The initial EIP awareness could be performed through networking with key individuals and organizations; organizing public events with media coverage; conducting workshops or conferences; launching an informative website; and planning activities in universities (Lowe, 2001). The US EIPs were successful in this regard since the project management highly stimulated and encouraged the involvement of local community and NGO's in the form of so-called "planning and design charettes" (Heeres et al., 2004).

Nevertheless, Koenig (2005) highlights the importance of following awareness campaigns with effective structures for providing continuous technical assistance to guide companies, specifically small and mid-size companies (SMEs), to the right information and technology suitable to their needs as the majority of firms fail to catch on due to the difficulty of these dissemination methods and the overwhelming content. Moreover, Chertow (2007) adds that a 'coordinative function' is needed to support the management of inter-company information flows, play matchmaker for recycling opportunities, and provide assistance & coordination in their application similar to the centralized "Regional Recycling Information System" (REGRIS) in the Oldenburger Munsterland Region of northwest Germany (Milchrahm and Hasler, 2002) as well as in Kalundborg's IS.

Information exchange is essential since it facilitates for companies to find suitable business matches and allows sharing of all available tools and resources within the community (Heeres et al., 2004). The best candidates for information collection and exchange are EIP managers. However these services are considered by them to be additional to the basic infrastructure services for tenants mandated by law (Koenig, 2005). The EIP champion(s) should intervene by either developing these information sharing platforms independently or by convincing the park management to expand its role to be both an 'information and service' provider.

Chertow (2007) and Chertow and Lombardi (2005) pointed out that sometimes energy and materials exchanges exist in industrial estates without awareness of involved companies about EIP concepts as was the case in the Kalundborg IS in Denmark and the Styria case in Austria, where the system arose for economic and regulatory reasons although it was never labeled as an EIP. Chertow elaborated further that these 'hidden' exchanges are usually 'uncovered' by a third party, such as an academic institution or business association, after they have implemented material's and energy sharing activities and have attained environmental and economic benefits.

In Egypt, despite the relatively good awareness of the pollution prevention and cleaner production concepts among regulatory bodies, industries, local consultants and academics due to the effort of the donor-funded projects; however there is little knowledge about IE/EIP at all levels. Certainly, dissemination of information especially about some successful stories of existing EIPs worldwide and through the implementation of demonstration projects are vital activities that could help to introduce the EIP concept to Egypt. Another gap is the scarcity of updated information about the environmental impacts of industrial estates and the resistance to exchange information between relevant entities. The key environmental data collector is the Egyptian Ministry of Environmental Affairs (EEAA). The Industrial Pollution Information System (IPIS) at the EEAA Inspection Unit contains data on firms that have been inspected for compliance with Environment Law 4 of 1994 Fig. 1.

These inspections should collect a general description of the industrial facility, data on its inputs and outputs, a description of the production processes, data on the utilities within the facility, information concerning previous violations by the facility, information on sources, types and quantities of pollution within a facility, and changes in any of these data since the last inspection. However these data are available only to the Inspection Unit staff and are not a representative sample of Egyptian industry because the Inspection Unit chooses to focus on specific sectors (i.e. major

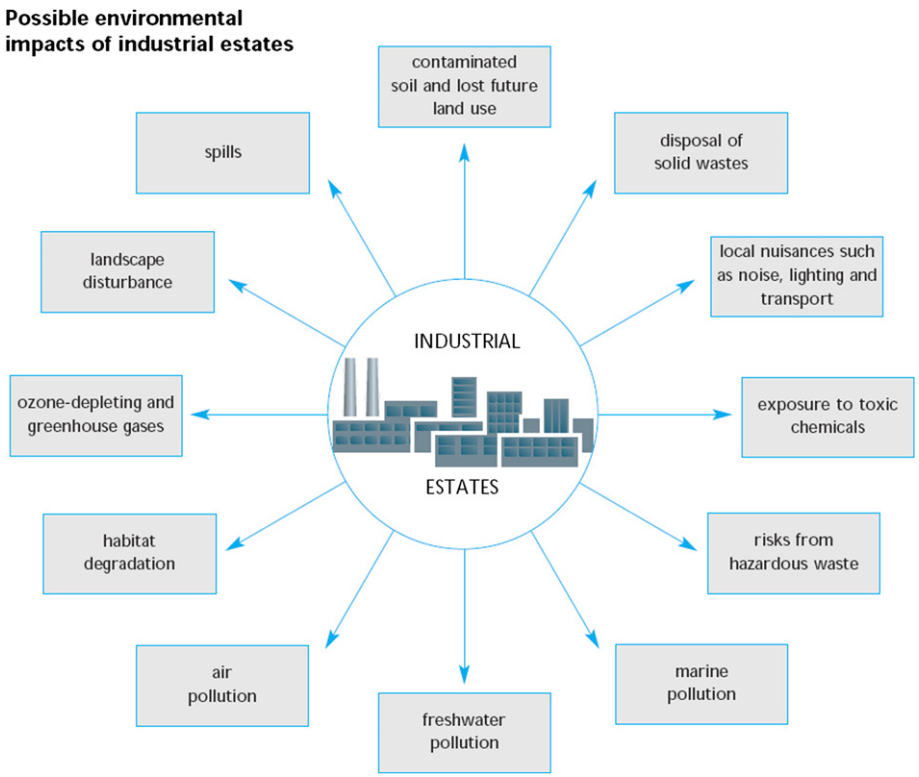

Fig. 1. Possible environmental impacts of industrial estates (UNEP, 1997).

polluters), on certain geographical locations due to political pressure, or when a complaint is lodged against them. The only information regularly made public includes summary reports of the air and coastal water measurements carried out by EEAA's Environmental Information and Monitoring Program (EIMP), but beyond this the data are for internal use within the ministry or for carefully arranged exchange with other ministries. It is not for public use due to the absence of an effective information dissemination strategy based on an understanding of the users and their information needs (Hecht, 2004).

4.4. Policy & regulatory framework

Although business economic benefits are or can be a main driver for firms to engage in material's exchanges, however, the top management usually does not have the time, commitment or capabilities to identify and take advantage of these opportunities. As a result, governmental policy should be designed and implemented to play an "enabling role" by providing political, coordinative, educational, and infrastructural support (Gibbs and Deutz, 2007). This is especially the case in the Far Eastern countries; where IE and EIPs are initiated because of national policy. For example, China declared EIPs as one of the main components of its CE strategy. Similarly, Thailand, Korea, and the Philippines are developing national strategies for EIPs to help alleviate extensive environmental degradation caused by failures of "end-of-pipe" pollution control approaches (Koenig, 2005).

In the Ulsan EIP initiative in Korea, there was in integrated approach at three policy levels: national level, city level, and local level. On the national level the sustainable industrial strategy assisted in upgrading environmental technology and creating symbiotic networking opportunities; while at the city level, both the Eco-Polis Ulsan program and the Ulsan EIP transition initiative applied IE principles on the overall development in the region; and finally on the local level the local government managed the developmental activities, i.e. housing, municipal services, and infrastructure (Park and Won, 2007).

Chertow (2007) pointed out that the government could play three roles through policy to advance IS: "1) bring to light kernels of cooperative activity that are still hidden; 2) assist the kernels that are taking shape; and 3) provide incentives to catalyze new kernels by identifying "precursors to symbiosis". On the other hand, the high involvement of the government in the development of eco-industrial parks can be a double-edged approach if not implemented wisely as in the case of the US EIPs. In Fairfield, Baltimore, and Maryland the local politicians' approach didn't convince industries to participate since they considered "the project as a job creation initiative and not as an economic program designed to help the economic and environmental performance of the companies involved" (Heeres et al., 2004).

Another important issue to be addressed by government is to bring current environment legislation and standards in line with the principles of EIPs. Actually, incentives-based regulatory framework encouraging by-product utilization and continual improvement in environmental performance are two of the most valuable lessons to be learned from the Kalundborg IS, since it allowed firms "to focus their energies on finding creative ways to become more environmentally benign instead of fighting the regulator" (Desrochers, 2002; Gertler, 1995).

Another relevant example, is Sarnia, the oil refining city in the Canadian province of Ontario. It has faced regulatory barriers to export wastes to the United States and in several US EIPs it was not possible for firms to exchange several substances because they would be classified as "hazardous waste" under the Resource Conservation and Recovery Act (RCRA) (Desrochers, 2002). In contrast, the Public Utilities Regulatory Policy Act (PURPA) in the United States encouraged many industries to co-generate steam and electricity due to the pricing benefits provided by the law

(Chertow, 2007). However, it should be noted that stringent environmental laws and standards are important driving forces for firms to adopt pollution prevention approaches, especially projects that can provide both economic gains and improved environmental performance, such as IS; on the condition that they would be effectively monitored through relevant governmental agencies.

With regard to Egypt, to be successful the environmental strategies should encompass a mix of innovative policy tools that is based on creating a demand for compliance and enforcement. Through donor-funded projects, the EEAA was able to provide technical and financial support to pollution prevention efforts (i.e. the National Industrial Pollution Prevention Program). However, these projects stressed that in order to attract more industries to adopt such measures there should be strict enforcement as an external pressure. The Egyptian experience in compliance and enforcement of environmental laws has been very weak; which resulted to being non-supportive to the regulating system. The lack of considerations of these factors could be the reason for this weakness: "soft law enforcement for justifiable social and economic reasons; high costs of environmental monitoring and testing; lack of skilled and trained human resources; unclear roles & responsibilities of regulatory bodies; inadequate flexibility (for instance permitting); and by devising legal tools for promoting changes in environmental perception and behavior when other tools would have been much more cost effective and efficient" (El-Zayat et al., 2006; Genena, 1996).

Furthermore, mainstreaming EIP into the country's national strategy is vital for its success and continuity similar to China's circular economy. EIPs should be integrated into national development planning processes to link it to national plans, budgets, sector strategies, and local level implementation within the wider stakeholder community. This would allow the Government to use EIPs as one of the mechanisms to achieve economic growth and sustainable industrial development. Recently, it was stated in Egypt's Industrial Development Strategy that the development of "Eco-Industrial Parks" is currently on the top of the agenda of the Ministry of Trade and Industry (MTI); where the private sector will be involved through a collaborative partnership approach with the government in the formulation, establishment, and operation of EIP to achieve an 'Integrated Industrial Development Model'[2] (IMC, 2009). Although this is a good indicator that Egypt is moving toward industrial ecology; however the mentioned EIP conceptualization focus strictly on the economical factor leaving out the environmental and social pillars. Moreover, no action plan followed this declaration to setup the measures required to create EIPs in Egypt.

4.5. Institutional & organizational setups

A successful strategy to make EIP an integrated scheme is to fit the planned bilateral planned exchanges into the corporate organizational structure of each involved firm and in the overall management system of the park. Trust is a central mean for achieving cooperation in inter-organizational relationships. Erkman (2001) indicates that there should be a change in the mindset of traditional management that highly risks "competitive relationships" to adopt "over-the-fence management systems" where companies collaborate together in achieving common or new goals more effectively in the EIP system.

Information communication technologies and infrastructures significantly facilitates collaboration and information exchange between firms. For example in INES case in the Netherlands, the presence of the BIM-Network[3] in the project organization structure was an additional success factor as it created a communication platform among the various companies (Heeres et al., 2004).

It is essential to examine the organizational cultures within industrial estates; since low levels of inter-firm cooperation in an area means that there are behavioral barriers that resist or prevent companies to work across organizational borders that even sound economic advantages aren't sufficient to overcome them (Gibbs and Deutz, 2007). Therefore, IS may be easier to establish when there is an 'already' established base for exchanges and cooperation (Chertow, 2000; Heeres et al., 2004; Baas and Boons, 2004; Chertow, 2007; Korhonen, 2002; Schwarz and Steininger, 1997). Sometimes the cause of this lack of interest is external to the firm, specifically in multinational firms that are part of a worldwide corporate network, where the subsidiary company may have limited decision-making powers (Gibbs and Deutz, 2007). It can be the opposite if the headquarters company has a well established group-level system for corporate social responsibility or similar systems (i.e. environmental management system), then it would promote such environmental initiatives at its subsidiary companies as well.

4.6. Technical factors

The most challenging technical issue facing eco-industrial developments is the absence of an internationally accepted standard to define it, to guide its planning and implementation, and to evaluate its performance to allow ranking & benchmarking among them. This causes confusion and misleading claims of what it means to develop an industrial ecosystem. Currently, only individual criteria exist such as adopting a "3–2" as a minimum criterion by Chertow (Chertow, 2007) and colleagues to distinguish EIPs from other types of exchanges; where "at least *three* different entities must be involved in exchanging at *least* two different resources to be counted as a basic type of industrial symbiosis". Peck (2002) recommended the development of a performance rating system, similar to the LEED[4] rating system, which would result in better acceptance of the concept and help to facilitate its integration to other internationally recognized standards like ISO 14001 for environmental management systems. Another important issue is the lack of local technical know-how capable of identifying and evaluating IS opportunities, and implementing the technologies and measures needed to realize the IS benefits.

There are several authors who argue that IE tends to be a form of extended pollution prevention and there are other views skeptical that IS may negatively affect firm-level environmental measures such as cleaner production. Pollution prevention and cleaner production overlap with IE in many ways, where they clearly share a breadth of purpose and similar objectives (Lowe, 2001). Actually,

[2] The definition of 'Integrated Development Model' according to Egypt's Industrial Development Strategy is: "the overall goal of developing EIP in Egypt is achieving an Integrated Industrial Development Model that enforces the business relations and networking linkages between firms operating within each and every industrial entity or region, connects potential clusters of companies producing related/complementary products, and engages different stakeholders and institutions in the development of these parks in order to achieve economies of scale, create more jobs, increase Egyptian exports, attract FDI {foreign direct investment}, and contribute to the overall growth of the economy".

[3] "BIM-Network is a communications platform formed, in the course of the EBB BIM-project, by a cluster of Industries located in the Europoort–Botlek region. The companies represented in this network kept each other informed about their progress and problems in the implementation of pollution prevention and environmental management systems" (Heeres et al., 2004).

[4] LEED: Leadership in Energy & Environmental Design. It is a rating system developed by US Green Building Council. It is voluntary and internationally recognized that evaluates if the establishment meets 'green building' criteria through a 100-point scale.

Table 7
Summary of success and limiting factors for EIP development.

	Lead Role	Success Factors	Limiting Factors
Symbiotic business relationships	Champion(s)	• Establishment of the essential 'symbiotic' exchange relationships between the companies participating in the project. • Collaboration and formation of business networks. • The active participation and empowerment of stakeholders. • Champions functioning as a communication platform between the companies themselves and provides company management and staff with important "social" contacts. • Existing social networks may help to encourage environmental networking through forming mutual trust. • Trust in the competence of other companies. • Goodwill of other companies.	• To think that 'physical' energy, water, materials and by-product exchanges are the most important features of EIP development. • Lack of company interest. • Cooperation between companies cannot be mandated by the government. • Lack of stakeholders' involvement. • Absence of a champion. • Absence of trust in new dependency links.
Added economic value	*Champion*(*s*): spread awareness of potential economic benefits *Government*: incentives and partial finance & *Universities & Consultants*: evaluating economic feasibility	• Involved parties gain an added economical value. • Willing to invest time, money and other resources in the development of an EIP.	• An exchange might be economically unsound or economically risky from a company perspective. • Lack of finance. • Costs of EIP planning are solely carried by the government.
Awareness & information sharing	Champion(s) Universities Consultants Government Park managers	• In order to stimulate development, it is important to focus on the establishment of low cost, high benefit utility sharing projects and "simple" exchanges. • Educate and inform companies of the potential benefits that can be achieved through the establishment of an EIP. • Effective structures for continuous technical assistance. • Transparent and efficient information exchange system.	• Unawareness of EIP principles and benefits. • Failure of companies to become engaged in the EIP even after participating in the awareness campaigns. • The right people do not have the needed information at the right time.
Policy & regulatory framework	*Government*: Establish, implement and enforce policies and regulations *Universities & Consultants*: advise government on regulatory mechanisms to promote implementation of EIPs	• Policy intervention plays an enabling/catalysing role in helping to identify opportunities and creating the appropriate conditions for inter-firm networking to take place. • Stringent environmental laws that are effectively monitored and enforced by governmental agencies.	• Too much direct involvement from the government promoting an unattractive agenda from the companies' perspective. • Existing regulations do not support EIP principles.
Organizational & institutional setups	*Champion*(*s*), *Universities, & Consultants*: Engage in awareness raising & motivation of firms to adopt CSR or EMS	• Bilateral exchanges fit within corporate organizational structure and overall management system of the park. • Highly cooperative organizational culture in the area. • Well established Corporate Social Responsibility (CSR) or similar systems (i.e EMS).	• The intended exchange might not fit in the current corporate organizational structure. • Behavioral resistance toward cooperation across organizations. • Perceiving collaboration as risky for competitive relationships". • Limited decision-making powers.
Technical factors	*Universities, Consultants, Previous EIPs & standardization institutions*: set standards, guidelines, case studies, and technical feasibility studies	• Already some energy, waste and materials exchanges exist among various companies. • Utilising local technical-know-how.	• Absence of internationally accepted EIP standard.
Balance between Capabilities	All parties	• There is a balance of emphasis upon different capabilities: Such as economic, values, technical, political, unlearning.	• Dominance of one type of capability.

pollution prevention and cleaner production are important elements of IE (Baas, 1998). The three concepts are designed to help company leaders and their employees to reduce the generation of polluting substances to avoid the cost of clean-ups and disposal, to protect human health, and to minimize impacts on the environment and resources (UNEP, 1997). However, preventive approaches such as pollution prevention and cleaner production have their limits, as they are concerned with reducing materials inputs and reducing wastes at the level of the firm, and should be integrated into a broader perspective such as industrial metabolism and industrial ecology (Erkman, 1997; Gibbs and Deutz, 2005). It is unlikely that the generation of wastes will be entirely eliminated through pollution prevention and cleaner production, therefore recycling, reusing wastes, and energy recovery within companies or by exchanging wastes between companies is another option to be examined that has both environmental and economic benefits (UNEP, 1997). Especially cleaner production at the micro level of single companies can be interconnected to IE at the meso level of industrial estates, and further to Sustainability through a systems approach labeled *Cleaner Production Systems* or *Sustainable Consumption and Production Systems* (Baas, 2006).

5. Conclusions

Industrial symbiosis essentially represents a development that moves forward from dealing with localized environmental impacts on the individual firm or process level, although still considered important, but need to be connected to the wider industrial ecosystem (Gibbs and Deutz, 2007). Eco-industrial parks are designed to address the industrial system as a whole, where it considers technologies, process economics, the inter-relationships of businesses, financing, overall governmental policy, and the entire spectrum of issues that are involved in the management of commercial enterprises as equally important as environment protection and optimizing the use of scarce resources (Erkman, 2001).

Based on the literature review of experiences from various industrial symbioses worldwide, the success and limiting factors were arranged into six categories as summarized in Table 7, and the party who should take the lead role in enabling each factor is suggested. The *first factor* is the establishment of the social network between companies and stakeholders and maintaining their continuous interest, mutual trust, and involvement. The *second factor* focuses on gaining added economic value to all involved parties whether increased revenues, reduced costs or taxes, or even to have a better competitive edge. The *third factor* is awareness raising, which is inter-related strongly to the other five factors and effective information sharing between firms. The *fourth factor* is establishing national vision and objectives for industrial ecology and adapting relevant legislation to promote implementation of EIP principles. The *fifth factor* is fitting industrial symbiosis to corporate policies and organizational culture and taking actions that would promote EIP's acceptance by the companies. The *sixth factor* is the development of internationally recognized EIP standards and providing technical know-how locally to help industrialists to integrate the concepts and approaches of EIPs with pollution prevention and cleaner production approaches on the level of the firm and at level of the cluster of firms. Finally, a *seventh factor* could be added which is the balance between all the capabilities mentioned under the former categories (such as the values, economic, political, technical, etc.) without the dominance of one type of capability (Baas and Huisingh, 2008).

The above factors are general and applicable for any country; however there are specific localities for every nation due its economic circumstances, social & cultural considerations, and policies & regulations setup for industry and environmental protection – what is referred to in this paper as "context". In Egypt, industrial cities & zones lack social cohesion based on cooperation and trust between companies. Symbiotic relations has to be built through a "champion" recommended to be from industrial association of the industrial city or the park manager in case of privately-owned industrial developments. The government has very important enabling role – specifically the EEAA and relevant bodies for the Ministry of Trade and Industry – to make the current legislation in line with the principles of EIPs (i.e. transport & utilization of waste, incentives for energy efficiency & water conservation, pollution tax, etc.). Strengthening law compliance and enforcement is also a crucial push for industries to seek alternative pollution prevention approaches which would then prove to be more economic due to the increase in cost of end-of-pipe disposal methods. In parallel, an action plan for the implementation of the 'Integrated Industrial Development Model' mentioned in Egypt's Industrial Development Strategy should be activated on the national & industrial estate levels. At the early phases of EIP development, it is recommended that the government and industrial estates attract donor funds & technical support to assist in awareness campaigns, establishing information sharing infrastructure, and setting-up the EIP management system. Then, the EIPs should set 5–10 year target to achieve economic independence & sustainability through utilization of local finance mechanisms.

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